SEWARD PENINSULA – NULATO HILLS – KOTZEBUE LOWLANDS
RAPID ECOREGIONAL ASSESSMENT
FINAL REPORT II-3-c

# Appendix A: Change Agents in the Seward Peninsula – Nulato Hills – Kotzebue Lowlands Ecoregion

**REA Final Report for:**
Department of the Interior
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Rapid Ecoregional Assessments

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# A. CHANGE AGENTS

This appendix contains the following content relating to change agents:

- **Climate**: Detailed data and methods on the climate trends assessment are included here, greatly expanded on from methods described in the Methods chapter of the main report. **However, all results and discussion for this topic are entirely contained in the Current or Future chapters of the main report.**
- **Permafrost**: Detailed data and methods on permafrost trends assessment are included here, greatly expanded on from methods described in the Methods chapter of the main report. **However, all results and discussion for this topic are entirely contained in the Current or Future chapters of the main report**, with the exception of the detailed, by HUC, compilation of mean annual ground temperature results for all three model years.
- **Fire**: Additional details on methods **and** results of fire modeling are included here; the overall fire modeling results are summarized in the Future Conditions chapter in the main report, but this section of this appendix offers additional detail. Two other fire-related management questions not covered in the main report due to space constraints are also covered here.
- **Development**: Detailed descriptions of data and methods used to map current and future distributions of development change agents are included here. Summary results are included, and these results are also contained the relevant sections of the Current and Future Conditions chapters in the main report.

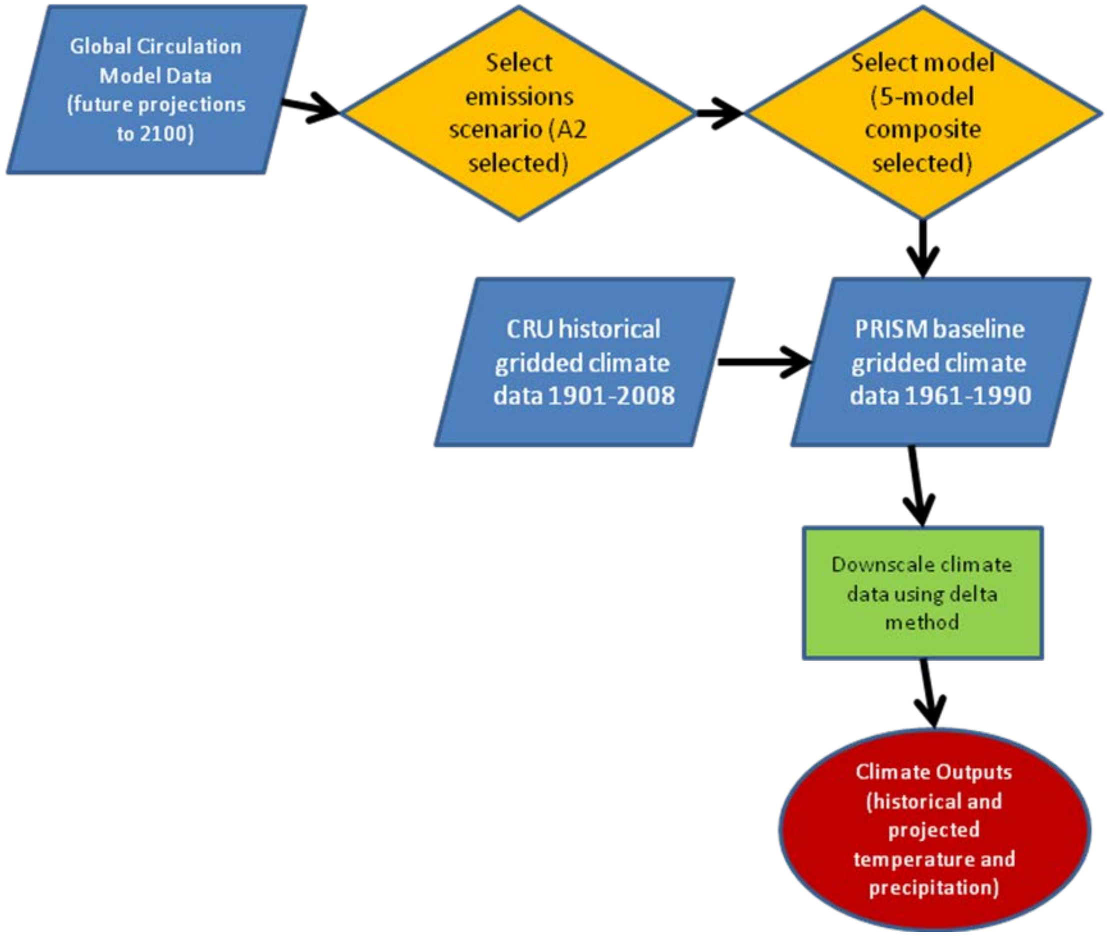
## *A-1 Climate Trends Assessment: Detailed Data and Methods*

### A-1.1 Climate Data: Background

In order to make global climate data useful for planning, the Scenarios Network for Alaska and Arctic Planning (SNAP), a collaborative research group at the University of Alaska, downscales global model outputs to the local level (Figure A-1). SNAP's principal products are downscaled historical and monthly projected climate data, primarily temperature and precipitation. Additionally, SNAP produces derived data from the above base datasets through various modeling efforts. For the purposes of this REA, climate-linked permafrost and fire models were selected as being of critical importance to the SNK ecoregion, in addition to SNAP's core temperature and precipitation projections.

As with any data, analysis or interpretation, multiple sources of uncertainty are always present. Understanding the uncertainty inherent in the input and output data can help in determining how these climate projections are best utilized and interpreted, as is discussed in the context of the Future Conditions chapter. All data used in this project are freely available, either from the SNAP website (www.snap.uaf.edu) or via datasets provided directly to the BLM.

**Figure A-1: Conceptual model of downscaled climate products**




## A-1.2 Climate Projections

SNAP selected the five General Circulation Models (GCMs) that perform best in Alaska and the Arctic. General Circulation Models (GCMs) are developed by various research organizations around the world. For this project, SNAP utilized the CMIP3 model outputs from the IPCC's fourth assessment report (AR4). Each GCM has different strengths and weaknesses, and some can be expected to perform better than others for northern regions of the globe (Table A-1).

Dr. John Walsh, a SNAP collaborator, and his team evaluated the performance of a set of fifteen global climate models used in the Coupled Model Intercomparison Project (Walsh et al 2008). They calculated the degree to which each model's output concurred with actual climate data for the years 1958–2000 for each of three climatic variables (surface air temperature, precipitation, and sea level pressure) for three overlapping regions (Alaska, Greenland, 60–90°N latitude, and 20–90°N latitude.)

The core statistic of the validation was a root-mean-square error (RMSE) evaluation of the differences between mean model output for each grid point and calendar month, and data from the European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis, ERA-40. The ERA-40 directly assimilates observed air temperature and sea level pressure observations into a product spanning 1958–2000. Precipitation is computed by the model used in the data assimilation. The ERA-40 is one of the most consistent and accurate gridded representations of these variables available.

To facilitate comparison between GCMs and validation against the ERA-40 data, all monthly fields of GCM temperature, precipitation and sea level pressure were interpolated to the common 2.5° × 2.5° latitude–longitude ERA-40 grid. For each model, Walsh et al. calculated RMSEs for each month, each climatic variable, and each region, and then added the 108 resulting values (12 months × 3 features × 4 regions) to create a composite score for each model. A lower score indicated better model performance.

Since several models had substantially smaller systematic errors than the other models, the differences in greenhouse projections implied that the choice of a subset of models might offer a viable approach to narrowing the uncertainty and obtaining more robust estimates of future climate change in regions such as Alaska. Thus, SNAP selected the five best-performing models out of the fifteen, which are listed in Table A-1. These five models are used to generate climate projections independently, as well as in combination, in order to further reduce the error associated with dependence on a single model.

**Table A-1: Global Circulation Models used for SNAP downscaled climate projections.**

| Center | Model Name and Version | Acronym |
|---|---|---|
| Canadian Centre for Climate Modelling and Analysis | General Circulation Model version 3.1 - t47 | cccma_cgcm31 |
| Max Planck Institute for Meteorology | European Centre Hamburg Model 5 | mpi_echam5 |
| Geophysical Fluid Dynamics Laboratory | Coupled Climate Model 2.1 | gfdl_cm21 |
| UK Met Office - Hadley Centre | Coupled Model 3.0 | ukmo_hadcm3 |
| Center for Climate System Research | Model for Interdisciplinary Research on Climate (MIROC) | miroc3_2_medres |

Projected data are produced for three emission scenarios (B1, A1B, A2) as described in the 4$^{th}$ Assessment (IPCC 2000); this project focuses on the A2 scenario. The A2 scenario describes a future featuring a world of independently operating, self-reliant nations, with continuously increasing population and regionally oriented economic development. While once viewed as a relatively pessimistic scenario, it is now considered relatively likely, as compared to other scenarios (Anderson and Bows 2008, 2011).

## A-1.3 Historical CRU Data

The Climate Research Unit (CRU) at the University of East Anglia in England is one of the leading research organizations for the study of natural and anthropogenic climate change. CRU hosts a large number of global climate datasets, which are managed by a variety of people and projects. CRU global climate data are based on 3,000 monthly temperature stations over land as well as additional sea surface temperature (SST) measurements over water. SNAP obtains CRU data directly from their website or from the British Atmospheric Data Centre. SNAP utilizes CRU 5° × 5° temperature and precipitation data and TS 3.0/3.1 high-resolution gridded data as base data from which to further downscale historical climate grids to 2km resolution.

## A-1.4 Parameter-elevation Regressions on Independent Slopes Model (PRISM)

GCM outputs and historical CRU data were then downscaled using PRISM data—which accounts for land features such as slope and elevation (from remotely-sensed digital elevation models), and proximity to coastlines—as baseline climate data. The final products are high-resolution monthly climate data for

~1901-2100 for Alaska and large regions of Canada. Outputs from the five models are averaged in order to reduce the error associated with dependence on a single model.

(PRISM) data are the highest quality, spatially explicit climate data currently available for Alaska and the United States as a whole. PRISM data can be obtained through multiple sources, although the data is produced by the same organization.

## A-1.5 Delta Method Downscaling Procedure

SNAP currently employs a model bias correction in tandem with a statistical downscaling approach called the "delta method."

In order to determine projected changes in climate and the amount of model bias inherent in that change, SNAP needed to first determine a reference state of the climate according to the GCMs. The first step was to utilize twentieth-century (20c3m) scenario GCM data values to calculate climatologies for the same temporal range used in the high-resolution data being downscaled to (e.g., 1961–1990 PRISM, 1971–2000 PRISM). These climatologies are simply GCM mean monthly values across a reference period (usually 30 years) from the 20c3m scenario outputs. The values represent modeled data and contain an expected model bias which is adjusted as described below. This calculation was completed for a worldwide extent at the coarse GCM spatial resolution, which ranges from 1.875 to 3.75 degrees latitude/longitude.

Next, SNAP calculated monthly absolute (for temperature) or proportional (for precipitation) anomalies by taking the future monthly value (e.g., May 2050 A1B scenario) and subtracting the 20c3m climatology for temperature or dividing by the 20c3m climatology for precipitation. This calculation was completed for a worldwide extent at the coarse GCM spatial resolution.

When proportional anomalies for precipitation are calculated using division, and the specific year (numerator) is outside the range of years used to create the climatology (denominator), the possibility of dividing future scenario values by zero, or near-zero, climatology values is introduced. This cannot be prevented, particularly in grid cells over arid regions, but in the rare instances that it does occur, the denominator must be adjusted. To achieve this, the top 0.5% of anomaly values were truncated to the 99.5 percentile value for each anomaly grid.

This results in:

1. **no change** for the bottom 99.5% of values,
2. **little change** for the top 0.5% in grids where the top 0.5% of values are not extreme, and
3. **substantial change** only when actually needed; that is, in cases where a grid contains one or more cells with unreasonably large values resulting from dividing by near-zero.

No attempt is made to omit precipitation anomaly values of a certain magnitude; instead a quantile, based on data distribution, is used to truncate the most extreme values. The 99.5% cutoff was chosen after careful consideration of the ability of various quantiles to capture extreme outliers. This adjustment allows the truncation value to be different for each grid because it is based on the distribution of values across a given grid.

Temperature and precipitation anomalies were then interpolated with a first-order bilinear spline technique across an extent larger than our high-resolution climatology dataset. A larger extent is used to account for the climatic variability outside of the bounds of our final downscaled extent. The interpolated anomalies are then added to (for temperature) or multiplied by (for precipitation) the high-resolution climatology data (e.g., PRISM). This step effectively downscaled the data and removed model biases by using observed data values as baseline climate. The final products are high resolution (2km or 800m for PRISM) data.

## A-1.6 Uncertainty

While the baseline climate data used in SNAP's downscaling procedure (e.g., PRISM and CRU data) have been peer reviewed and accepted by the climate community, SNAP also validated these procedures by directly comparing twentieth century scenario (20c3m) GCM data to actual weather station data. Additionally, all of SNAP's projected future monthly output data are plotted and inspected by a committee of climate experts.

Nonetheless, data—including its analysis and interpretation—can almost never be 100% certain. Multiple sources of uncertainty are inherent to SNAP's work. Understanding these sources can help in effectively and appropriately using SNAP's products. All models involve simplification of real-world interactions (e.g., ocean currents are not modeled at the level of individual $H_2O$ molecules). Most models rely on incomplete input data (e.g., historical climate data exists only for sites with climate stations). In addition, climate modeling deals with some inherently unpredictable variables (e.g., the exact location and timing of lightning strikes). Multiple sources of uncertainty can combine to have multiplicative effects. In some cases, uncertainty yields a range of possible outcomes that occur on a continuum, such as a projected temperature increase of 2 to 5 degrees Celsius. In other cases, uncertainty involves thresholds or tipping points, as can be the case with fire, insect outbreaks, or permafrost thaw. Depending on the project and the needs of planners, land managers researchers, or local residents, it can be best to examine a range of possible yet divergent outcomes.

The outline below breaks down and discusses some of the primary sources of uncertainty in SNAP's modeling efforts for this REA.

### A-1.6.1 Raw climate projections

SNAP's most basic climate data are the monthly mean values for temperature and precipitation, available for every month of every year from 1900–2006 (historical data) and 1980–2099 (projected data). The projected data are available for five different models and three different emission scenarios. Each of these fifteen datasets offers a slightly different scenario of future climate, based on differing algorithms and assumptions; the differences between them can be viewed as one measure of the uncertainty inherent in such projections.

### A-1.6.2 Historical and projected datasets

The historical and projected datasets are both subject to uncertainty based on interpolation, gridding and downscaling, as well as uncertainty based on the inherent variability of weather from month to month and year to year. Historical datasets are based on weather station data that has been interpolated to a relatively coarse-scale grid using algorithms from Climate Research Unit (CRU), and then further downscaled to a finer grid by SNAP using the Parameter-Regression on Independent Slopes Model (PRISM). Projected datasets are downscaled by interpolation between large-scale grid cells (splining) followed by PRISM downscaling.

### A-1.6.3 Interpolation, gridding and downscaling

- Climate stations are very sparse in the far north, and precipitation in particular can vary enormously over very small areas and time frames, so interpolation is challenging and imperfect regardless of method
- PRISM uses point data, a digital elevation model, and other spatial data sets to generate gridded estimates

- CRU data uses different algorithms from PRISM, and does not utilize data on slope and aspect and proximity to coastlines
- Overall, PRISM seems to do the best job of capturing fine-scale landscape climate variability

#### A-1.6.4 Natural variability

- Even when trends (e.g., warming climate) are occurring, they can be obscured by normal ups and downs in weather patterns
- GCM outputs simulate this normal variability, but the variations cannot be expected to match actual swings
- Uncertainty is inevitably greater for precipitation than for temperature, since natural variability across both time and space is greater for precipitation

#### A-1.6.5 Projected data

Projected data are also subject to uncertainty related to the accuracy of the General Circulation Models upon which they are based; historical data are not subject to this source of uncertainty.

#### A-1.6.6 Inputs to GCMs

- Solar radiation is essentially a known quantity
- Future levels of greenhouse gases are uncertain, but accounted for by varying emissions scenarios (see emission scenarios in FAQs, www.snap.uaf.edu/faq.php#faq_1)

#### A-1.6.7 GCM algorithms

- Although SNAP uses the best General Circulation Models, produced by international teams of scientists and relied upon by the IPCC, oceanic and atmospheric circulation are extremely hard to predict and model
- Interactions modeled in GCMs include thresholds (tipping points) such as ocean currents shifting or shutting down
- GCMs don't fully account for short-term phenomena such as the Pacific Decadal Oscillation (PDO), which can affect Alaska's climate over time periods of years or even decades

### A-1.7 Addressing Uncertainty

Multiple options exist for dealing with uncertainty—either by lessening it, or by describing a range of possible futures, or both. These choices are heavily dependent on the needs of the stakeholders involved in any particular project.

#### A-1.7.1 Natural variability

- Averaging across all five models (using the composite model, as was done in this project) can reduce the ups and downs built into the models
- Averaging across years (decadal averages), also used in this project, can reduce uncertainty due to natural variability
- Both these methods reduce the ability to examine extreme events

#### A-1.7.2 GCM uncertainty

- The five GCMs used by SNAP have been tested for accuracy in the north
- GCMs have been widely used and referenced in the scientific literature
- Variation between models can be used as a proxy for uncertainty in GCM algorithms
- Averaging across all five models (using the composite model) can reduce any potential bias, but reduces the ability to examine extreme events

- SNAP's model validation study depicts uncertainty by region, model, and data type based on comparisons between model results and actual station data

#### A-1.7.3 Interpolation, gridding, and downscaling

- Both CRU and PRISM have been validated in other studies, available in the literature

# *A-2 Permafrost Trends Assessment*

## A-2.1 Permafrost Modeling: Detailed Data and Methods

#### A-2.1.1 Background

Climate/permafrost modeling for the SNK REA was performed using SNAP climate data (see previous section) coupled with modeling by the University of Alaska – Fairbanks (UAF) Geophysical Institute Permafrost Laboratory (GIPL), a research group that deals with scientific questions related to the circumpolar permafrost dynamics and feedbacks between permafrost and global change. The focus of GIPL's research is permafrost modeling, permafrost process studies, permafrost monitoring, and the prediction of impacts of permafrost changes on the natural environment. The lab collects and analyzes data related to the thermal and structural state of circumpolar permafrost. GIPL is interested in all aspects of how permafrost is affected by global change with respect to climate as well as natural and human induced disturbances, and closely collaborates with many other researchers and students at UAF and other institutions (see http://permafrost.gi.alaska.edu/ for more information).

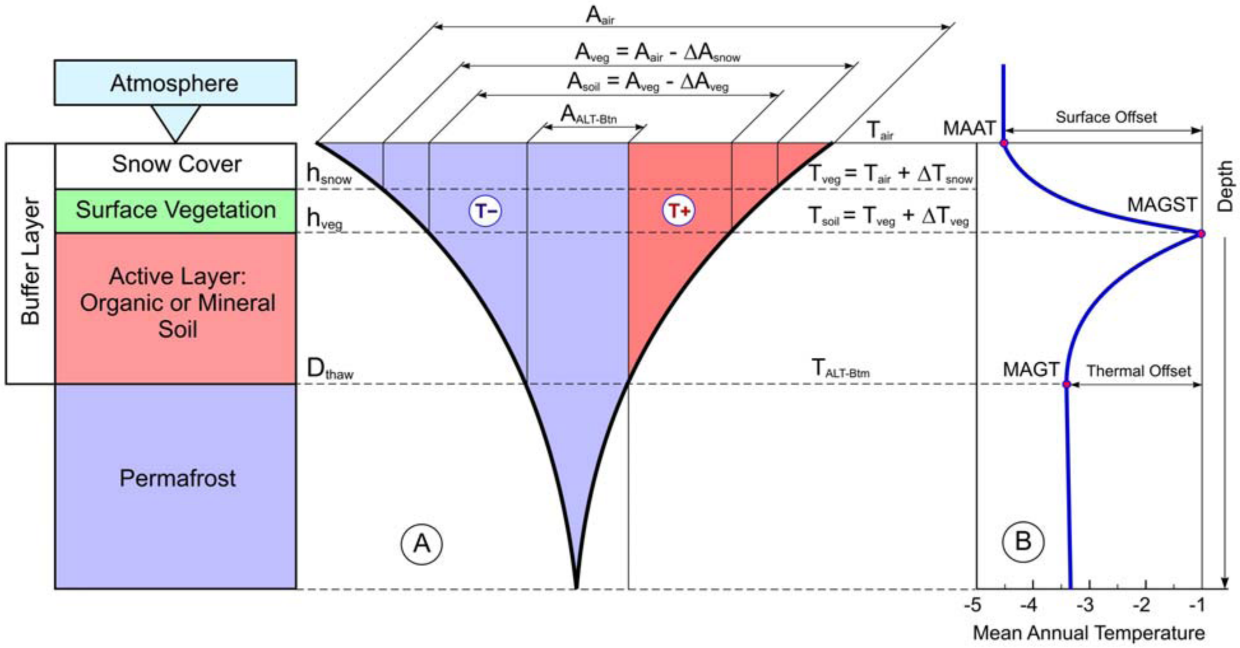
The GIPL model was developed specifically to assess the effect of a changing climate on permafrost. The GIPL 1.0 model is a quasi-transitional, spatially distributed, equilibrium model for calculating the active layer thickness and mean annual ground temperature. The GIPL-1 model accounts effectively for the effects of snow cover, vegetation, soil moisture, and soil thermal properties (Table A-2). The GIPL-1 model allows for the calculation of maximum active layer thickness (ALT) and mean annual ground temperatures (MAGT) at the bottom of the active layer. The approach to determine the ALT and MAGT is based on an approximate analytical solution that includes freezing/thawing processes and provides an estimation of thermal offset due to the difference in frozen and thawed soil thermal properties (Kudryavtsev et al., 1974). It uses the idea of applying the Fourier temperature wave propagation theory to a medium with phase transitions, such as freezing/thawing ground. Application of this approach resulted in the discovery of the thermal offset and an understanding of the laws that govern the dynamics of the ground thermal regime. These discoveries led to an understanding of the effects that the thermal properties of the ground have upon the MAGTs and ALT, and how periodically (seasonally) varying climatic parameters affect permafrost dynamics. The output parameters of this method are given as annual averages. The effect of geothermal heat flux is ignored because it is considered to have a minimal impact on the MAGT and ALT values. For the areas with permafrost, the MAGT is the same as a mean annual temperature at the permafrost table (upper surface of permafrost). Where permafrost is absent, the MAGT is the mean annual temperature at the bottom of seasonally frozen layer.

**Table A-2: GIPL permafrost model inputs and outputs.**

| Input Variables | Notation | Units |
|---|---|---|
| Seasonal range of air temperature variations (amplitude) | $A_a$ | ºC |
| Mean annual air temperature | $T_a$ | ºC |
| Snow Water Equivalent | SWE | m |
| Height of vegetation cover | $H_v$ | m |
| Thermal diffusivity of vegetation in frozen state | $D_{vf}$ | $m^2/s$ |
| Thermal diffusivity of vegetation in thawed state | $D_{vt}$ | $m^2/s$ |
| Thermal conductivity of frozen soil | $K_f$ | W/(m*K) |
| Thermal conductivity of thawed soil | $K_{th}$ | W/(m*K) |
| Volumetric water content | VWC | Fraction of 1 |
| Volumetric latent heat of ice fusion | 334e6 | $J/m^3$ |
| Volumetric heat capacity of snow cover | $C_{sn}$ | $J/m^3K$ |
| Volumetric heat capacity of thawed ground | $C_{th}$ | $J/m^3K$ |
| Volumetric heat capacity of frozen ground | $C_f$ | $J/m^3K$ |
| **Output Variables** | | **Notation** |
| Correction to air temperature accounting for snow cover effect, ºC | | $\Delta T_{sn}$ |
| Correction to air temperature amplitude accounting for snow cover effect, ºC | | $\Delta A_{sn}$ |
| Correction to air temperature accounting for vegetation cover , ºC | | $\Delta T_v$ |
| Correction to air temperature amplitude accounting for vegetation cover , ºC | | $\Delta A_v$ |
| Seasonal range of temperature variations at the ground surface, ºC | | $A_{gs}$ |
| Mean annual temperatures at the ground surface, ºC | | $T_{gs}$ |
| Snow density, $kg/m^3$ | | $\rho_{sn}$ |
| Snow thermal conductivity, W/(m*K) | | $K_{sn}$ |
| Thermal offset, ºC | | $\Delta T_k$ |
| Mean annual soil surface temperature, ºC | | MAGST |
| Mean annual soil temperature at the bottom of ALT , ºC | | MAGT |
| Active layer thickness, m | | ALT |

Throughout the years, simplified analytical solutions for the ALT have been applied for structural engineering and other practical purposes. Most of these methods have been based on the Stefan solutions, and they do not yield a good level of accuracy (Romanovsky and Osterkamp 1997). It was determined that the best method for computation of the ALT and MAGTs was a modified version of Kudryavtsev's approach (Romanovsky and Osterkamp 1997). This approach is the core of the GIPL-1 model, which treats the complex system including air, snow cover, surface vegetation, and active layer, as a set of individual layers with different thermal properties (Figure A-2). In the regions of Alaska and eastern Siberia that were analyzed, surface vegetation consists of lichens, grass, and moss (sphagnum or feather mosses) (Feldman et al., 1988; Brown and Kreig 1983). The upper level of vegetation consisting of trees and shrubs is not considered in the model. This upper level vegetation affects the thickness and density of the snow cover, along with the amount of solar radiation reaching the ground surface. The model takes into account only low-level vegetation (surface vegetation) that is less than 0.5 meter high, because the information about higher vegetation such as trees and tall shrubs is already incorporated into the monthly surface air temperature data, which were used as input data in the model.

**Figure A-2: The GIPL-1 model conceptual diagram (A) and schematic profile of mean annual temperature through the lower atmosphere, active layer and upper permafrost (B).**




Snow cover plays an important role in heat exchange processes between the surface of the ground and the atmosphere. The warming effect of the snow cover has been calculated using approximate formulas derived by Lachenbruch (1959) and Romanovsky (1987), which incorporate ground properties, vegetation cover, and their respective effect on heat turnovers through the snow. Heat turnovers are defined as the quantity of incident heat (during the heating period), or out-going heat (during the cooling period) throughout the media over a given time interval (usually half year increments). Thus, the heat turnover is the sum of the heat flux through the ground surface as a function of time.

The GIPL-1 model takes into account only conductive heat transfer through the surface vegetation (lichens, moss, and grasses). The rate of heat turnover between the ground and atmosphere has been shown to have a strong dependence on vegetation cover. In summer, surface vegetation prevents solar radiation from penetrating into the ground and warming it. In wintertime, surface vegetation acts as an insulator and keeps heat in the ground.

The seasonal freezing and thawing cycles cause changes in the thermal properties of soils within the active layer. Typically, this effect leads to a decrease in MAGTs with depth within the active layer. The thermal offset is defined as the difference between the mean annual temperature MAGT at the bottom of the active layer and the mean annual temperature at the ground surface (Kudryavtsev et al. 1974; Goodrich 1978; Burn and Smith 1988). The thermal offset depends on soil moisture content and thermal properties, and has the most pronounced effect within a peat layer (Marchenko and Romanovsky 2007). The analytical equation to estimate the thermal offset was given by Kudryavtsev (1981) (no derivation was published), and was formally derived by Romanovsky and Osterkamp (1995).

The approach to simulate MAGT in the GIPL-1 model is the consecutive layer-by-layer introduction of thermal effects of snow, ground surface vegetation, and the soils within the active layer on mean annual temperatures and seasonal amplitudes at each considered level (snow surface, vegetation surface, and ground and permafrost table). However, this scheme is not totally additive because the estimation of the impact of each new layer already includes the thermal effects of all layers above it. Moreover, in this approach, the thermal effect of snow reflects the thermal properties and temperature field dynamics in the subsurface layers through the heat turnover estimation. As a result, this approach takes into account some negative and positive feedbacks between designated layers in the “atmosphere-permafrost” system.

#### A-2.1.2 The Active Layer Thickness

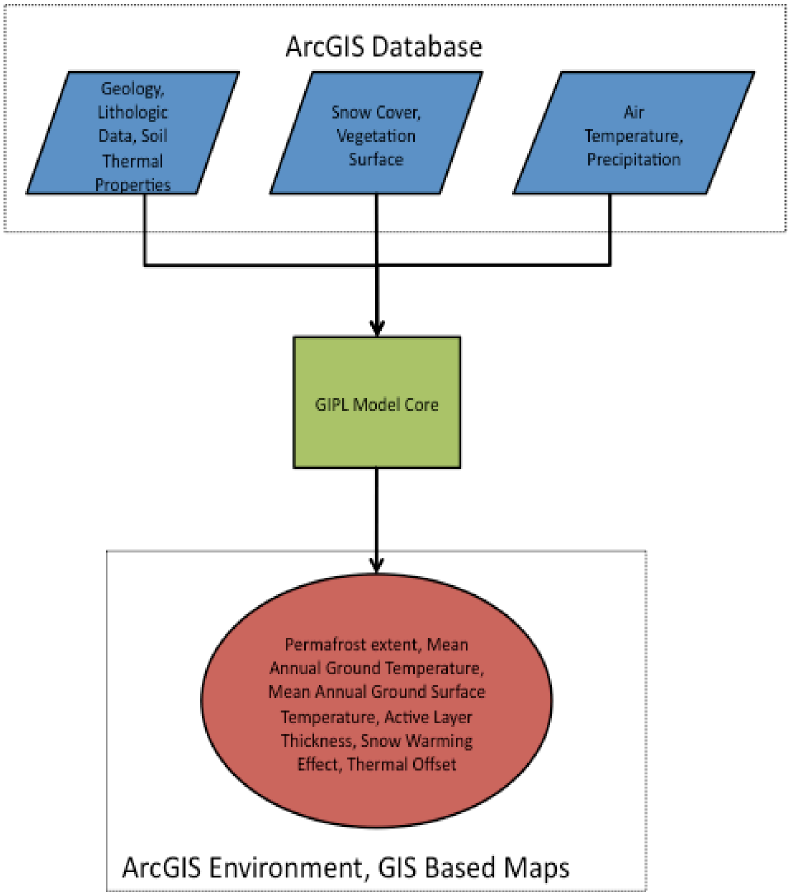
Calculation of the ALT is the final step in the GIPL-1 model (Romanovsky and Osterkamp 1997). The formula was derived for homogeneous ground, but in actuality, even if the soil properties are the same throughout the active layer, the moisture content or mode of heat flow may vary significantly. This can make the active layer heterogeneous with regard to its thermal properties. Also, the model does not take into account unfrozen water, which can exist in the frozen active layer even at temperatures below zero Celsius, and has a significant effect on the ground’s thermal properties (Williams, 1964; Williams & Smith, 1989). The assumption of a periodically steady state temperature regime seems to be a good approximation when applied to the annual temperature cycle, which varies from year to year (Romanovsky and Osterkamp, 1997). Considering the advantages along with the shortcomings, the GIPL-1 model appears to give a good representation of the coupling between permafrost and the atmosphere. When applied to long-term (decadal and longer time scale) averages, this approach shows an accuracy of ±0.2-0.4ºC for the mean annual ground temperatures and ±0.1 – 0.3 m for the active layer thickness calculations (Sazonova and Romanovsky, 2003). The relative errors do not exceed 32% for the ALT calculations, but typically they are between 10 and 25%. The differences in 0.2-0.4°C between calculated and measured mean annual ground temperatures were obtained for the long-term multi-year average estimations.

#### A-2.1.3 The Input Dataset

At the present stage of development, the GIPL-1 model is combined with ArcGIS to facilitate preparation of input parameters (climate forcing from observations or from global or regional climate models) and visualization of simulated results in the form of digital maps.

In order to assess possible changes in the permafrost thermal state and the active layer thickness, the GIPL-1.3 model was implemented for the entire Alaskan permafrost domain. For this REA, the team used an input data set with 2 x 2 km spatial resolution. Input parameters to the model are spatial datasets of mean monthly air temperature and precipitation, prescribed vegetation, soil thermal properties, and water content, which are specific for each vegetation and soil class and geographical location (Figure A-3). The Scenarios Network for Alaska Planning (SNAP) data set was used for climate forcing (http://www.snap.uaf.edu/).

Figure A-3: Conceptual model of GIPL permafrost model




#### A-2.1.4 Uncertainty

In addition to the uncertainty associated with SNAP modeling as described previously, uncertainty is associated with all GIPL outputs. Algorithms to determine the depth of active layer are dependent on calculations of the insulating properties of varying ground cover and soil types, as well as on climate variables. Although GIPL researchers have used the best available data for all inputs, some datasets are incomplete.

Model uncertainty has several ramifications for management, which are discussed in the Future Conditions chapter. Uncertainty inherent to model outputs must be considered in conjunction with additional uncertainty in model interpretation, stemming from complex interactions between permafrost, climate, fire and development; relatively coarse model resolution, with reference to extremely localized phenomena; and complex interactions between soil conditions and hydrologic change. Uncertainty dictates the need to manage for multiple future scenarios, particularly in areas near the threshold for permafrost thaw (MAGT near 0°C at one meter depth). For example, for crucial resources such as community drinking water supplies, it behooves managers to plan for altered hydrology and potential contamination issues even if such changes are uncertain. On the other hand, managing the exact drainage patterns of large lake systems may be beyond the scope of reasonable management strategies.

## A-2.2 Permafrost Trends: Detailed Results

The table below provides the complete data on mean annual ground temperature, for 2011, 2025, and 2060, for all watersheds in this ecoregion. The synthesis and interpretation of the permafrost modeling is contained in the Future Conditions chapter of the main report.

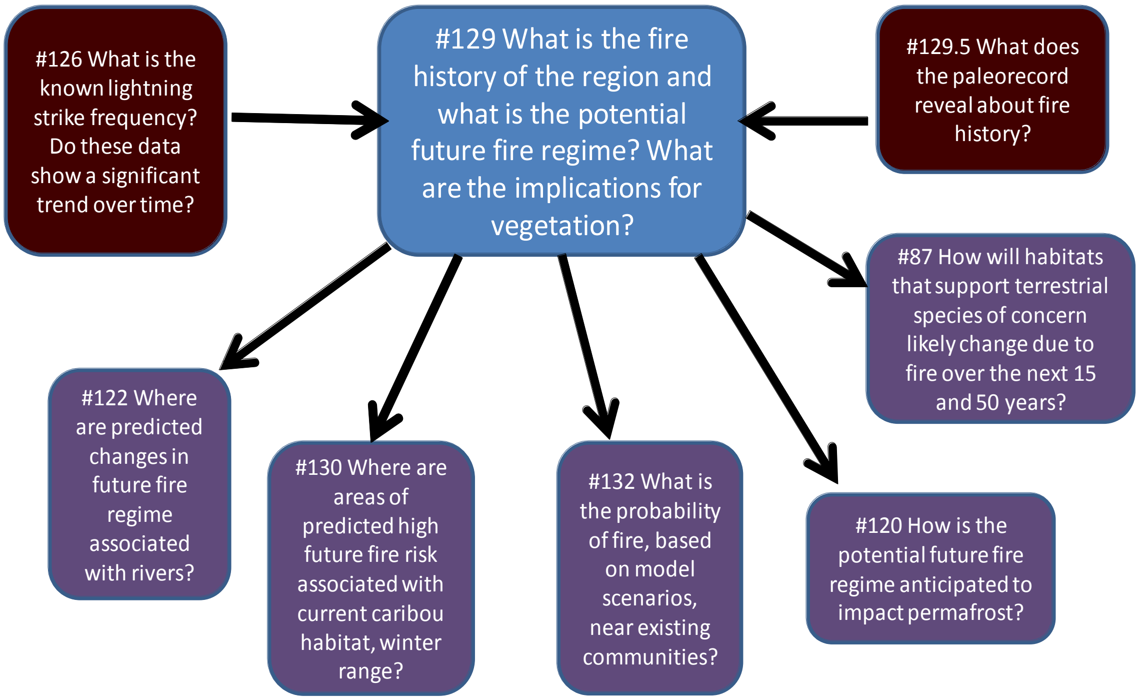
### Table A-3: Complete data on mean annual ground temperature (MAGT) by year and 5th-level HUC. Data are sorted from coldest to warmest.

| Name (HUC 10) | 2011 MEAN | 2025 MEAN | 2060 MEAN | Name (HUC 10) | 2011 MEAN | 2025 MEAN | 2060 MEAN | Name (HUC 10) | 2011 MEAN | 2025 MEAN | 2060 MEAN | Name (HUC 10) | 2011 MEAN | 2025 MEAN | 2060 MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ingruksukruk Creek | -4.8 | -4.1 | -3.3 | Middle Kateel Creek | -2.4 | -1.5 | -1.0 | Headwaters Shaktoolik River | -1.8 | -0.8 | -0.5 | Headwaters Pilgrim River | -1.1 | -0.3 | -0.2 |
| Ekiek Creek | -4.4 | -3.6 | -2.8 | Hunter Creek | -2.4 | -1.5 | -1.0 | Outlet Kugarak River | -1.8 | -1.1 | -0.6 | Ninemile River | -1.1 | -0.2 | 0.1 |
| Outlet South Fork Huslia River | -4.2 | -3.4 | -2.7 | North Fork Buckland River | -2.4 | -1.6 | -1.0 | Casadepaga River | -1.8 | -0.7 | -0.5 | Outlet Niukluk River | -1.1 | 0.0 | 0.2 |
| Derby Creek | -4.1 | -3.3 | -2.6 | Rodo River | -2.4 | -1.3 | -0.8 | Upper Andreafsky River | -1.7 | -0.5 | -0.2 | Port Clarence-Frontal Bering Sea | -1.1 | -0.7 | -0.4 |
| Nulitna River | -4.0 | -3.2 | -2.5 | Solomon River | -2.4 | -1.2 | -1.1 | Nazuruk Channel-Frontal Hotham Inlet | -1.7 | -0.9 | -0.3 | Headwaters East Fork Andreafsky River | -1.1 | 0.1 | 0.4 |
| Headwaters Selawik River | -4.0 | -3.3 | -2.6 | Hotham Inlet-Frontal Kotzebue Sound | -2.4 | -1.6 | -0.9 | Outlet Fish River | -1.7 | -0.5 | -0.2 | Headwaters Kugarak River | -1.1 | -0.4 | 0.1 |
| North Fork Huslia River | -3.9 | -3.2 | -2.4 | Headwaters Kuzitrin River | -2.4 | -1.4 | -1.2 | Headwaters Kougarok River | -1.7 | -1.1 | -0.8 | Upper Kateel River | -1.1 | -0.2 | 0.1 |
| Headwaters South Fork Huslia River | -3.9 | -3.0 | -2.3 | Lopp Lagoon-Frontal Chukchi Sea | -2.4 | -1.8 | -1.3 | Lower Selawik River | -1.7 | -1.0 | -0.4 | Upper Anvik River | -1.1 | 0.0 | 0.4 |
| Pish River | -3.9 | -3.0 | -2.6 | South Fork Serpentine River | -2.4 | -1.7 | -1.4 | Grayling Creek-Yukon River | -1.7 | -0.4 | 0.0 | Deer Hunting Slough-Yukon River | -1.0 | 0.3 | 0.6 |
| Headwaters Billy Hawk Creek | -3.9 | -3.2 | -2.5 | Mangoak River | -2.3 | -1.5 | -1.0 | Sanaguich River | -1.7 | -1.1 | -0.8 | Hawk River | -1.0 | 0.3 | 0.6 |
| Huslia River | -3.8 | -3.1 | -2.4 | Rathlatulik River | -2.3 | -1.2 | -0.8 | Headwaters West Fork Buckland River | -1.7 | -0.7 | -0.3 | Outlet Pilgrim River | -1.0 | -0.1 | 0.1 |
| 1904060601 | -3.8 | -3.0 | -2.3 | Serpentine River | -2.3 | -1.6 | -1.3 | Outlet Noxapaga River | -1.7 | -0.8 | -0.5 | Headwaters Nulato River | -1.0 | -0.1 | 0.2 |
| Pitka River | -3.8 | -2.8 | -2.2 | Headwaters Kugruk River | -2.3 | -1.3 | -1.0 | Norton Bay-Frontal Norton Sound | -1.7 | -0.5 | -0.1 | Kuyukutuk River | -1.0 | 0.4 | 0.6 |
| Outlet Billy Hawk Creek | -3.7 | -3.0 | -2.3 | Anikovik River-Frontal Bering Sea | -2.3 | -1.7 | -1.3 | Arctic River | -1.7 | -1.2 | -0.8 | Golsovia River | -1.0 | 0.1 | 0.4 |
| Rabbit River | -3.7 | -3.0 | -2.3 | Headwaters Unalakleet River | -2.3 | -1.2 | -0.7 | Steamboat Slough-Yukon River | -1.7 | -0.6 | -0.1 | Sineak River-Frontal Norton Sound | -1.0 | 0.2 | 0.7 |
| Middle Buckland River | -3.7 | -2.7 | -2.0 | Eschscholtz Bay-Frontal Kotzebue Sound | -2.3 | -1.4 | -0.8 | Kugrupaga River | -1.7 | -1.2 | -0.7 | Lower Anvik River | -1.0 | 0.3 | 0.6 |
| Kingmetolik Creek | -3.7 | -2.5 | -2.0 | Old Woman River | -2.3 | -1.1 | -0.7 | First Chance Creek | -1.7 | -0.6 | -0.2 | South Fork Nulato River | -0.9 | 0.0 | 0.3 |
| Lower Kateel River | -3.6 | -2.8 | -2.1 | June Creek-Frontal Kotzebue Sound | -2.2 | -1.4 | -0.8 | Espenberg River | -1.7 | -1.1 | -0.6 | Imuruk Basin | -0.9 | -0.4 | -0.2 |
| Ikagoak River | -3.6 | -2.8 | -2.0 | Kougachuk Creek | -2.2 | -1.6 | -1.1 | Pikmiktalik River | -1.7 | -0.4 | -0.1 | Arvesta Creek | -0.9 | 0.0 | 0.3 |
| Outlet Goodhope River | -3.6 | -2.7 | -2.3 | Inmachuk River | -2.2 | -1.5 | -1.1 | Cripple River | -1.7 | -0.8 | -0.5 | Headwaters Bonasila River | -0.9 | 0.4 | 0.7 |
| Upper Buckland River | -3.5 | -2.6 | -1.9 | Outlet Kiwalik River | -2.2 | -1.2 | -0.7 | Outlet Kougarok River | -1.6 | -0.8 | -0.6 | Headwaters Gisasa River | -0.9 | 0.0 | 0.3 |
| Bitzla River-Koyukuk River | -3.5 | -2.6 | -2.0 | Kiwalik Lagoon-Frontal Kotzebue Sound | -2.2 | -1.4 | -0.8 | Lower Inglutalik River | -1.6 | -0.6 | -0.1 | Tuckers Slough-Yukon River | -0.9 | 0.6 | 0.8 |
| Keruluk Creek | -3.5 | -2.8 | -2.1 | Kachauik River | -2.2 | -1.1 | -0.8 | Headwaters Ungalik River | -1.6 | -0.7 | -0.3 | Eldorado River | -0.8 | 0.1 | 0.2 |
| Kalusuk Creek | -3.5 | -2.5 | -1.8 | Headwaters North River | -2.1 | -1.1 | -0.7 | Middle Koyuk River | -1.6 | -0.5 | 0.0 | South River | -0.8 | 0.3 | 0.7 |
| Imikruk Lagoon-Frontal Chukchi Sea | -3.5 | -2.6 | -1.9 | Outlet Noatak River | -2.1 | -1.3 | -0.8 | Headwaters Kiwalik River | -1.6 | -0.6 | -0.2 | Middle Andreafsky River | -0.8 | 0.5 | 0.7 |
| Upper Selawik River | -3.5 | -2.8 | -2.1 | Peace River | -2.1 | -1.0 | -0.5 | Upper Koyuk River | -1.6 | -0.5 | -0.1 | Quekilok Creek-Frontal Norton Sound | -0.8 | 0.4 | 0.8 |
| Wrench Lake | -3.4 | -2.5 | -1.9 | Ekichuk Lake-Frontal Hotham Inlet | -2.1 | -1.2 | -0.6 | Boston Creek | -1.6 | -0.7 | -0.4 | Headwaters Atchuelinguk River | -0.7 | 0.4 | 0.8 |
| Honhosa River | -3.4 | -2.4 | -1.8 | Headwaters Noxapaga River | -2.1 | -1.2 | -0.9 | Shishmaref Inlet-Frontal Chukchi Sea | -1.6 | -1.0 | -0.8 | Nome River | -0.7 | 0.3 | 0.3 |
| Baldwin Penninsula-Frontal Kotzebue Sound | -3.3 | -2.4 | -1.6 | Sevisok Slough-Noatak River | -2.1 | -1.1 | -0.6 | Outlet Unalakleet River | -1.6 | -0.4 | 0.1 | Poltes Slough-Yukon River | -0.7 | 0.7 | 0.9 |
| Dakli River | -3.3 | -2.6 | -2.0 | Niaktuvik Creek-Kobuk River | -2.0 | -1.4 | -0.6 | Stink Creek | -1.6 | -0.6 | -0.1 | Sinuk River | -0.7 | 0.1 | 0.3 |
| Kuchuk Creek | -3.3 | -2.6 | -1.8 | North Fork Serpentine River | -2.0 | -1.4 | -1.1 | Klikitarik River | -1.6 | -0.3 | 0.0 | Safety Sound-Frontal Norton Sound | -0.6 | 0.5 | 0.7 |
| Middle Inglutalik River | -3.2 | -2.1 | -1.5 | Headwaters Goodhope River | -2.0 | -1.4 | -1.0 | Box River | -1.5 | -0.7 | -0.3 | Allen Creek | -0.6 | 0.6 | 0.7 |
| Outlet West Fork Buckland River | -3.2 | -2.2 | -1.6 | Kauk River | -2.0 | -1.2 | -0.6 | Selawik Lake | -1.5 | -0.7 | -0.2 | Bear Creek | -0.6 | 0.2 | 0.8 |
| Nikolai Slough-Koyukuk River | -3.2 | -2.3 | -1.7 | Singauruk River | -2.0 | -1.2 | -0.7 | Mint River | -1.5 | -0.9 | -0.6 | Outlet Agiapuk River | -0.6 | -0.3 | -0.1 |
| Upper Inglutalik River | -3.2 | -2.1 | -1.6 | Lower Tagagawik River | -2.0 | -1.3 | -0.7 | Outlet Shaktoolik River-Shaktoolik Bay | -1.5 | -0.5 | 0.0 | Paradise Creek | -0.5 | 0.7 | 1.0 |
| Nuleargowik River | -3.2 | -2.5 | -1.7 | Burnt River | -2.0 | -1.1 | -0.7 | Egavik Creek | -1.5 | -0.4 | 0.1 | Grantley Harbor-Frontal Port Clarence | -0.5 | -0.3 | 0.0 |
| Patsy Slough-Yukon River | -3.1 | -2.1 | -1.6 | Kaviruk River | -2.0 | -1.1 | -1.0 | Klokerblok River | -1.5 | -0.3 | -0.1 | Flambeau River | -0.5 | 0.6 | 0.7 |
| Middle Tagagawik River | -3.1 | -2.3 | -1.7 | Anakeksik Creek | -2.0 | -0.9 | -0.5 | Middle Selawik River | -1.5 | -0.8 | -0.3 | Pastolik River | -0.5 | 0.6 | 0.7 |
| Tukrok River-Frontal Kotzebue Sound | -3.0 | -2.1 | -1.5 | Artic Lagoon | -1.9 | -1.3 | -1.0 | Kwiniuk River | -1.5 | -0.3 | 0.0 | Mountain Creek | -0.4 | 1.0 | 1.3 |
| Duck Creek | -2.9 | -2.0 | -1.3 | 1905030117 | -1.9 | -1.2 | -0.6 | Cobblestone River | -1.4 | -0.7 | -0.6 | Outlet East Fork Andreafsky River | -0.4 | 1.0 | 1.2 |
| Headwaters Tagagawik River | -2.9 | -2.1 | -1.5 | Fish River | -1.9 | -1.1 | -0.6 | Cowpack River | -1.4 | -0.9 | -0.5 | Outlet Bonasila River | -0.4 | 0.8 | 1.2 |
| Woodyard Creek | -2.9 | -2.0 | -1.4 | Outlet North River | -1.9 | -0.7 | -0.2 | Outlet Ungalik River | -1.4 | -0.4 | 0.0 | Upper Atchuelinguk River | -0.4 | 0.9 | 1.2 |
| Upper Tagagawik River | -2.9 | -2.1 | -1.5 | Chiroskey River | -1.9 | -0.8 | -0.3 | Tubutulik River-Frontal Norton Bay | -1.4 | -0.3 | 0.0 | Otter Creek | -0.3 | 0.6 | 0.9 |
| East Fork Koyuk River | -2.9 | -1.8 | -1.2 | Kwik River | -1.9 | -0.7 | -0.2 | Honeymoon Slough-Yukon River | -1.4 | -0.3 | 0.1 | Pastoliak River | -0.3 | 0.8 | 1.0 |
| Lower Buckland River | -2.9 | -1.9 | -1.3 | Outlet Kuzitrin River | -1.9 | -0.9 | -0.7 | Nuluk River | -1.4 | -1.0 | -0.6 | Headwaters Agiapuk River | -0.3 | -0.1 | 0.2 |
| Village Creek-Frontal Chukchi Sea | -2.8 | -2.1 | -1.6 | Headwaters Fish River | -1.9 | -0.9 | -0.6 | Kogok River | -1.4 | -0.2 | 0.1 | Five Day Slough | -0.3 | 1.0 | 1.2 |
| North Fork Unalakleet River | -2.8 | -1.6 | -1.2 | Cowpack Inlet-Frontal Chukchi Sea | -1.9 | -1.2 | -0.7 | Outlet Gisasa River | -1.4 | -0.5 | -0.2 | Middle Atchuelinguk River | -0.2 | 1.1 | 1.3 |
| Sullivan Creek-Frontal Kotzebue Sound | -2.8 | -2.0 | -1.4 | Kungealarook Creek-Frontal Kotzebue Sound | -1.9 | -1.2 | -0.7 | Pinguk River | -1.4 | -0.8 | -0.6 | Lower Atchuelinguk River | -0.2 | 1.1 | 1.4 |
| Three Day Slough-Koyukuk River | -2.8 | -2.0 | -1.3 | Nugnugaluktuk River | -1.9 | -1.3 | -0.9 | Headwaters American River | -1.4 | -0.9 | -0.5 | Beaver Creek | -0.1 | 0.8 | 1.3 |
| Kaiyuh Slough-Yukon River | -2.8 | -1.7 | -1.3 | Pargon River | -1.9 | -0.8 | -0.5 | Feather River-Frontal Bering Sea | -1.4 | -0.7 | -0.5 | Snake River | -0.1 | 0.9 | 1.0 |
| Kawichiark River | -2.6 | -2.0 | -1.4 | Thompson Creek-Yukon River | -1.9 | -0.6 | -0.2 | Big Eightmile Island-Yukon River | -1.4 | -0.4 | 0.0 | Blackburn Creek-Yukon River | -0.1 | 0.7 | 1.3 |
| Black River | -2.6 | -2.0 | -1.2 | Golovnin Bay-Frontal Norton Sound | -1.9 | -0.6 | -0.3 | Tagoomenik River | -1.4 | -0.2 | 0.2 | Kuiak River-Frontal Norton Sound | 0.0 | 1.1 | 1.4 |
| Holtz Creek | -2.6 | -1.6 | -1.2 | Yellow River | -1.9 | -0.6 | -0.2 | Headwaters Niukluk River | -1.3 | -0.4 | -0.2 | Middle Anvik River | 0.1 | 1.0 | 1.4 |
| Outlet Kugruk River | -2.6 | -1.7 | -1.2 | Portage Creek-Kobuk River | -1.8 | -1.1 | -0.5 | Cross Slough-Yukon River | -1.3 | 0.1 | 0.3 | Stuyahok River | 0.1 | 1.1 | 1.5 |
| McDonald Creek | -2.6 | -1.3 | -0.9 | Headwaters Koyuk River | -1.8 | -0.9 | -0.6 | Kaltag River | -1.3 | -0.4 | 0.0 | Anuk River-Yukon River | 0.1 | 1.1 | 1.2 |
| Lower Koyuk River | -2.6 | -1.4 | -0.8 | Nunavulnuk River | -1.8 | -0.6 | -0.3 | Engineer Creek | -1.3 | 0.1 | 0.3 | Koserefski River | 0.1 | 1.3 | 1.7 |
| Tuklomarak Lake | -2.5 | -1.7 | -1.1 | Kugachevik Creek-Kobuk River | -1.8 | -1.2 | -0.5 | Nageethluk River | -1.3 | 0.1 | 0.3 | Nanvaranak Slough | 0.2 | 1.1 | 1.2 |
| Middle Fork Buckland River | -2.5 | -1.6 | -1.1 | Melvin Channel | -1.8 | -1.0 | -0.4 | Kako Creek | -1.2 | 0.3 | 0.5 | Archuelinguk River | 0.2 | 1.2 | 1.3 |
| South Fork Buckland River | -2.5 | -1.6 | -1.0 | Quartz Creek | -1.8 | -0.8 | -0.4 | Outlet American River | -1.2 | -0.6 | -0.4 | Lower Andreafsky River | 0.2 | 1.4 | 1.5 |
| Hugo Creek | -2.5 | -1.7 | -1.1 | Bonanza River | -1.8 | -0.7 | -0.5 | Outlet Nulato River | -1.2 | -0.3 | 0.0 | Town of Fish Village | 0.9 | 1.6 | 1.7 |

# *A-3 Fire*

The primary management question relating to fire is "*What is the fire history of the region and what is the potential future fire regime? What are the implications for vegetation?*" Data and literature reviews were used to characterize the fire history of the region, and Boreal ALFRESCO (Alaska Frame-Based Ecosystem Code) (Rupp et al. 2000; Lloyd et al. 2002) was used to address the potential future fire regime and its impact on vegetation. The results of this review and Boreal ALFRESCO modeling inform the answers to related management questions as illustrated in Figure A-4. The question "How will habitats that support terrestrial species of concern likely change due to fire over the next 15 and 50 years" is directly addressed by the Boreal ALFRESCO modeling results in this appendix. MQs 126 and 129.5, relating to lightning strike frequency and fire history are addressed here; the other fire-related management questions are addressed in Appendix D.

**Figure A-4: Schematic of MQs related to fire.**




## A-3.1 Fire History and Influences

**129.5**: What does the paleorecord reveal about fire history?

### A-3.1.1 Historical Data and Literature Review

Fire maps include all fire perimeters since 1940, although these files do not contain data on fire severity, such as crown fires vs. ground fires, or partial vs. complete burns. Since some factors, such as impacts on permafrost, are strongly affected by fire severity, the data are therefore somewhat incomplete. However, clear regional and temporal patterns do emerge.

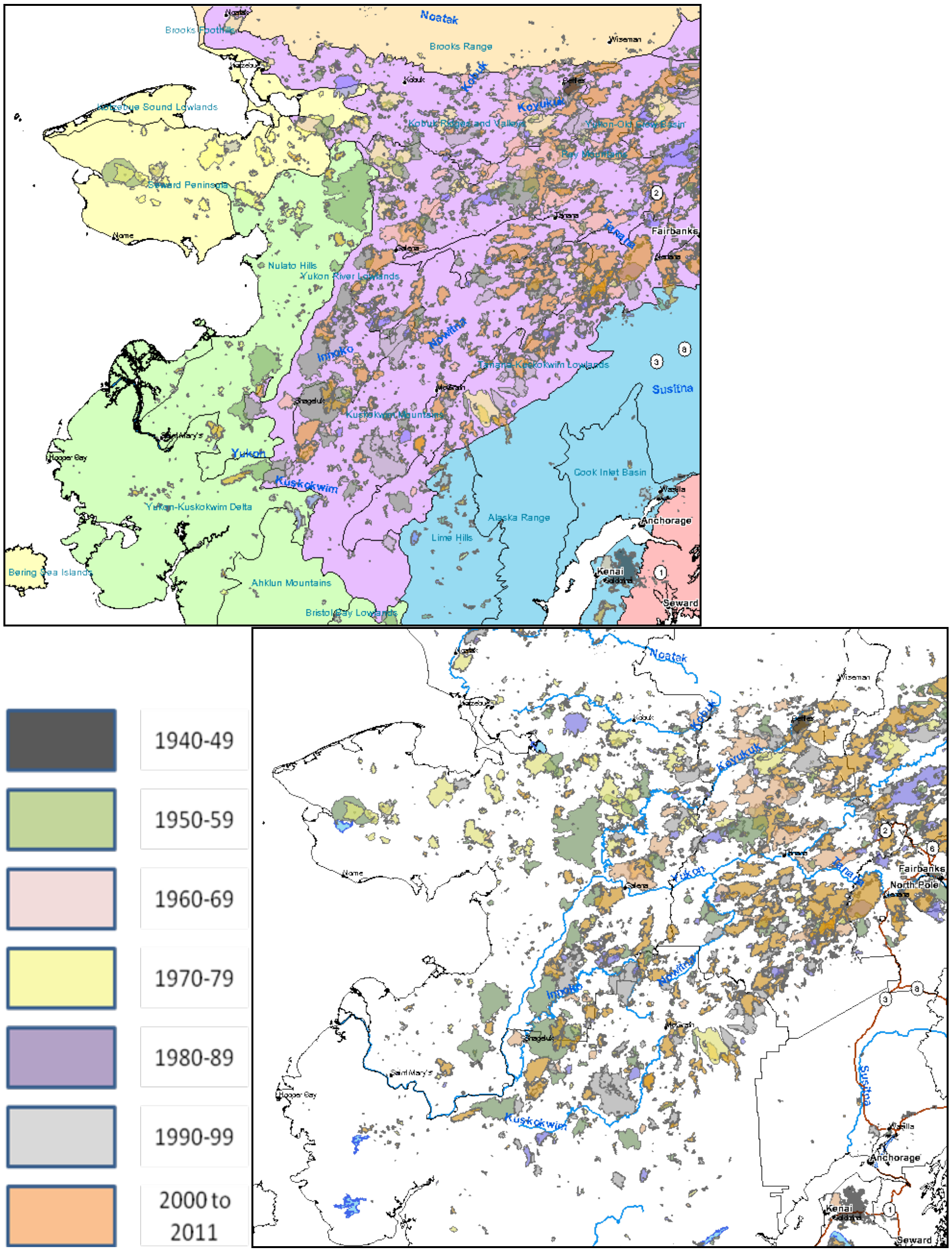
### A-3.1.2 Findings

The paleorecord reveals that although fire has been historically far less common in the Seward Peninsula portion of the SNK ecoregion than in the interior boreal forest, it has also been quite variable. Some periods within the past several thousand years show much higher frequency of fire than recent decades.

Recent historical fire records show many areas remaining unburned over the past seventy years (Figure A-5). However, large fires have occurred, particularly in more inland areas (e.g., the Nulato Hills).

In tundra, lichens are slow to regrow after fire, with lichen cover of only 3-4% 24-25 years post-fire on the Seward Peninsula (Jandt et al. 2008). Recent decades have seen marked change in Arctic tundra ecosystems due to the interplay of climate change, wildfire, and disturbance by caribou and reindeer; these interdependent changes are all implicated in the observed significant reduction of terricolous lichen ground cover and biomass (Joly et al. 2009). Fire can also lead to vegetation shift. In one study on the Seward Peninsula, it was found that shrub cover was higher on the burned plots than the unburned plots, and that cover of cottongrass (*Eriophorum vaginatum*) initially increased following the fire, and remained so for more than 14 years (Jandt et al. 2008).

**Figure A-5: Historical fires shown with ecoregion boundaries (above) and without ecoregion boundaries (below).**



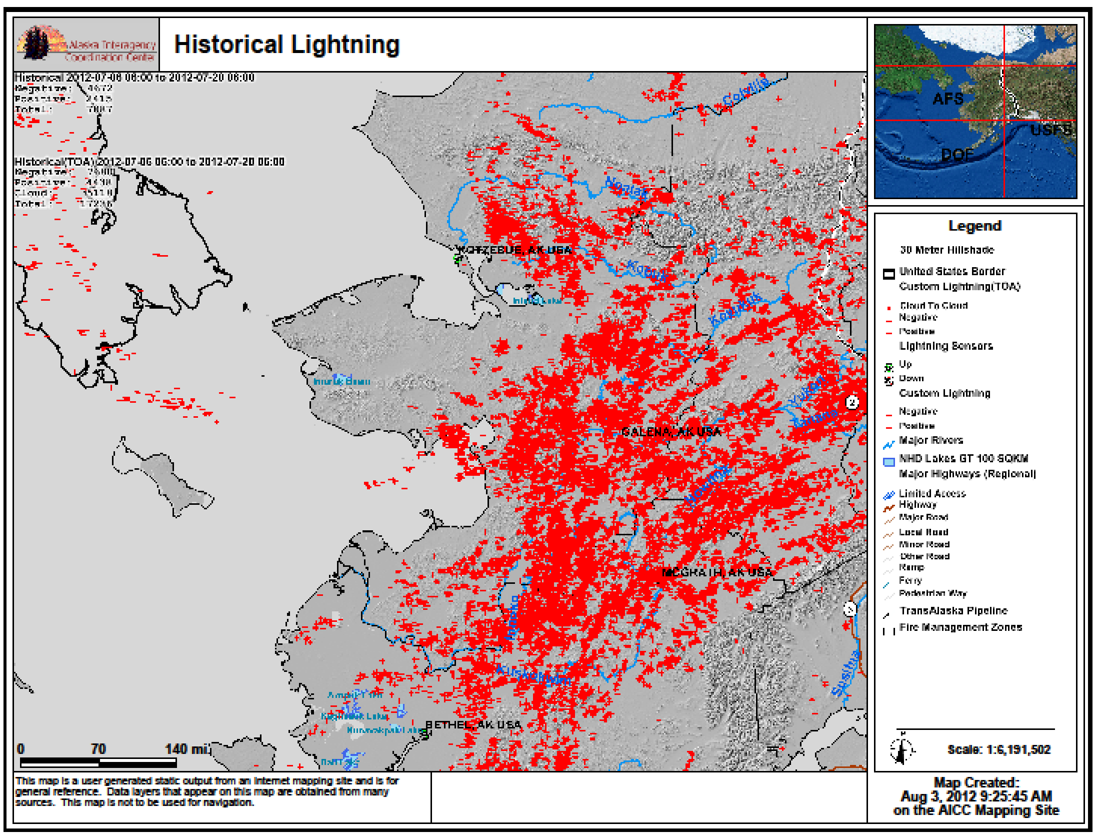
**126**: What is the known lightning strike frequency? Do these data show a significant trend over time?

Lightning data and data on fires statewide are available from the Alaska Fire Service (http://afsmaps.blm.gov/imf/imf.jsp?site=lightning). This interactive map viewer allows users to zoom, pan, download, and print maps in static and GIS formats. Available map layers for lightning include current and recent lightning strikes, and lightning strikes for every year back to 1990, plus 1986 and 1988.

Fire frequency is dependent not only on the flammability of the landscape, but also on fire ignitions from lightning, meaning that a hotter, drier climate does not necessarily mean more fires (Lynch et al. 2004). Although lightning strikes are tracked by the Alaska Fire Service (http://afsmaps.blm.gov/imf/imf.jsp?site=lightning), accuracy of measurement has been inconsistent over time, meaning that no consistent trends can be identified using historical data. However, in some cases, climate change appears to be positively correlated with increased cloud-to-ground lightning activity (Kochtubajda et al. 2011).

Lightning strikes are far more common in inland areas than on the Seward Peninsula, as evidenced by two weeks of lightning data from July 2012 (Figure A-6).

**Figure A-6: Sample lightning data from July 2012.**



## A-3.2 Projected Fire Risk and Impacts on Vegetation

### A-3.2.1 ALFRESCO: Background

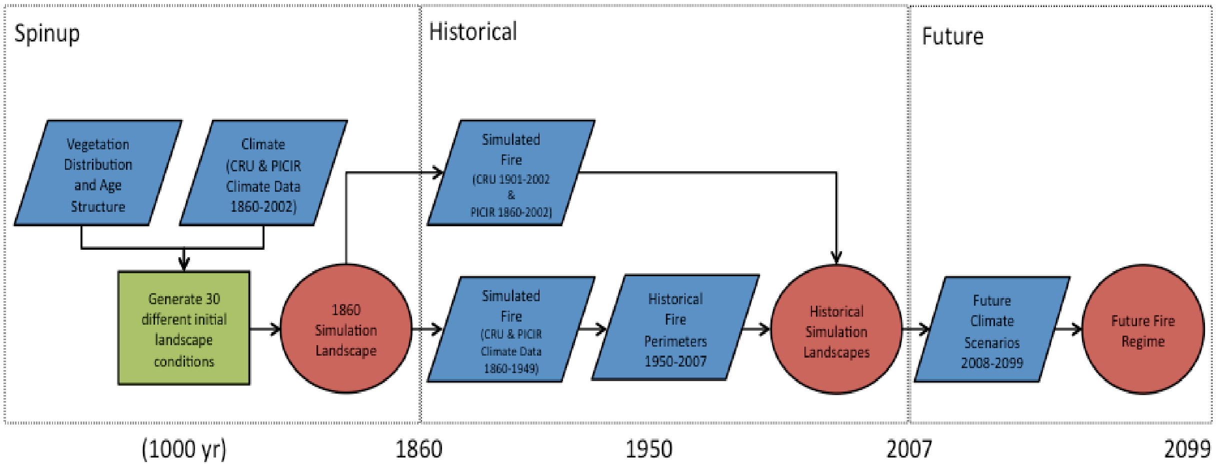
ALFRESCO simulates the responses of subarctic and boreal vegetation to transient climatic changes, and has been previously used in the Seward Peninsula region. For relevant discussion of the model, see also Rupp et al. 2000a; Rupp et al. 2000b; Rupp et al. 2001; Rupp et al. 2002.

ALFRESCO is a spatially-explicit cellular automata model that simulates fire and successional dynamics on a one-year time step. The model simulates five major subarctic/boreal ecosystem types: upland tundra, black spruce forest, white spruce forest, deciduous forest, and grassland-steppe. These ecosystem types represent a generalized classification of the complex vegetation mosaic characteristic of the circumpolar arctic and boreal zones of Alaska. SNAP climate data can be used as ALFRESCO inputs, thus creating projections of the impacts of changing climate on fire regime. ALFRESCO does not model fire behavior but rather models the empirical relationship between growing-season (May–September) climate (e.g., average temperature and total precipitation) and total annual area burned (i.e., the footprint of fire on the landscape). ALFRESCO also models the changes in vegetation flammability that occur during succession through a flammability coefficient that changes with vegetation type and stand age (i.e., succession) (Chapin et al. 2003).

The model focuses on system interactions and feedbacks. The fire regime is simulated stochastically and is driven by climate, vegetation type, and time since last fire (Rupp et al. 2000b; Rupp et al. 2007). ALFRESCO employs a cellular automaton approach, where simulated fire may spread to any of the eight surrounding pixels. "Ignition" of a pixel is determined as a function of the flammability value of that pixel and a randomly generated number (Rupp et al. 2000b; Rupp et al. 2002). The flammability of each pixel is a function of vegetation type and age, meaning that ignitions will be concentrated in pixels with the highest fuel loads and the driest climate conditions. Fire spread depends on the flammability (i.e., fuel loading and moisture) of the receptor pixel. Some pixels, e.g., non-vegetated areas and large water bodies, do not burn and thus serve as fire breaks. Suppression activities were not simulated.

ALFRESCO has been calibrated using available literature regarding burn rates and stand compositions (Rup et al. 2007). However, most of these data came from interior AK, well to the east of the SNK ecoregion. In addition, the model is generally calibrated through use of a "spin-up" period of 1000 years of simulated fire history, in order to match outputs as closely as possible to historical fire patterns (Figure A-7). The model parameters derived during this spin-up period are then used to create future projections. However, as discussed below, this form of calibration proved inappropriate to the model and the study area.

**Figure A-7: Conceptual model showing the Boreal ALFRESCO simulation design.**




### A-3.2.2 ALFRESCO: Uncertainty

The ALFRESCO model uses SNAP input data as a basis for projecting fire on the landscape. Thus, all the sources of uncertainty associated with SNAP data (described below) apply when assessing ALFRESCO outputs. In addition, although this model is well-calibrated to match historical climate conditions to historical fire records, all future projections are inherently uncertain because they depend on assumptions and estimates regarding the frequency and location of fire starts as well as the calculated relationship between climate, forest age and type, and fire spread.

Several limiting factors contributed to the uncertainty for this particular project. ALFRESCO was primarily designed to simulate fire in boreal forests. However, tundra comprised 61% of the study area; this proportion did not change because ALFRESCO does not currently incorporate treeline shift or other modes of succession from tundra to forest. In addition, apparent increases in spruce and decreases in deciduous cover are misleading, due to ALFRESCO's assumed deciduous to spruce trajectory. In other words, the model assumes that all deciduous pixels will, if unburned for long enough, undergo forest succession and become spruce pixels. This is accurate for some forested pixels within the study area, but inaccurate for areas of willow and alder that are likely to remain shrubby. In order to correct for this problem, the model was run with some adjustments to the normal spin-up cycle. A thousand-year spin-up allowed the landscape to become unrealistically populated with spruce, so the current landscape was corrected to match existing vegetation maps and fire scars. However, the deciduous to spruce trajectory persisted in future projections; this is a serious flaw in the model. However, although its ramifications are not universally applicable throughout the SNK REA, when the results are viewed at a more localized scale, ALFRESCO proved to be useful despite this problem. Moreover, no other existing fire model offered a better approach to mapping and predicting fire at the resolution desired for this project, and no other model offered the opportunity to directly link known landscape conditions, fire history, lightning strikes, existing vegetation data, and future fire projections into a comprehensive set of predictions. Nonetheless, 2025 results are likely more reliable than 2060 results.

It should also be noted that although the A2 emissions scenario was used for other portions of this project, ALFRESCO runs on the A1B scenario. This would be likely to make outputs slightly more conservative than they would have been for the A2 scenario.

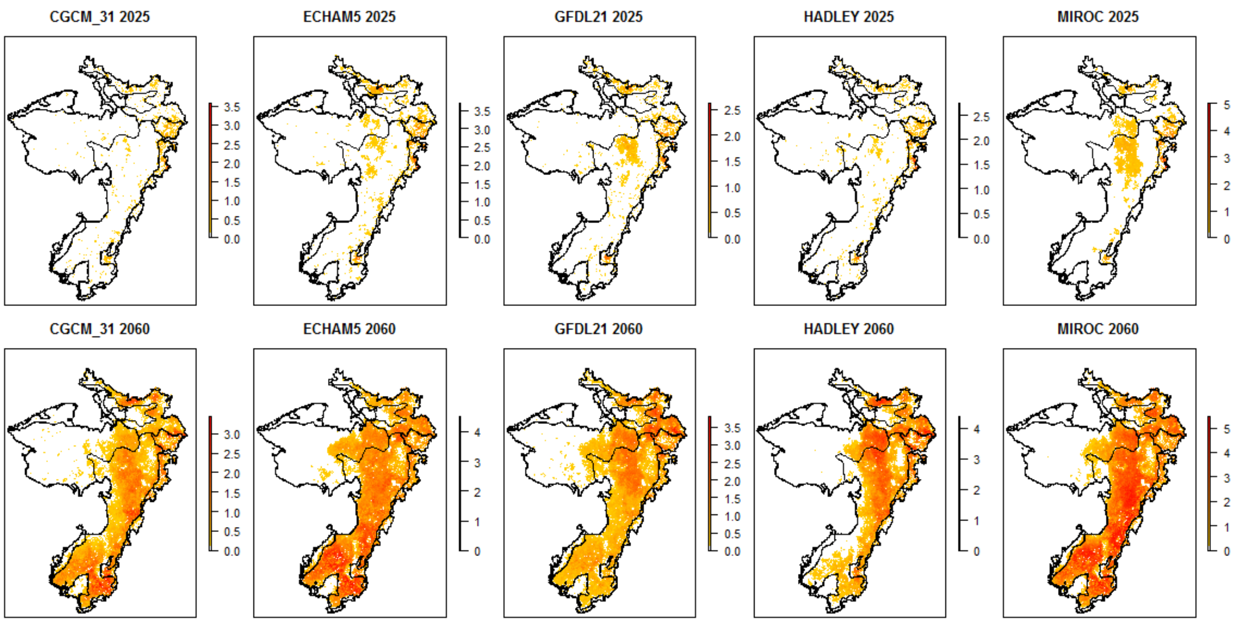
## A-3.3 Fire Trends and Impacts on Vegetation: 2025 and 2060

**129**: What is the known fire history of the region and what is the potential future fire regime? and What are the implications for vegetation?

**87**: How will habitats that support terrestrial species of concern likely change due to fire over the next 15 and 50 years?

Despite difficulties calibrating the ALFRESCO model to deal with the shrubby/deciduous vegetation class prevalent in some areas of the SNK ecoregion, modeling results clearly indicate an increase in fire frequency across the future time period (2025 and 2060). All five GCMs used by SNAP offer similar results (Figure A-8).

**Figure A-8. Fire risk as the % of times a pixel burns across 60 ALFRESCO replicates, averaged for 15 years prior (i.e., 2010 to 2025, and 2045 to 2060). The legend scale refers to annual fire risk.**




Modeling difficulties related to deciduous/black spruce trajectories mean that results should be considered only on a location-by-location basis, with the greatest credence given to predictions for areas of coniferous forest (or early-succession deciduous vegetation in burned coniferous forest) and grassy tundra. The model should not be considered reliable for shrubby areas, areas of deciduous vegetation that cannot be classified as early-succession coniferous forest, or areas in transition (shrubbification).

For forested areas, comprising much of the eastern portion of the SNK region, models predict much shorter fire cycles (as compared to historical averages) by the 2050s and 2060s. Table A-4 summarizes the percentage of flammable coniferous forest in each ecoregion, as well as providing an estimate of average fire cycle lengths across that ecoregion. Note, however, that fire cycles vary significantly within as well as between ecoregions, and that not all of each listed ecoregion occurs within the SNK area.

While it is impossible to pinpoint exact predicted locations or timing of fires (due to the stochastic nature of the ALFRESCO model and the innate unpredictability of individual fire events), it is clear that the magnitude of change in fire cycle length is likely to cause significant vegetative shift, and fire cycles to shorten – in the most fire-prone sites – to as little as 20-40 years (represented by fire probabilities of 2.5-5% in Figure A-8.

In addition to shortened fire cycles in spruce forest, more frequent tundra burning is very likely. In the Seward and Kotzebue regions where tundra percentages are high and deciduous percentage is low, model uncertainty may also be less of an issue than it is in transitional and shrubby zones.

**Table A-4. Fire-related variables by ecoregion. Adapted from Kasischke et al. 2002. Only fire-prone ecoregions were included in this study.**

| Ecoregion | Average Lightning Strikes (per 10x10 km per year) | Tree cover | Total conifer cover | Fire cycle |
|---|---|---|---|---|
| Nulato Hills | 1.2 | 19 | 17 | 356 |
| Seward Peninsula | 0.3 | 1 | 1 | 340 |
| Kobuk Ridges and Valleys | 3 | 47 | 43 | 215 |
| Tanana-Kuskokwim Lowlands | 3.7 | 83 | 64 | 214 |
| Yukon River Lowlands | 0.3 | 78 | 55 | 146 |

## *A-4 Development*

A series of management questions were identified relating to development activities and infrastructure. They generally ask the same three-part question for a variety of different development features:

1. Where is current development?
2. Where is planned/future development?
3. Where do these current and planned developments overlap with CEs?

This section provides additional detail on the data and methods used to develop map layers to address the first two components of these questions – where are the current and planned/future locations?

**50**: Where are current and planned roads located and where do they overlap with CEs and other relevant habitat?

**45:** Where are current and planned oil/gas activities located and where do they overlap with CEs or other relevant habitats?

**52:** Where are potential wind and biomass sites located within 25 miles of communities?

**46**: Where are historic, current, and potential mining activities located, and where do they overlap with CEs or other relevant habitat?

**49**: Where are historic, current, and potential recreation use areas located, and where do they overlap with CEs or other relevant habitat?

**51**: Where are historic, current, and military sites areas located, and where do they overlap with CEs or other relevant habitat?

**111**: Where are hazardous waste sites?

## A-4.1 Current and Future Distribution: Data, Methods, and Results

Eleven development change agents were identified and mapped within the SNK REA: ten current development change categories and eleven future development change agent categories (Table A-5, Figure A-9 and Figure A-10).

It is assumed that current development footprints will generally persist into the future; all current development footprints were included as part of the future development footprints. Six development change agents were modeled into the future: communities, ports, roads, railroads, contaminated sites, and recreation. For these six development categories, their current footprints were combined with their modeled future (proposed) footprints. (Categories with modeled future development footprints are italicized and bolded in Table A-5). No site-specific, future (proposed) mapped information was available for trails, renewable energy fund sites, military lands, mines or landing strips/airports; for these five classes, only the current development footprints were used for future analysis/mapping. Of note, many development change agent footprints overlap. Current development footprints represent less than 1% of the total area of the ecoregion. In Table A-5, future area statistics were not calculated because there is too much uncertainty about the location/spatial extent of the modeled future development footprints and because multiple scenarios were mapped for ports, roads and railroads.

**Table A-5. Development change agent area statistics and source data. Six categories of development infrastructure or features had information that could be used to develop maps of future footprints of proposed infrastructure; these categories are shown in italics/bold text. Site-specific mapped information on proposed additions or projected extent was not available for the other five development categories; therefore, only their current footprints were used for future analysis/mapping. Future development footprints combine current and, where available, future (proposed) footprints.**

| Development Change Agent Category | Current Development Change Agent | | | Future Change Agent |
|---|---|---|---|---|
| | Total Area (acres) | Percent of Ecoregion | Source Data | Source Data |
| ***Human Population Center/Community*** | 207,641 | 0.121 | 2010 Tiger Census Places (http://www.census.gov/geo/www/tiger/tgrshp2010/tgrshp2010.html) | 2010 Tiger Census Places (http://www.census.gov/geo/www/tiger/tgrshp2010/tgrshp2010.html); Shishmaref – Updated Relocation Plan, Bristol project No. 210029 (Figure 2) |
| ***Port*** | 58,818 | 0.034 | 2010 Tiger Census Places (http://www.census.gov/geo/www/tiger/tgrshp2010/tgrshp2010.html) | 2010 Tiger Census Places (http://www.census.gov/geo/www/tiger/tgrshp2010/tgrshp2010.html); Ambler Mining District Access Summary Report (AKSAS 63812) 2011; Kotzebue to Cape Blossom Road - Reconnaissance Study (State Project No. 76884) 2011; Expert Knowledge |
| Trail | 51,691 | 0.030 | Alaska Department of Natural Resources 63,360 line transportation infrastructure data (http://www.asgdc.state.ak.us/); Northwest Arctic Borough winter trails data; Iditarod National Historic Trail data (http://sdms.ak.blm.gov/isdms/imf.jsp?site=sdms) | Used data for current footprint to reflect known future footprint; no projections or information on proposed additions to this infrastructure category are available. |
| Renewable Energy Fund Site | 39,956 | 0.023 | Alaska Energy Authority (AEA) Renewable Energy Atlas ftp://ftp.aidea.org/AEAPublications/2011_RenewableEnergyAtlasofAlaska.pdf); 2010 Tiger Census Places (http://www.census.gov/geo/www/tiger/tgrshp2010/tgrshp2010.html) | Used data for current footprint to reflect known future footprint; no projections or information on proposed additions to this infrastructure category are available. |
| Military (active) | 25,893 | 0.015 | USGS Protected Areas Database 1.2 (http://gapanalysis.usgs.gov/data/padus-data/) | Used data for current footprint to reflect known future footprint; no additional military facilities have been proposed for this ecoregion to date. |

| Development Change Agent Category | Current Development Change Agent | | | Future Change Agent |
|---|---|---|---|---|
| | Total Area (acres) | Percent of Ecoregion | Source Data | Source Data |
| ***Road*** | 5,809 | 0.003 | Alaska Department of Natural Resources 63,360 line transportation infrastructure data (http://www.asgdc.state.ak.us/) | Alaska Department of Natural Resources 63,360 line transportation infrastructure data (http://www.asgdc.state.ak.us/); Proposed Kotzebue to Cape Blossom Road Environmental Documentation, Project Number NCPD-0002(204)/76884; Kotzebue to Cape Blossom Road - Reconnaissance Study (State Project No. 76884) 2011; Ambler Mining District Access Summary Report (AKSAS 63812) 2011; Road to Nome dataset from Dowl Engineering |
| Mine | 1,882 | 0.001 | USGS Alaska Resource Data File (ARDF) (http://ardf.wr.usgs.gov/) | Used data for current footprint to reflect known future footprint; no projections or information on proposed additions to this infrastructure category are available. |
| Landing Strip or Airport | 780 | 0.000 | Alaska Department of Natural Resources 63,360 polygon transportation infrastructure data ((http://www.asgdc.state.ak.us/) | Used data for current footprint to reflect known future footprint; no projections or information on proposed additions to this infrastructure category are available. |
| ***Railroad*** | 762 | 0.000 | Alaska Department of Natural Resources 63,360 line transportation infrastructure data (http://www.asgdc.state.ak.us/) | Ambler Mining District Access Summary Report (AKSAS 63812) 2011; |
| ***Contaminated Site*** | 26 | 0.000 | Alaska Contaminated Sites Database (http://dec.alaska.gov/spar/csp/db_search.htm) | Alaska Contaminated Sites Database (http://dec.alaska.gov/spar/csp/db_search.htm); 2010 Tiger Census Places |
| ***Recreation*** | 0 | 0.000 | | Bureau of Land Management, Kobuk-Seward Peninsula Resource Management Plan (KSPRMP) and Environmental Impact Statement, 2006 |

#### Figure A-9. Current development footprint change agent map.

Ports completely overlap with the communities of Kotzebue, Nome, and St. Mary's and are shown as blue on this map. Renewable energy fund sites are not shown on this map because they completely overlap with communities and ports and all three categories cannot be visually displayed on one map.

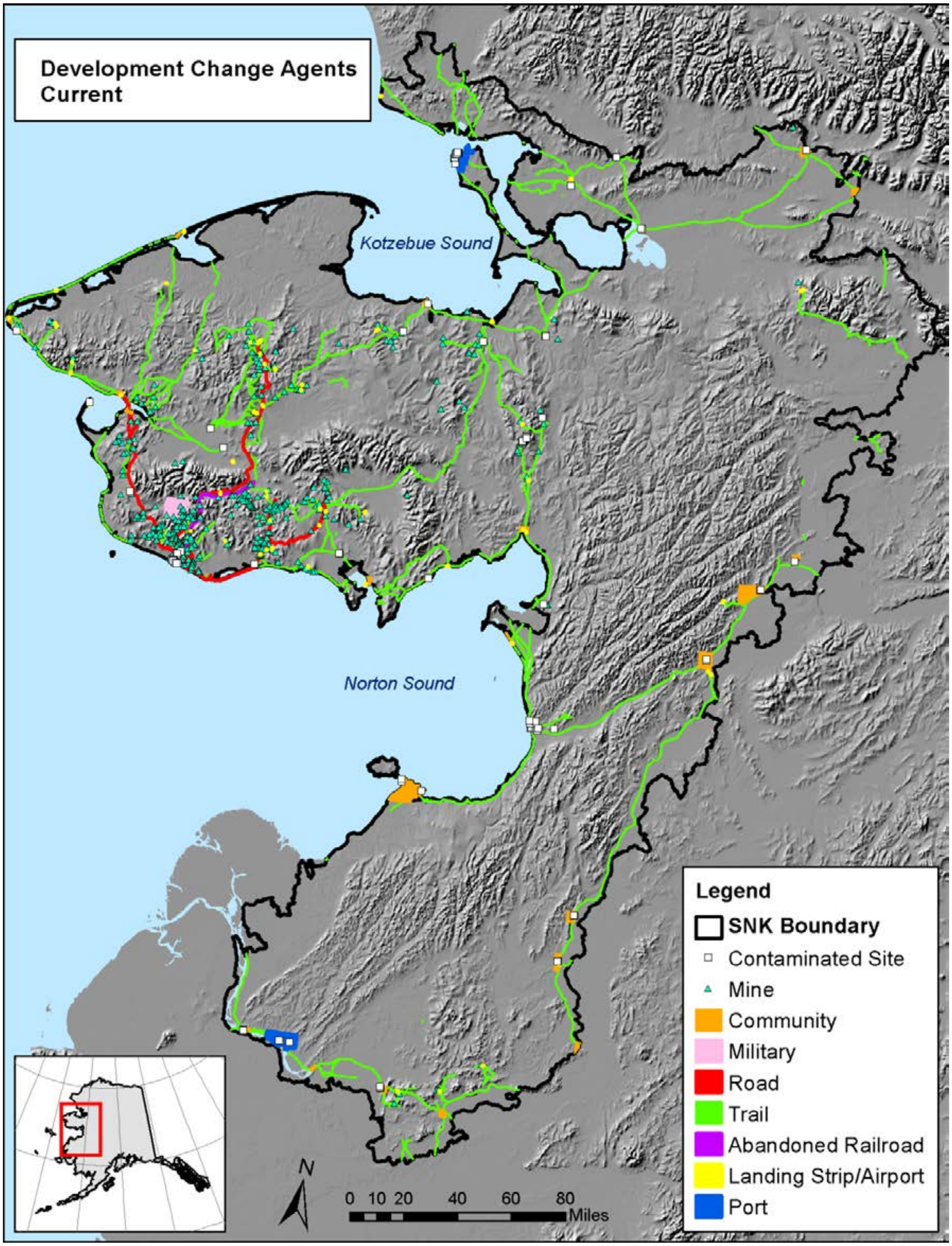


**Figure A-10. Current development footprint change agent zoom map of Nome area.**

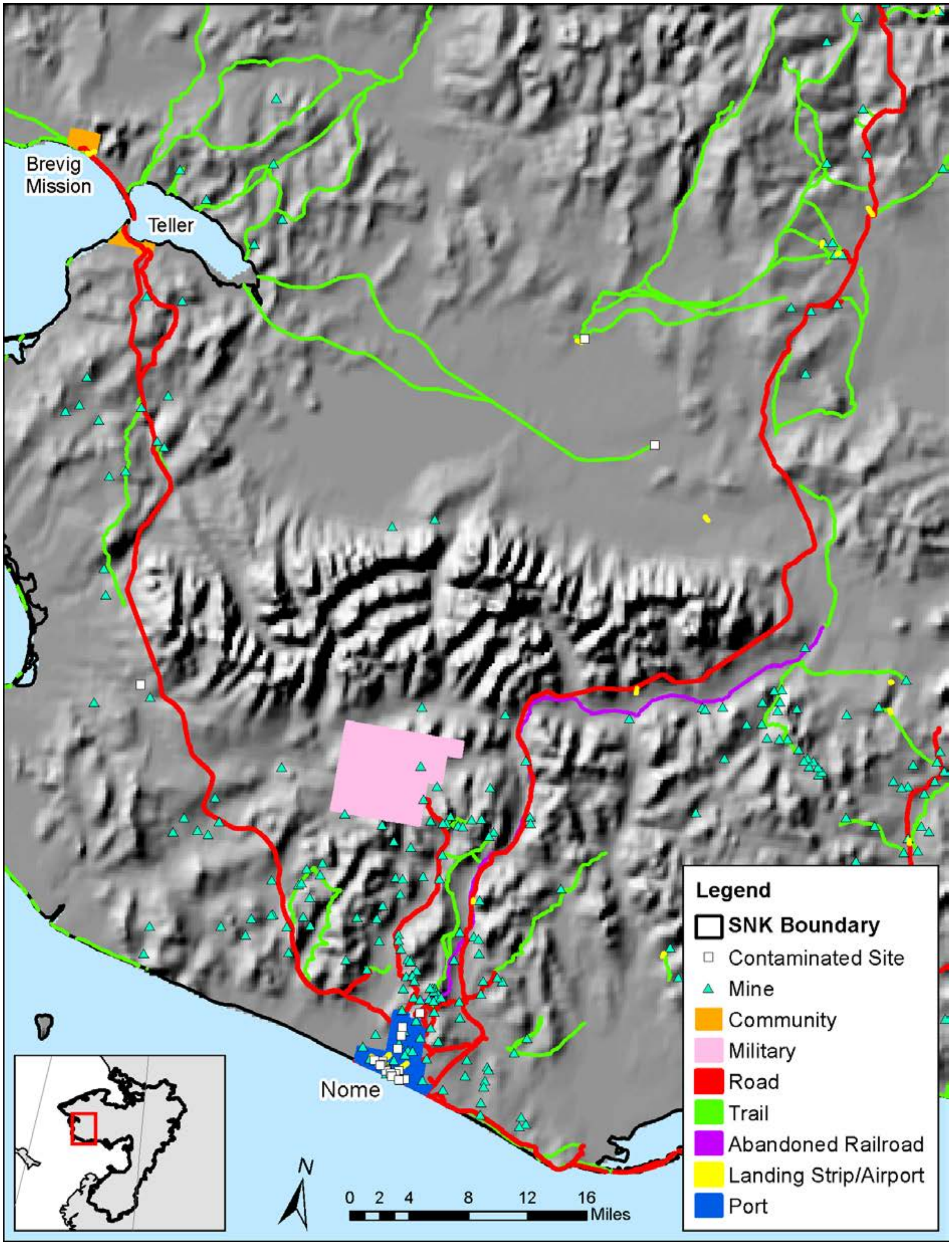


**Figure A-11. Future (current and proposed) development footprint change agent map.**

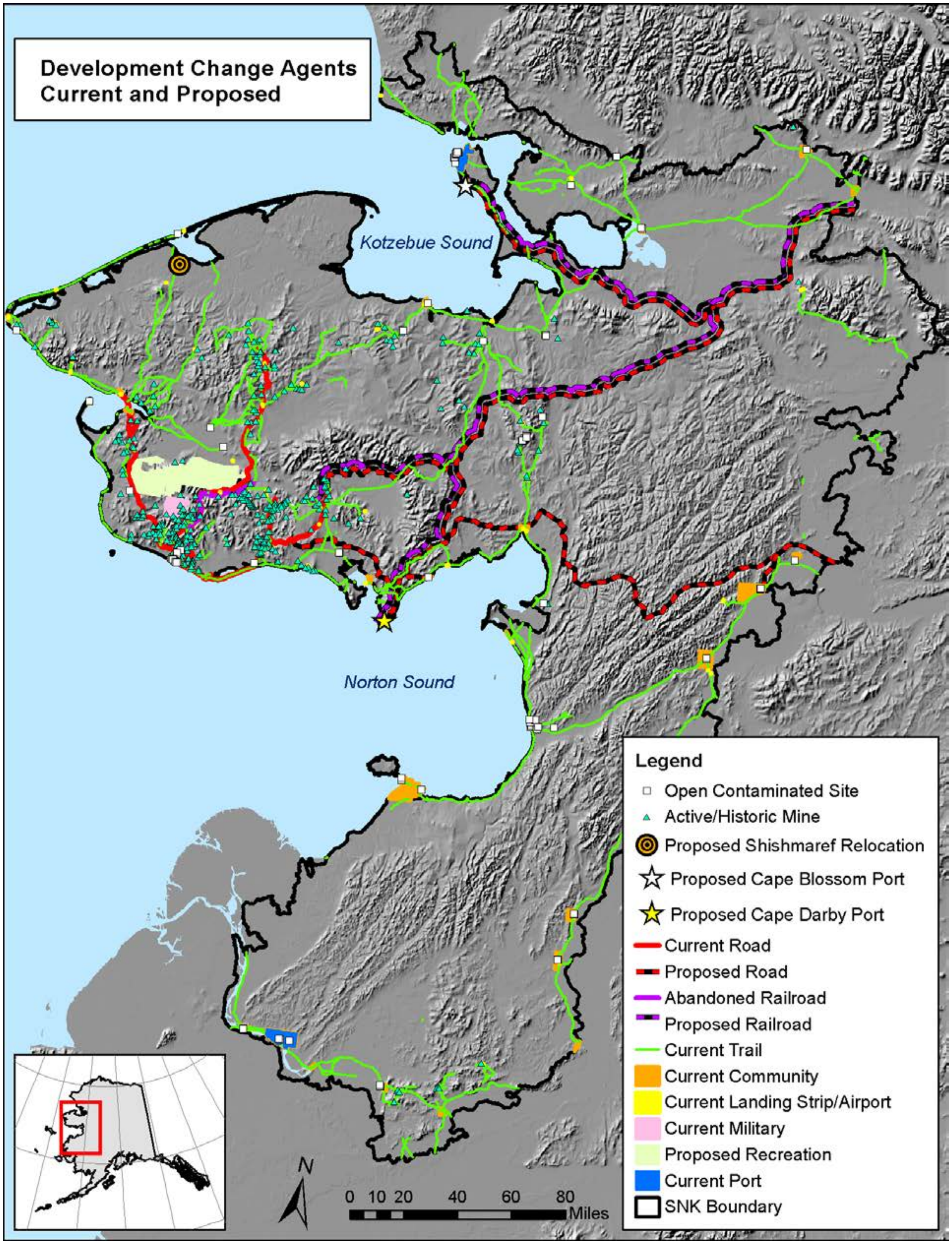
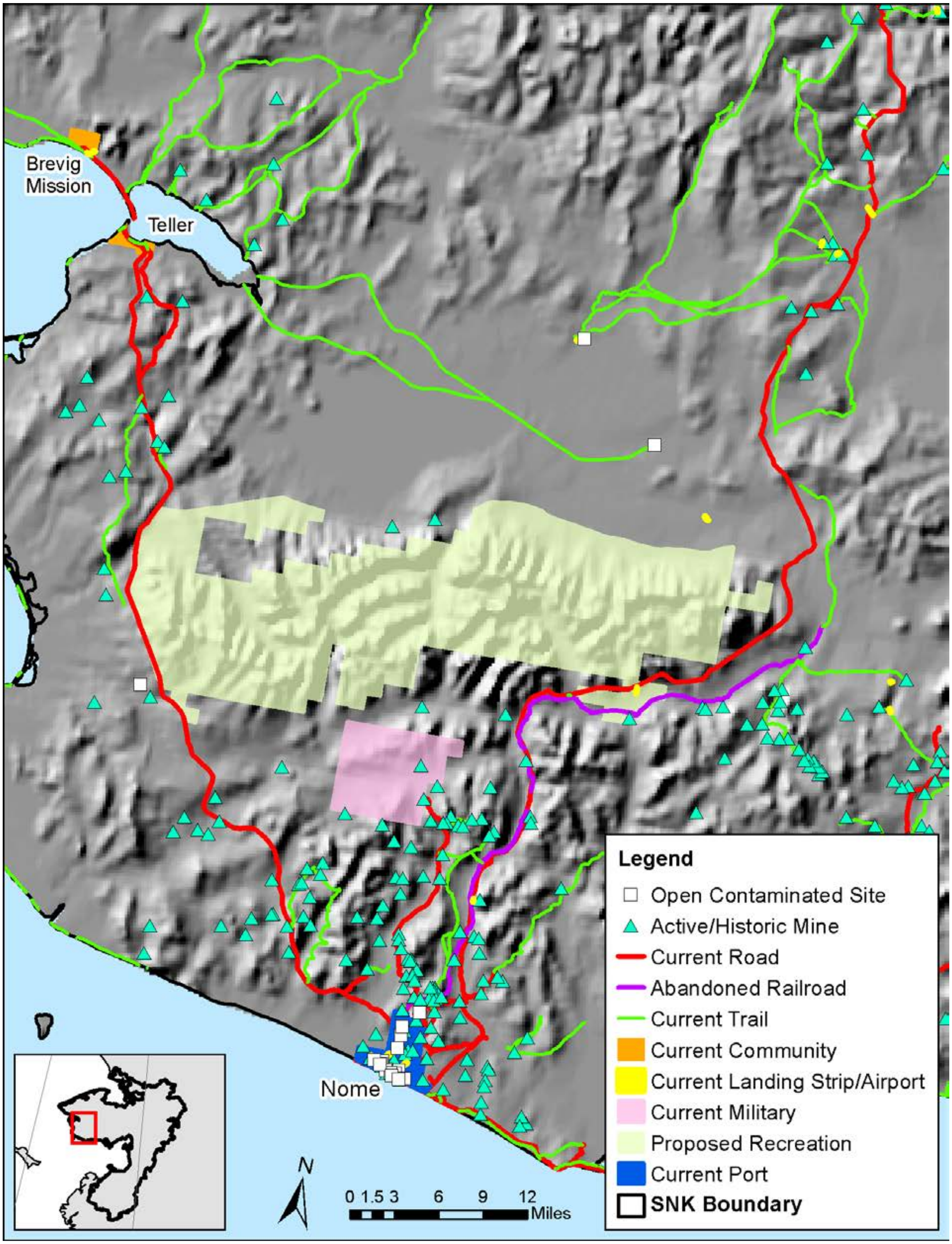


**Figure A-12. Future (current and proposed) development footprint zoom map of Nome area.**



Other types of current development change agents were reviewed but not ultimately included in the SNK REA due to a lack of mapped information and/or because they were not considered significant in terms of development impact, including: commercial aquaculture, commercial agriculture, commercial forestry, landfills, electrical/pipeline infrastructure, and recreation.

There may be one small-scale fish hatchery, but no large-scale commercial aquaculture is identified within the ecoregion.

Lichen is used as forage by domesticated reindeer, but there is no large-scale commercial agricultural production, in the conventional sense, within the ecoregion.

Wood is harvested for local fuel in the east, but there is no large-scale commercial logging within the ecoregion.

No comprehensive mapped data is available about community landfills; they are included within the community footprints because roads are seasonal and therefore not viable in winter for use in hauling refuse any distance from the communities.

Very small segments of linear transportation features in the Alaska Department of Natural Resources 63,360 linear transportation infrastructure are identified as electricity/telegraph/pipelines, but all are believed to be abandoned, and of no significant development impact.

There is little to no current recreation development, in the conventional sense of high impact, within this ecoregion.

#### A-4.1.1 Communities

Thirty-three human population centers/communities are located within the ecoregion. Community footprints were derived from the 2010 Tiger Census Places data. Nome and Kotzebue are the two largest towns, with populations over 3,000, while the rest of the communities are all relatively small (Table A-6).

Port Clarence was included in the 2010 Tiger Census Places dataset as a community; however, it is actually an abandoned military site and therefore was removed from the current community footprint.

The Tiger Census Places footprints tend to be larger than the actual on-the-ground development infrastructure because they include all municipal incorporated lands and therefore the development impact of communities may be over-estimated.

Three communities occur along the SNK REA boundary and spill over into the adjacent REA: Ambler, Shungnak, and Holy Cross. The areal extent of the Tiger Census Places data for these three communities was clipped to the buffered SNK REA.

The coastline on the barrier island community of Shishmaref is rapidly eroding and in the near future the community will need to relocate to the mainland. To model this change in the future community footprint dataset, the current polygon footprint of the community of Shishmaref was deleted from the current community dataset and a circular polygon of the proposed future location of Shishmaref at Tin Creek was on-screen digitized from the map (Figure 2 in the Shishmaref – Updated Relocation Plan (Bristol project No. 210029). The areal extent of the circle was based on the total area of the current footprint for the community of Shishmaref (1,423 acres).

The geographic extent of all other community footprints remain the same in the future community dataset, as derived from the 2010 Tiger Census Places dataset, even though some of them may grow in population. In general, the Tiger Census municipal footprints are already more extensive than the current built environment and therefore modeling community footprints based on population growth/expansion would likely over-estimate the geographic extent of future communities.

**Table A-6. Human population centers.**

| Place | 2010 Population (2010 Census) |
|---|---|
| Nome | 3,598 |
| Kotzebue | 3,201 |
| Selawik | 829 |
| Mountain Village | 813 |
| Unalakleet | 688 |
| Noorvik | 668 |
| Pilot Station | 568 |
| Shishmaref | 563 |
| Stebbins | 556 |
| St. Mary's | 507 |
| Buckland | 416 |
| Marshall | 414 |
| St. Michael | 401 |
| Brevig Mission | 388 |
| Kiana | 361 |
| Koyuk | 332 |
| Elim | 330 |

| Place | 2010 Population (2010 Census) |
|---|---|
| Russian Mission | 312 |
| Nulato | 264 |
| Shungnak | 262 |
| Ambler | 258 |
| Shaktoolik | 251 |
| Teller | 229 |
| Grayling | 194 |
| White Mountain | 190 |
| Kaltag | 190 |
| Holy Cross | 178 |
| Golovin | 156 |
| Wales | 145 |
| Deering | 122 |
| Pitkas Point | 109 |
| Koyukuk | 96 |
| Anvik | 85 |

### A-4.1.2 Transportation

**50**: Where are current and planned roads located and where do they overlap with CEs and other relevant habitat?

#### *A-4.1.2.1 Roads*

There are only three roads outside of the communities in this ecoregion, all radiating out from Nome (Figure A-9 and Figure A-10). These are two-lane, raised, gravel roads, not maintained in winter. The three main roads (and their connectors) were selected from the Alaska Department of Natural Resources 63,360 linear transportation infrastructure dataset, based on a visual review of an Alaska Department of Transportation, Northwest Transportation Plan map.

Several roads may be constructed in the future within the ecoregion. A road from Kotzebue to Cape Blossom has been approved and funded and will be constructed in the near future. This route was on-screen digitized from the report map (Figure A-13), and adjusted using Bing Imagery and the 60 meter National Elevation Dataset (NED). Three of the eight potential road/railroad corridors from the proposed Ambler mine expansion extend through the ecoregion (Figure A-14). These routes were also on-screen digitized from report maps, and adjusted using Bing Imagery and the 60 meter NED. Although the NED is known to have significant artifacts (inaccuracies in digital elevation values in a regular blocky pattern), it is currently the best digital elevation model data available for the entire study area, and was used only as a very general reference to visually adjust the proposed linework (i.e., to try to ensure the road/railroad routes were situated in valleys rather than adjacent mountain tops). In addition, a road from Nome connecting to Manley Hot Springs (Fairbanks) in the interior of Alaska has been extensively studied but not yet approved or funded (Figure A-13). All proposed roads were merged with current roads, to produce a future road dataset (Figure A-11). All of these proposed future road footprints are a best guess approximation of where these routes might eventually be located and should not be considered positionally accurate.

There is significant uncertainty about the likelihood that a road/railroad corridor from Ambler mining district and/or the road from Nome to Manley Hot Springs will actually be constructed. Of note, all three alternate Ambler mining district expansion routes are included in the SNK REA future road dataset, even though only one road/railroad scenario might eventually be constructed. The AMT decided it was best to include all three alternatives, rather than include none or only one, because it is unknown which, if any, of the proposed routes will be constructed.

**Figure A-13. Proposed Kotzebue to Cape Blossom Road (left) and proposed road to Nome (right).** The spatial location of the proposed Kotzebue to Cape Blossom Road was obtained from Environmental Documentation, Project Number NCPD-0002(204)/76884. The digital proposed road to Nome was obtained from Dowl Engineering.

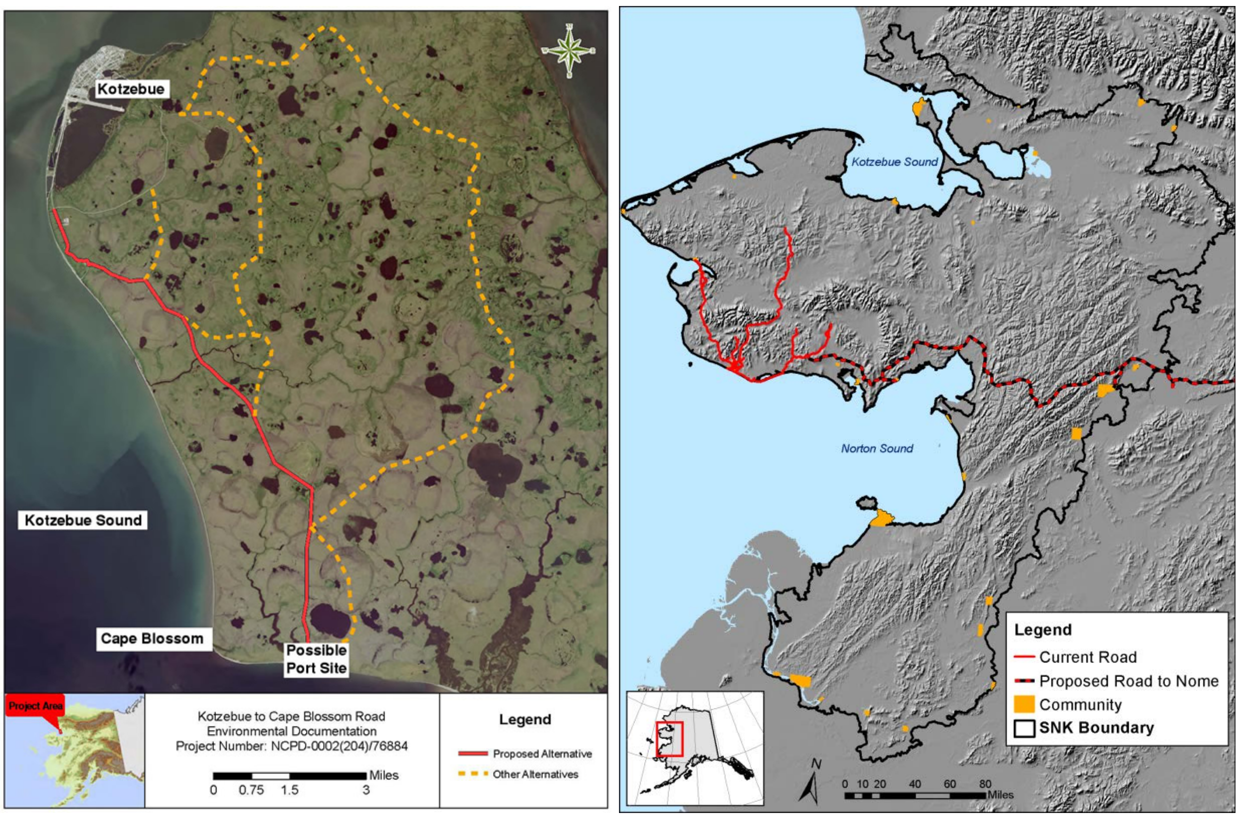
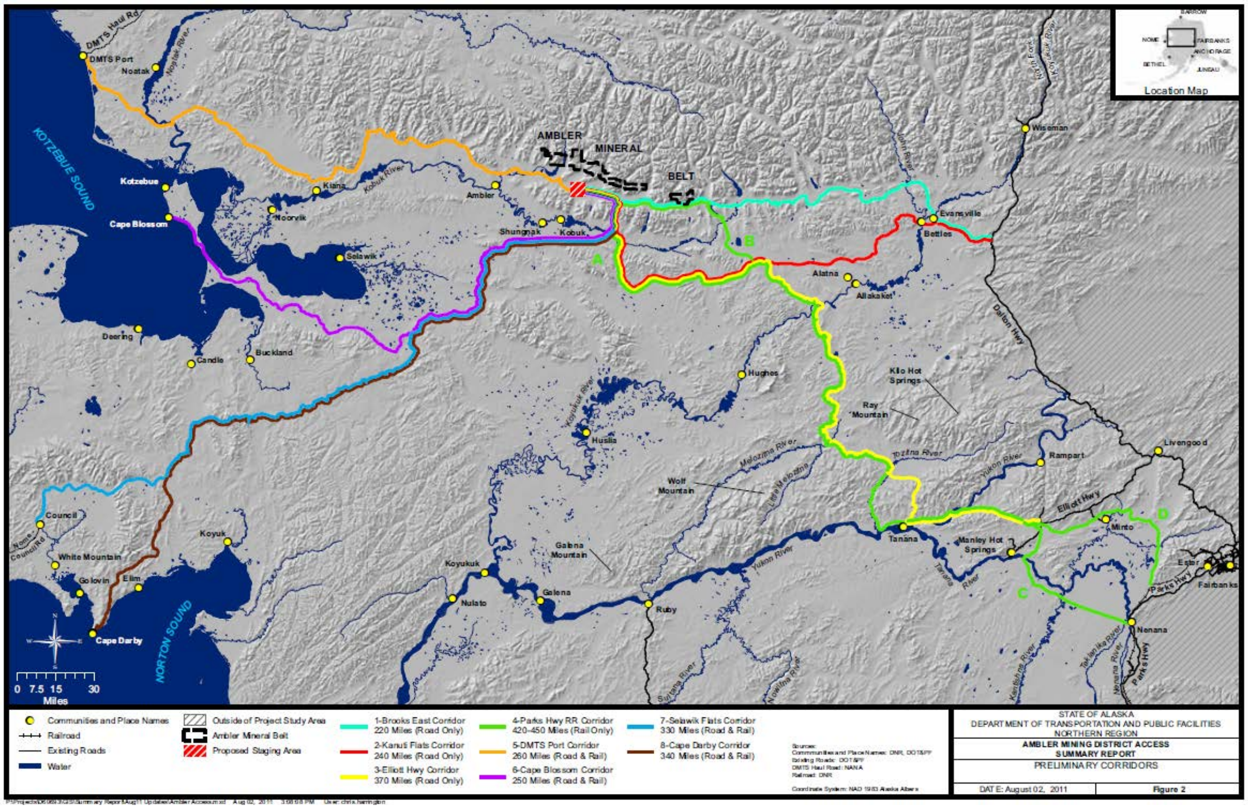


**Figure A-14. All eight proposed alternate road/railroad corridor routes for the Ambler mine expansion, from the Ambler Mining District Access Summary Report (AKSAS 63812), 2011, Figure 2. Routes 6, 7, and 8 from this map that occurred within the SNK were on-screen digitized.**




### *A-4.1.2.2 Trails*

Seasonal trails or ice roads occur throughout the ecoregion and are used to access camps, hunting areas, and in some cases, nearby communities. All trails, ice roads and secondary roads (excluding the roads around Nome) were selected from the Alaska Department of Natural Resources 63,360 linear transportation infrastructure dataset. The assumption was that any secondary roads identified in this dataset were really trails, given that the only roads suitable for car travel are identified as the routes around Nome. These trails were then merged with all of the trails from the Northeast Arctic Borough Trails dataset and the Iditarod Historic Trail dataset (Figure A-9 and Figure A-10). Given the seasonal / ephemeral nature of trails, this dataset is likely somewhat incomplete and/or out-of-date depending on whether trail routes have changed since the mapped information was collected. Ice roads can have an impact on the surrounding landscape if the communities dam a lake or divert water to raise the water level in a river; however, no spatial information was available to assess the environmental impact of ice roads.

### *A-4.1.2.3 Railroads*

There are currently no active railroads in the ecoregion. There is an abandoned railroad and proposed railroads.

An abandoned railroad corridor was identified in the Alaska Department of Natural Resources 63,360 linear transportation infrastructure data (Figure A-9 and Figure A-10). This railroad corridor was built approximately 100 years ago and has since been abandoned and/or partially converted to roads, and therefore may have very little impact in terms of development (Figure A-11 and Figure A-14).

A proposed railroad linking the Ambler mine to the coast may be constructed in the future within the ecoregion. Three of the eight potential road/railroad corridors from the proposed Ambler mine expansion extend through the ecoregion (Figure A-14). These routes were on-screen digitized from report maps, and adjusted using Bing Imagery and the 60 meter NED.

There is significant uncertainty about the likelihood that a road/railroad corridor from Ambler mining district will be constructed. Of note, all three alternate Ambler mining district expansion routes are included in the SNK REA future road/railroad dataset, even though only one road/railroad scenario might eventually be constructed. The AMT decided it was best to include all three alternatives, rather than include none or only one, because it is unknown which, if any, of the proposed routes will be constructed.

#### *A-4.1.2.4 Landing Strips/Airports*

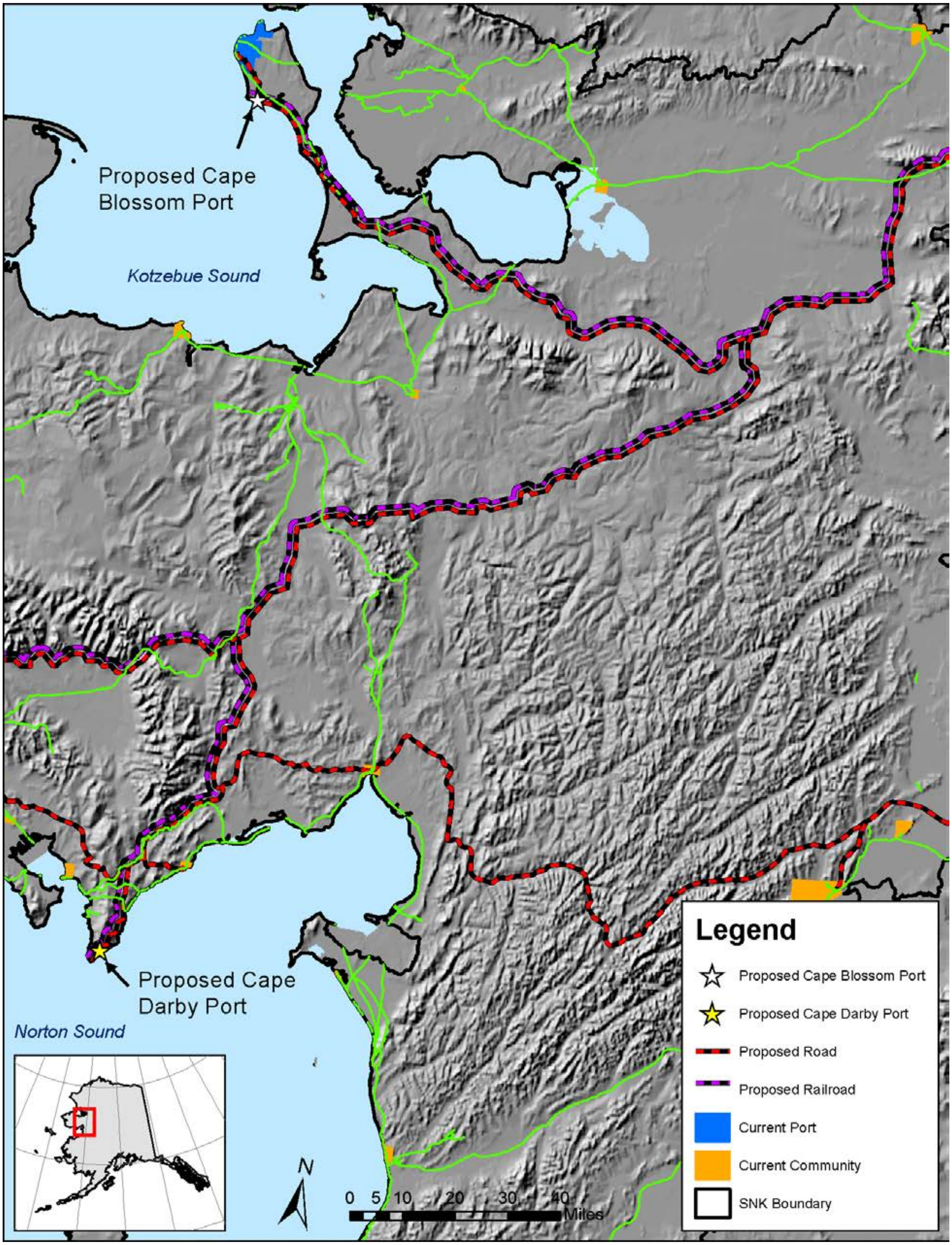
Within the SNK ecoregion, 102 landing strips were identified in the Alaska Department of Natural Resources 63,360 polygon transportation infrastructure dataset. However, this dataset may not be complete and/or up-to-date, since some of these are likely historic, and any substantial river gravel bar is readily used as a natural landing strip. Nome and Kotzebue have small, commercial airports, while the interior region is served by numerous gravel landing strips (Figure A-9 and Figure A-10).

#### *A-4.1.2.5 Ports*

There are three small-scale, commercial ports in the communities of Nome, Kotzebue and St. Mary's. However, spatial data showing the specific location and extent of the port facilities within these three communities is not available. As a surrogate, the spatial extent of the footprints for those three communities (from the 2010 Tiger Census Places dataset) was used to represent port footprints; they appear in blue in Figure A-9. Consequently, the actual areal extent of the ports is significantly over-estimated. Because of this over-estimation, and the fact that the port spatial extents are simply duplicates of the community footprints, ports were not included in the overlay of development change agents with conservation elements; the community footprints are assumed to also represent the ports.

There is a push in the U.S. at the national level to build a deep water port in the Arctic to facilitate the development of natural resources in the Arctic. There are two proposed port sites within the ecoregion: Cape Blossom (south of Kotzebue) and Cape Darby (east of Nome) (Figure A-15). Cape Blossom would have the shortest road/railroad access to the minerals coming out of Ambler (250 miles), compared to Cape Darby (340 miles) (Figure A-14). Cape Darby would be a true deep water port, whereas Cape Blossom would need to be dredged. For each proposed port site, small, semi-circular polygons were on-screen digitized near the terminus point of the proposed Ambler road/railroad corridor. These footprints are a best guess/highly subjective approximation of where one or both of these ports might eventually be located and should not be considered accurate in terms of location or areal extent. Therefore, future proposed ports were not used in the assessment of future development change agents by conservation elements.

**Figure A-15. Proposed port sites at Cape Blossom (south of Kotzebue) and Cape Darby (east of Nome).**



### A-4.1.3 Energy

#### *A-4.1.3.1 Oil and gas*

**45**: Where are current and planned oil/gas activities located and where do they overlap with CEs or other relevant habitats?

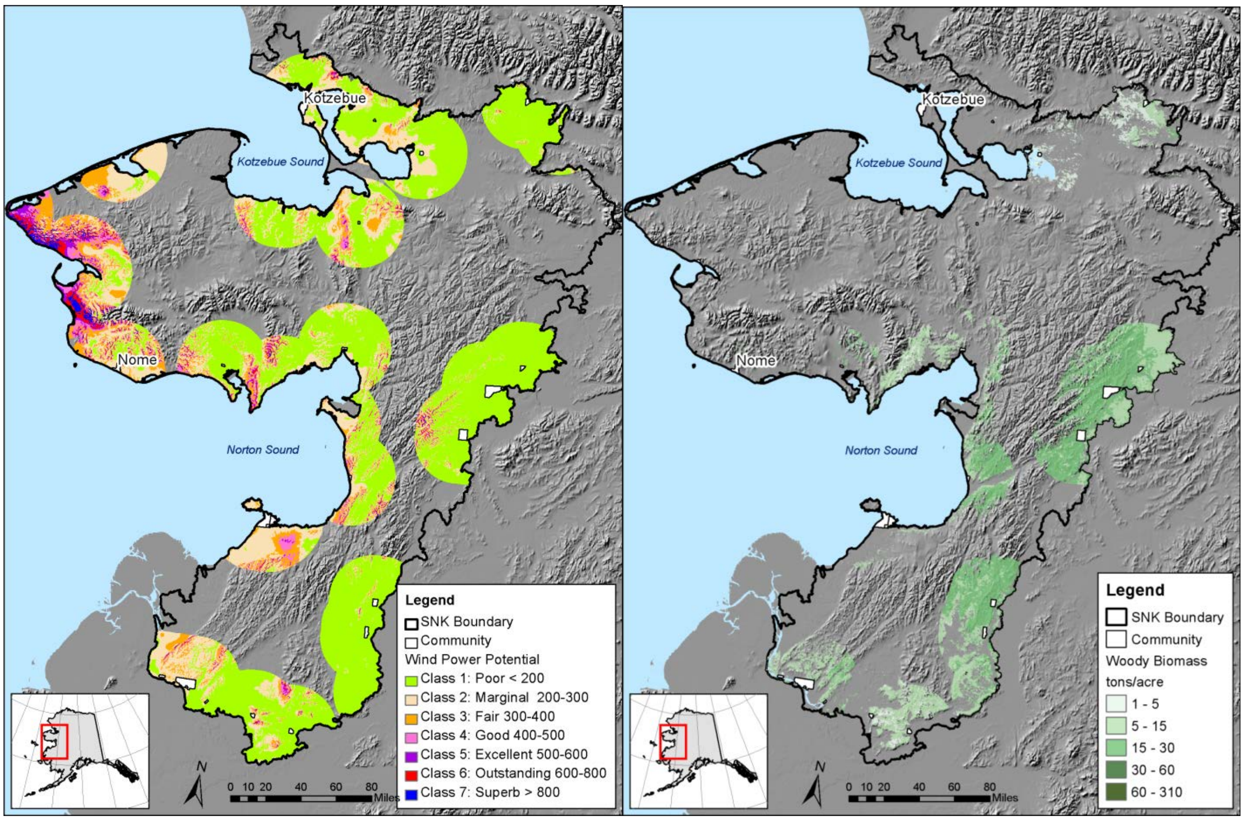
There are no current or planned oil/gas activities within the ecoregion.

#### *A-4.1.3.2 Renewable*

**52**: Where are potential wind and biomass sites located within 25 miles of communities?

Potential wind power within 25 miles of communities was derived from the Alaska Energy Authority's Alaska Renewable Energy Atlas Wind Power Potential map (Figure A-16). Potential woody forest biomass within 25 miles of communities was derived from USDA Forest Service Forest Inventory and Analysis Alaska Biomass map (Figure A-16).

**Figure A-16. Potential wind power within 25 miles of communities (left) and potential woody forest biomass within 25 miles of communities (right).**




Ten renewable energy fund sites occur within the ecoregion (Table A-7). These are currently funded projects, as listed in the Alaska Energy Authority's (AEA) renewable energy fund sites dataset. All of these sites are small-scale and limited to the communities within which they occur because there is no existing or planned powerline infrastructure between communities within this ecoregion. Site-specific footprints were not available for these renewable energy fund sites, but the data did identify the city where they were located; therefore, current community footprints were used to map the general location of renewable energy fund footprints. This is a polygon dataset, with the communities of Nome and Kotzebue each having two renewable energy fund sites and therefore two overlapping polygons (i.e., one community footprint polygon for each renewable energy fund site). The renewable energy fund site footprints overlap with themselves and overlap with the community footprints and therefore would not produce any meaningful results in an assessment of development change agents by conservation elements.

**Table A-7. Alaska Energy Authority (AEA) Renewable Energy Fund Sites.**

| Renewable Energy Fund Site Type | Location | Name | Applicant |
|---|---|---|---|
| Wind | Noorvik | Buckland/Deering/Noorvik Wind Farm Construction | Northwest Arctic Borough |
| Wind | Kotzebue | Kotzebue Wind Farm Expansion Construction | Kotzebue Electric Association |
| Heat Recovery | Kotzebue | Kotzebue HR and Ammonia Power Cycle | Kotzebue Electric Association |
| Wind | Deering | Buckland/Deering/Noorvik Wind Farm Construction | Northwest Arctic Borough |
| Wind | Buckland | Buckland/Deering/Noorvik Wind Farm Construction | Northwest Arctic Borough |
| Heat Recovery | Ambler | Ambler HR_City of Ambler | City of Ambler |
| Wind | Unalakleet | Unalakleet Wind Farm Construction | Unalakleet Valley Electric Cooperative, Inc |
| Wind | Shaktoolik | Shaktoolik Wind_AVEC | Alaska Village Cooperative (AVEC) |
| Transmission | Nome | Nome Banner Peak Wind Farm Transmission Construction | City of Nome d/b/a Nome Joint Utilities System |
| Wind | Nome | Nome/Newton Peak Wind Farm Construction | City of Nome d/b/a Nome Joint Utility System (NJUS) |

#### A-4.1.4 Mining

**46**: Where are historic, current, and potential mining activities located, and where do they overlap with CEs or other relevant habitat?

All mine records, excluding prospects and mineral occurrences, were selected from the USGS Alaska Resource Data File (ARDF) (Figure A-9 and Figure A-10). These represent mines that currently have production or have had production in the past. Each of the 380 mine sites were buffered to a five-acre circular polygon based on communications with Robert Loeffler, former head of the Alaska Division of Mines, Alaska Department of Natural Resources. Approximately 90% of placer mines in this ecoregion each have a disturbed land area under five acres because the state does not require bonding and permitting for mines on less than five acres of land (R. Loeffler, pers. comm.). Of the 380 mines in the ARDF database, only 26 sites are identified as active, and it is unknown how long ago the other 354 inactive (historic) mine sites were in production. The comments section of the ARDF sometimes makes reference to time period of production and some of the records appear to have been active over 100 years ago, so the impact of development change from these historic mines may be over-represented.

No future mining activities were identified within the ecoregion. The ARDF dataset includes prospects and mineral occurrences; however, virtually none of these prospect or mineral occurrence sites are likely to become productive mines (R. Loeffler, pers. comm.), so these sites were not used to identify future mining activities. BLM's 2006 Kobuk-Seward Peninsula Resource Management Plan (KSPRMP) and

Environmental Impact Statement includes future mining scenarios but they are defined as large geographic areas within the ecoregion that may be open or closed to different types of mining and therefore cannot be used to identify *site-specific* future mining activities; in other words, the geographic areas for potential mining scenarios are so extensive that it wouldn't provide a meaningful indication of potential impact on individual CEs if these areas were used in the assessment of future development Of note, the Ambler mine, located to the north of the SNK REA, is proposed for expansion and the potential road/railroad infrastructure that might be constructed within the ecoregion is evaluated (see transportation above).

#### A-4.1.5 Recreation

**49**: Where are historic, current, and potential recreation use areas located, and where do they overlap with CEs or other relevant habitat?

There is no historic or current recreation development, in the conventional sense, within this ecoregion. There are designated parks, Areas of Critical Environmental Concern (ACEC), and numerous ATV trails, that elsewhere are commonly used as a proxy to represent recreation as a development change agent. However, within this REA, off-road vehicle use is primarily by subsistence hunters, with impacts assumed to be extremely low and diffuse, and therefore not considered a significant development change agent. Therefore, recreation was not included as a current development change agent in the assessment.

Multiple future recreation planning scenarios are identified in BLM's 2006 Kobuk-Seward Peninsula Resource Management Plan (KSPRMP) and Environmental Impact Statement. However, the majority of these proposed future recreation planning areas extend across large portions of the ecoregion and are expected to have very low and diffuse impact, making it difficult to justify using any, or all of them, to represent areas of significant future recreation development change within the SNK REA. One exception is the proposed Salmon Lake Kigluaik Special Recreation Management Area (SRMA), north of Nome (Figure A-11). This is the only proposed future recreation site within the ecoregion that may incur significant recreation activity/impact to warrant inclusion as a future recreation development change agent.

#### A-4.1.6 Military

**51**: Where are historic and current military sites areas located, and where do they overlap with CEs or other relevant habitat?

Ten small-scale, historic (inactive) military sites were identified in the Alaska Contaminated Sites Database, based on the Site Name and Land Owner attributes (Table A-8). These are point sites and are assessed as part of the contaminated sites development change agent dataset.

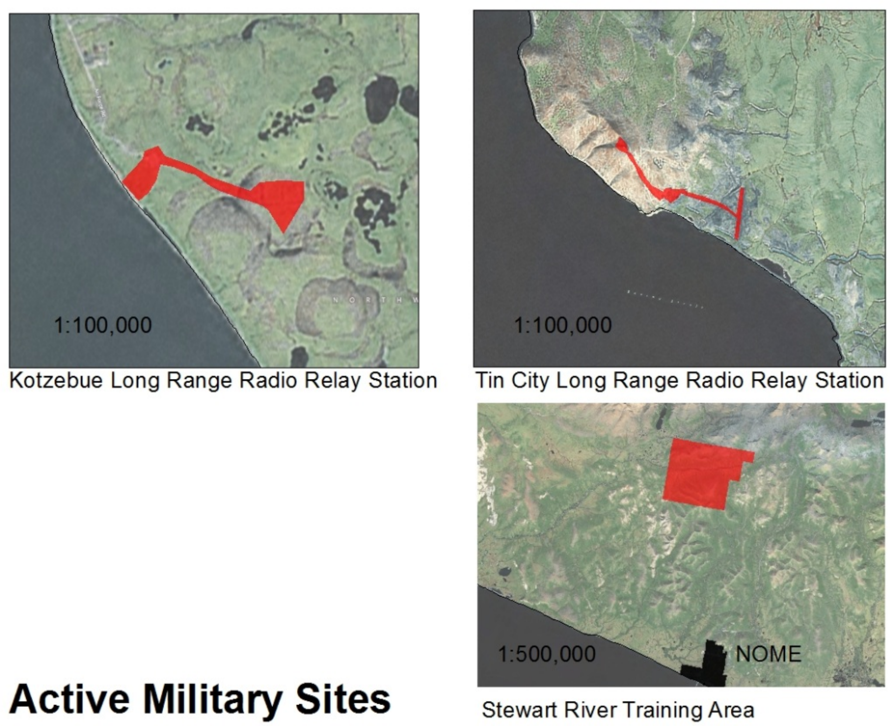
**Table A-8. Historic military sites.**

| Military Site Name | (Nearest) City |
|---|---|
| AKARNG Ambler Federal Scout Armory | Ambler |
| USCG Port Clarence Loran Station | Brevig Mission |
| Kotzebue Army Aviation Facility | Kotzebue |
| AKARNG Mountain Village FSA | Mountain Village |
| Former West Nome Tank Farm | Nome |
| AKARNG Saint Mary's FSA | Saint Mary's |
| AKARNG Selawik FSA | Selawik |
| AKARNG Stebbins FSA | Stebbins |
| North River RRS | Unalakleet |
| AKARNG Wales Federal Scout Armory | Wales |

There are three small-scale, active military sites in the ecoregion: Tin City Long Range Radio Relay Station, Kotzebue Long Range Radio Relay Station and the Stewart River Training Area north of Nome (Figure A-10 and Figure A-17). The footprints of the two radio relay station sites were on-screen digitized from Bing Imagery, while the Stewart River Training Area footprint was derived from the USGS Protected Areas Database (PADUS), version 1.2.

The Stewart River Training Area includes a substantial amount of wilderness, and it is not possible to identify the portion of the site with development infrastructure, so the development impact of military lands is likely over-represented.

**Figure A-17. Active military sites within the ecoregion.**



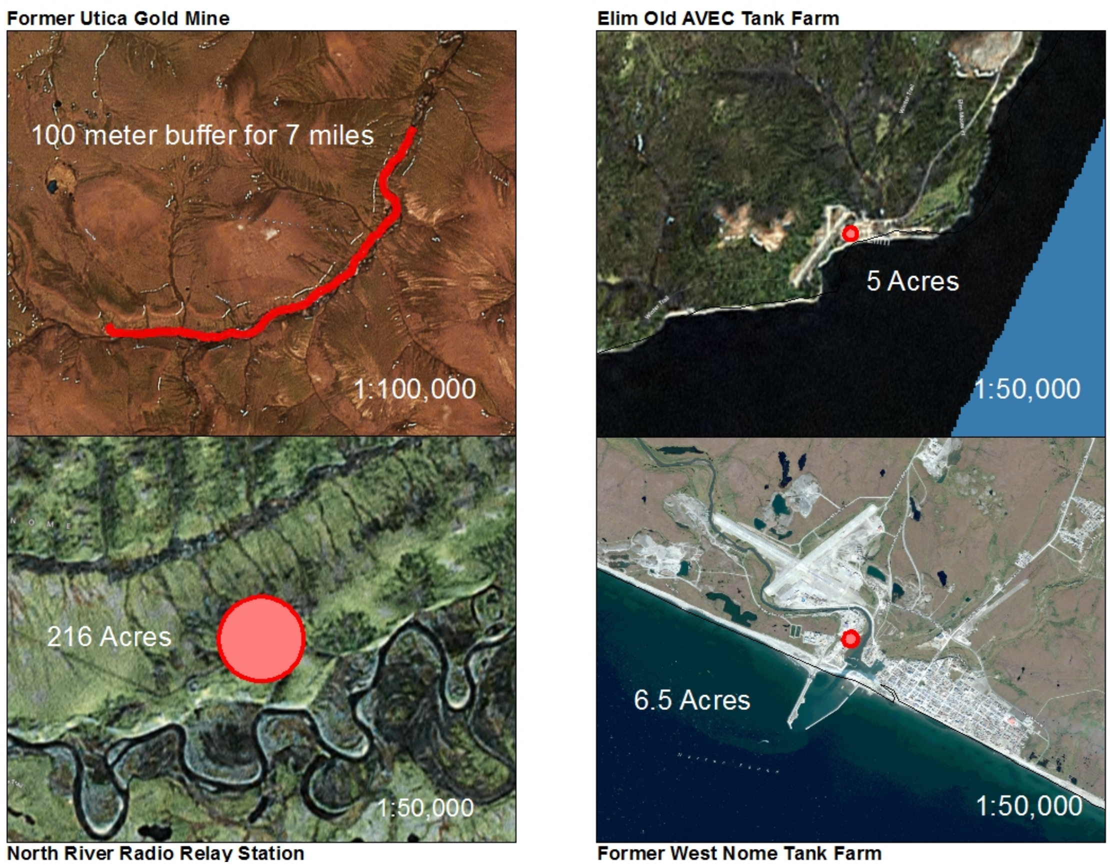

### A-4.1.7 Contaminated Sites

| **111**: Where are hazardous waste sites? |
|---|

Hazardous waste sites within the ecoregion were identified from the Alaska Contaminated Sites Database (http://dec.alaska.gov/spar/csp/db_search.htm). One hundred and twenty-one *open* contaminated sites were selected from the database (Figure A-9 and Figure A-10). There is no consistent, standardized information available about the areal extent of each contaminated site. The most conservative approach was applied in mapping the areal extent of these sites; each contaminated site was identified as a single 30 meter pixel for analysis. Many of them are small spills (e.g., residential fuel tank spill) and would actually be confined to this small a geographic extent. Given this mapping approach, the areal extent of contaminated sites is likely somewhat under-represented in the ecoregion. Using a larger buffer for all contaminated points would have been entirely arbitrary, and would likely significantly over-represent many of the contaminated sites which tend to be localized. In addition, there is no consistent, standardized information available about the significance or severity of each contaminated site. Therefore, it was not possible to identify the relative level of significance of contaminated sites.

Four of the contaminated sites are thought to be more significant, based on literature/expert knowledge, including the former Utica Gold mine, the Elim Old AVEC tank farm, the North River Radio Relay Station, and the Former West Nome Tank Farm (Figure A-18). These sites were initially identified as the only significant contaminated sites, assigned areal extents, and delivered to BLM. However, each of these four sites were subsequently reduced back to a single pixel to be consistent with the conservative mapping approach described above. This decision was based on the idea that a lack of information about the other 117 contaminated sites doesn’t necessarily mean they are not significant/shouldn’t preclude them from being included in the analysis.

**Figure A-18. Four significant contaminated sites within the ecoregion.**




The current location of the community of Shishmaref will be considered a contaminated site once the island is abandoned. A point was added to the future contaminated sites for the community of Shishmaref (Figure A-11). A point was added, rather than a polygon footprint, in order to maintain consistency with the methodology used for mapping the current contaminated sites.

The communities of Shaktoolik and Unalakleet are also both identified by the US Army Corps as in imminent danger from erosion (March 2009 Alaska Baseline Erosion Assessment). However, there is no information available about whether these communities would most likely be relocated, or whether the erosion would be mitigated; therefore, they were not included as sites in the future contaminated sites dataset.

SEWARD PENINSULA – NULATO HILLS – KOTZEBUE LOWLANDS
RAPID ECOREGIONAL ASSESSMENT
FINAL REPORT II-3-c

# Appendix B: Conservation Elements in the Seward Peninsula – Nulato Hills – Kotzebue Lowlands Ecoregion

**REA Final Report for:**
Department of the Interior
Bureau of Land Management
Rapid Ecoregional Assessments

Version Date: 22 October 2012

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# B Conservation Elements

This appendix contains additional detail on methods and results for assessment components relating to conservation elements.

Highly detailed methods are provided here for the modeling or mapping of CE distributions or predicted habitats; they are covered in far greater detail than the Methods chapter of the main report. Additional distribution results are provided in the form of maps, but the Current Conditions chapter contains the discussion relating to these results.

Both methods and results for the bioclimate envelope modeling are discussed in this Appendix with some additional detail that is not provided in the higher-level discussions contained in the Methods, Current Conditions, and Future Conditions chapters of the main report.

## *B-1 Spatial Modeling Methods for CE Assessments*

Available data and information largely determined the extent to which the current and future distributions of CEs could be projected within the SNK ecoregion within the context of a rapid assessment. Early in the REA process, only current distributions of individual CEs were proposed to be mapped or modeled, due to data limitations and model availability.

Boreal ALFRESCO permits a general characterization of the projected shifts in the spatial distribution of four broad vegetation classes – white spruce, black spruce, tundra, and deciduous – resulting from the effects of fire and successional dynamics in a changing climate. The model is not designed to be used with the more finely defined terrestrial coarse-filter CEs; instead, the ALFRESCO results show broad patterns of projected change in distribution that can be used to estimate changes to individual CEs. The Future Conditions chapter in the main report and Appendix A contain the results of the ALFRESCO fire modeling assessment.

Relative to the size of the ecoregion, the current development footprint is limited, and in the context of the entire ecoregion, projected development over the next 50 years will continue to be relatively limited. Models projecting the expansion of various categories of development are not available for Alaska as they are for the lower 48 (Bierwagen et al. 2009). Although much of the significant development proposed within the SNK ecoregion over the next 50 years is assumed to be generally known (e.g., roads and ports), there are multiple alternatives for each of these developments, and no certainty or likely indication of which alternatives will eventually be selected. Given the level of certainty of the mapped CE distributions and the uncertainty around the proposed development alternatives, it was not possible to accurately model potential changes in CE distributions resulting from projected development with a reasonable degree of certainty. However, a simple intersection of CEs with proposed development CAs was proposed and developed to look at approximate proportions of overlap and is summarized in Appendix D.

In relation to the major change agents in this ecoregion, climate is the one factor that was proposed to be modeled for its potential impact on the future distributions of individual CEs, through bioclimate envelope models, which are discussed later in this appendix (as well as in bioclimate sections of the Current and Future Conditions chapters of the main report). As noted in that section, these models do not represent the projected *distribution* of the CE, but rather the geographic area containing *suitable climatic conditions* for the CE.

## B-1.1 Spatial Modeling of Current CE Distributions

### B-1.1.1 Terrestrial Coarse-Filter CEs

The SNK REA terrestrial ecological system coarse-filter CE raster map (30 meter pixel resolution) has twenty-eight classes (Figure B-1 and Table B-1). The terrestrial ecological system CE map is primarily derived from a cross-walk of the Alaska Natural Heritage Program land cover mosaic to the NatureServe United States Terrestrial Ecological System Classification (Table B-2). Details of the development of the final terrestrial coarse-filter map are provided in this section.

**Figure B-1. Terrestrial coarse-filter ecological systems of the SNK ecoregion (28 classes).**

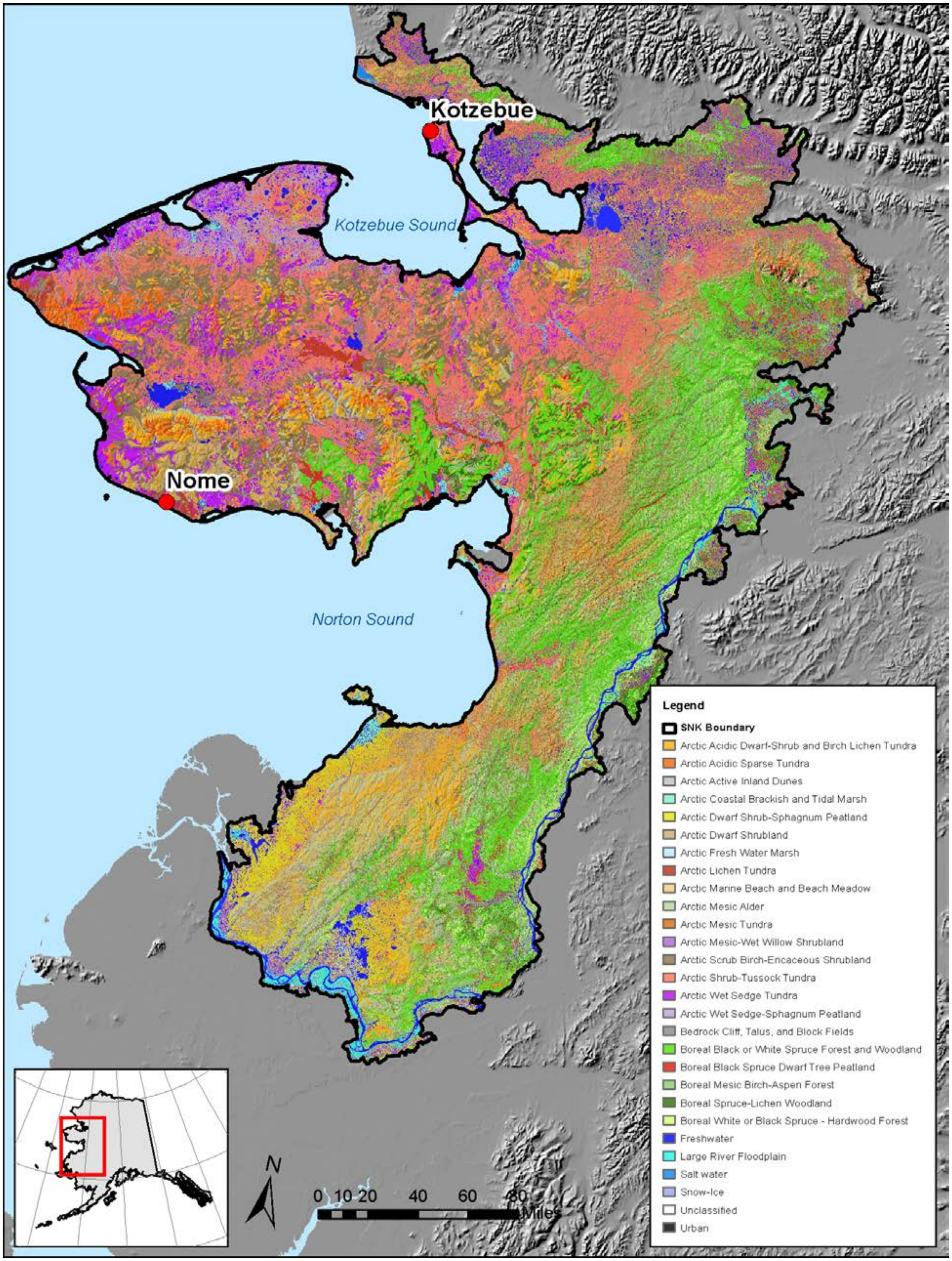

**Table B-1. Total acreage of each terrestrial coarse-filter ecological system and percentage of ecoregion it occupies.**

| CE Code* | Terrestrial Ecosystem Name | Total Area (Acres) | Percent Total Area of SNK REA |
|---|---|---|---|
| | **Upland Types** | | |
| 5277 | Arctic Scrub Birch-Ericaceous Shrubland | 6,118,470 | 16.02 |
| 9908 | Boreal Black or White Spruce Forest and Woodland | 5,481,040 | 14.35 |
| 9902 | Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra | 3,204,510 | 8.39 |
| 5328 | Arctic Mesic Alder | 2,464,510 | 6.45 |
| 5104 | Arctic Dwarf Shrubland | 1,907,550 | 5.00 |
| 4335 | Boreal White or Black Spruce - Hardwood Forest | 1,148,550 | 3.01 |
| 4162 | Boreal Mesic Birch-Aspen Forest | 1,145,390 | 3.00 |
| 4288 | Boreal Spruce-Lichen Woodland | 726,103 | 1.90 |
| 5103 | Arctic Acidic Sparse Tundra | 585,060 | 1.53 |
| 7166 | Arctic Lichen Tundra | 416,833 | 1.09 |
| 9901 | Arctic Mesic Tundra | 342,707 | 0.90 |
| 3196 | Bedrock Cliff, Talus, and Block Fields | 87,679 | 0.23 |
| 3130 | Snow-Ice | 9,202 | 0.02 |
| 3195 | Arctic Active Inland Dunes | 4,044 | 0.01 |
| | **Lowland Types** | | |
| 9903 | Arctic Shrub-Tussock Tundra | 6,065,470 | 15.89 |
| 9904 | Arctic Wet Sedge Tundra | 2,730,690 | 7.15 |
| 5276 | Arctic Mesic-Wet Willow Shrubland | 1,274,260 | 3.34 |
| 9358 | Arctic Dwarf Shrub-Sphagnum Peatland | 1,123,460 | 2.94 |
| 9424 | Arctic Wet Sedge-Sphagnum Peatland | 578,056 | 1.51 |
| 9376 | Boreal Black Spruce Dwarf Tree Peatland | 455,662 | 1.19 |
| 9900 | Large River Floodplain | 307,651 | 0.81 |
| 9419 | Arctic Fresh Water Marsh | 140,308 | 0.37 |
| | **Coastal Types** | | |
| 9414 | Arctic Coastal Brackish and Tidal Marsh | 217,717 | 0.57 |
| 7167 | Arctic Marine Beach and Beach Meadow | 18,711 | 0.05 |
| | **Other or Unknown Classes** | | |
| 9905 | Freshwater | 1,358,430 | 3.56 |
| 9906 | Salt water | 55,843 | 0.15 |
| 9907 | Urban | 1,152 | 0.00 |
| 9999 | Unclassified | 214,270 | 0.56 |
| | **Total** | **38,183,327** | **100.00** |

**The terrestrial coarse-filter CE map codes are NatureServe ecological system (ESLF) codes; some classes are mosaics, unique to this project, and do not exist in the NS ESLF classification, and therefore were assigned new unique numeric codes in the 9900 range for this assessment effort.

**Table B-2. Cross-walk between NatureServe terrestrial coarse filter ecological systems map classes and AKNHP land cover mosaic map classes, with detailed reclassification notes.**

| NS SNK REA Terrestrial Coarse Filter CE Class | MapCode (ESLF or New 99xx code) | Model Group | ANHKP SNK REA Land Cover Mosaic Mapped Class | Reclassification Notes |
|---|---|---|---|---|
| Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra | 9902 | upland | Dwarf Shrub Lichen and Low Shrub/Lichen | Renamed AKNHP Dwarf Shrub Lichen and Low Shrub/Lichen to NS Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra |
| Arctic Acidic Sparse Tundra | 5103 | upland | Sparse Vegetation | Renamed AKNHP Sparse Vegetation to NS Arctic Acidic Sparse Tundra |
| Arctic Active Inland Dunes | 3195 | upland | No Match in AKNHP - new NS SNK REA CE class | Burned in entire distribution of Landfire EVT Active Inland Dunes |
| Arctic Coastal Brackish and Tidal Marsh | 9414 | coastal | Tidal Marsh | Renamed AKNHP Tidal Marsh to NS Arctic Coastal Brackish and Tidal Marsh |
| Arctic Dwarf Shrubland | 5104 | upland | Dwarf Shrub | Renamed AKNHP Dwarf Shrub to NS Arctic Dwarf-Shrubland |
| Arctic Dwarf Shrub-Sphagnum Peatland | 9358 | lowland | No Match in AKNHP – new NS SNK REA CE class | Burned in entire distribution of Landfire EVT Arctic Dwarf-Shrub-Sphagnum Peatland |
| Arctic Freshwater Marsh | 9419 | lowland | Herbaceous Marsh | Renamed AKNHP Herbaceous Marsh to NS Arctic Freshwater Marsh |
| Arctic Lichen Tundra | 7166 | upland | Lichen | Renamed AKNHP Lichen to NS Arctic Lichen Tundra |
| Arctic Marine Beach and Beach Meadow | 7167 | coastal | Bareground and Herbaceous Mesic-Dry | Selected all AKNHP Bareground and AKNHP Herbaceous Mesic-Dry within 300 meters of coast under 100% slope and renamed to NS Arctic Marine Beach and Beach Meadow |
| Arctic Mesic Alder | 5328 | upland | Tall Shrub (open-Closed) | Split AKNHP Tall Shrub (open-Closed) on >20% slope and renamed to NS Arctic Mesic Alder |
| Arctic Mesic Tundra | 9901 | upland | Herbaceous Mesic-Dry | Renamed all AKNHP Herbaceous Mesic-Dry inland more than 300 meters from coast and renamed to NS Arctic Mesic Tundra |

| NS SNK REA Terrestrial Coarse Filter CE Class | MapCode (ESLF or New 99xx code) | Model Group | ANHKP SNK REA Land Cover Mosaic Mapped Class | Reclassification Notes |
|---|---|---|---|---|
| Arctic Mesic-Wet Willow Shrubland | 5276 | lowland | Tall Shrub (open-Closed) | Split out AKNHP Tall Shrub (open-Closed) on <20% slope and renamed to NS Arctic Mesic-Wet Willow Shrubland |
| Arctic Scrub Birch-Ericaceous Shrubland | 5277 | upland | Low Shrub | Renamed AKNHP Low Shrub to NS Arctic Scrub Birch-Ericaceous Shrubland |
| Arctic Shrub-Tussock Tundra | 9903 | lowland | Tussock Tundra (Low Shrub or Herbaceous) | Renamed AKNHP Tussock Tundra (Low Shrub or Herbaceous) to NS Arctic Shrub-Tussock Tundra |
| Arctic Wet Sedge Tundra | 9904 | lowland | Herbaceous Wet | Renamed all AKNHP Herbaceous Wet to NS Arctic Wet Sedge Tundra; And also burned in entire distribution of Landfire EVT Arctic Polygonal Ground Wet Sedge Tundra and renamed to NS Arctic Wet Sedge Tundra |
| Arctic Wet Sedge-Sphagnum Peatland | 9424 | lowland | No Match in AKNHP - – new NS SNK REA CE class | Burned in entire distribution of Landfire EVT Arctic Wet Sedge-Sphagnum Peatland |
| Bedrock Cliff, Talus, and Block Fields | 3196 | upland | Bareground | Renamed AKNHP Bareground to NS Bedrock Cliff, Talus, and Block Fields. And also selected all AKNHP landcover classes within 300 meters of coast on > 100% slope and renamed NS Bedrock Cliff, Talus, and Block Fields (these clearly represent documented coastal cliffs within the SNK REA). |
| Boreal Black or White Spruce Forest and Woodland | 9908 | upland | White Spruce or Black Spruce (Open-Closed) and White Spruce or Black Spruce (Woodland) | Renamed AKNHP White Spruce or Black Spruce (Open-Closed) to NS Boreal Black or White Spruce Forest and Woodland. Split out AKNHP White or Black Spruce (Woodland) on >3% slope and renamed to NS Boreal Black or White Spruce Forest and Woodland. |
| Boreal Black Spruce Dwarf-Tree Peatland | 9376 | lowland | White Spruce or Black Spruce (Woodland) | Split out AKNHP White Spruce or Black Spruce (Woodland) on <3% slope and renamed to NS Boreal Black Spruce Dwarf-Tree Peatland |
| Boreal Mesic Birch-Aspen Forest | 4162 | upland | Deciduous (Open-Closed) | Renamed AKNHP Deciduous (Open-Closed) to NS Boreal Mesic Birch Aspen Forest |

| NS SNK REA Terrestrial Coarse Filter CE Class | MapCode (ESLF or New 99xx code) | Model Group | ANHKP SNK REA Land Cover Mosaic Mapped Class | Reclassification Notes |
|---|---|---|---|---|
| Boreal Spruce-Lichen Woodland | 4288 | upland | White Spruce or Black Spruce/Lichen (Woodland/Open) | Renamed AKNHP White Spruce or Black Spruce/Lichen (Woodland/Open) to NS Boreal Spruce-Lichen Woodland |
| Boreal White or Black Spruce – Hardwood Forest | 4335 | upland | White spruce or Black spruce-Deciduous (Open-Closed) | Renamed AKNHP White Spruce or Black Spruce-Deciduous (Open-Closed to NS Boreal White or Black Spruce – Hardwood Forest |
| Freshwater | 9905 | Other | Freshwater | Same |
| Large River Floodplain | 9900 | lowland | Herbaceous (Aquatic) | Renamed AKNHP Herbaceous (Aquatic) to NS Large River Floodplain. And also burned in entire distribution of Landfire EVT classes Arctic Large River Floodplain and Western North American Boreal Lowland Large River Floodplain |
| Salt Water | 9906 | Other | Salt Water | Same |
| Snow-Ice | 3130 | upland | Snow-Ice | Same |
| Unclassified | 9999 | Unknown | Unclassified | Same |
| Urban | 9907 | Other | Urban | Same |
| Various | Various | Various | Cloud | Within Cloud areas, some Landfire EVT classes were cross-walked to NS Terr CE classification and burned in. See Cloud_Reclass.dbf and SNK REA TerrCE tbx model for details. |
| Various | Various | Various | Fire Scar | Within Fire Scar areas, some Landfire EVT classes were cross-walked to NS Terr CE classification and burned in. See FireScar_Reclass.dbf and SNK REA TerrCE tbx model for details. |
| Various | Various | Various | GAP (Nodata area in AKNHP Land Cover Mosaic in NorthEast) | Within Gap areas, some Landfire EVT classes were cross-walked to NS Terr CE classification and burned in. See Gap_Reclass.dbf and SNK REA TerrCE tbx model for details. |

Four regional land cover datasets, of varying spatial and classification resolution, were used as the source data for the AKNHP land cover mosaic: Natural Resources Conservation Service (NRCS) Vegetation, 1979-1984; Ducks Unlimited Interior EarthCov Mosaic, 2007; Arctic Network (ARCN) Ecotypes, 2009; and Yukon Delta Landcover Mosaic Phase 1n2, 2011 (Figure B-2). Figure B-3 illustrates the extent of each of these four data sets that was used to compile the land cover mosaic. The National Hydrologic Dataset (NHD) was also used as a source dataset to delineate lakes and estuaries. These five source datasets were cross-walked to the generalized AKNHP land cover mosaic classification (see Figure B-4 and Table B-3).

**Figure B-2. Four land cover source datasets used to produce the AKNHP land cover mosaic map.**

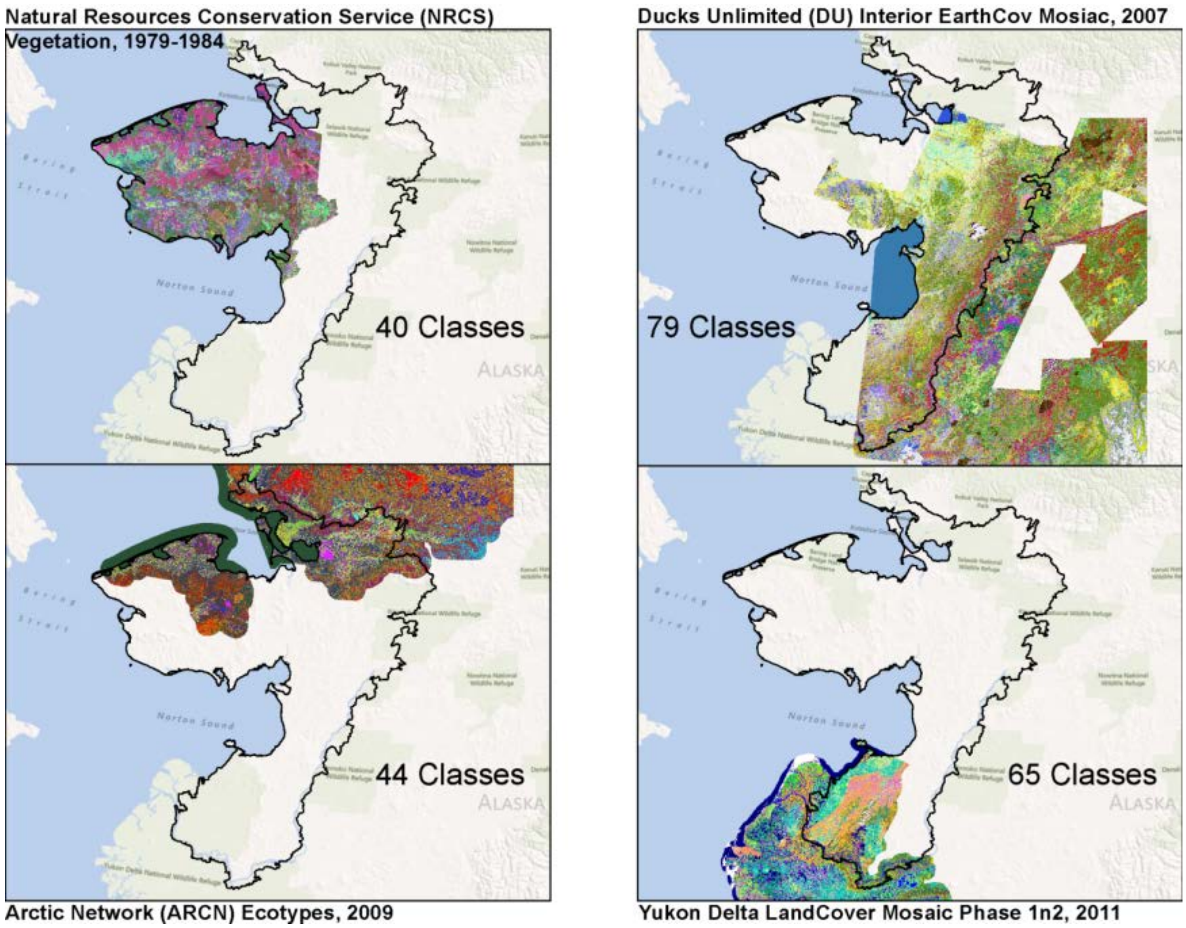

**Figure B-3. The geographic extent used from each of the four source land cover datasets to create the land cover mosaic.**

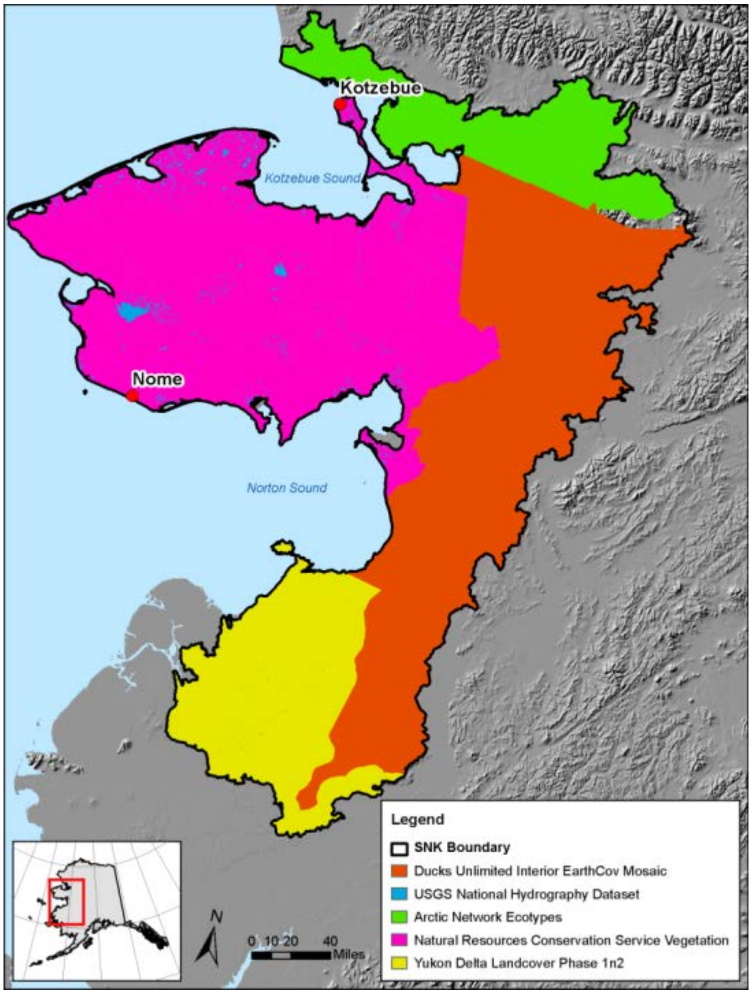

**Figure B-4. AKNHP land cover mosaic map (26 classes) plus the data gap (bright pink) in the northeast.**

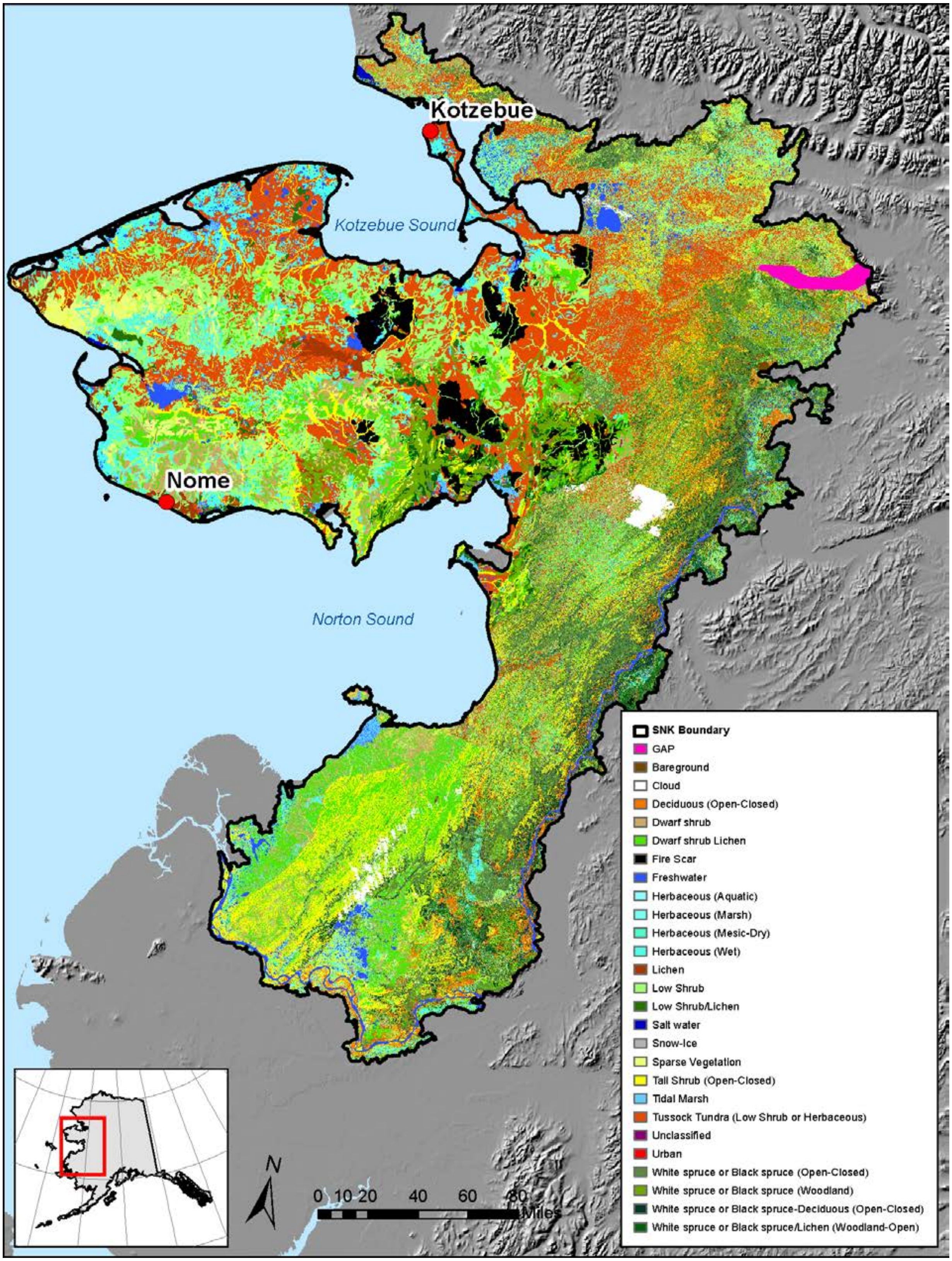

**Table B-3. Cross-walk between AKNHP land cover mosaic classification and the five source datasets used to create the land cover mosaic. NRCS = NRCS vegetation map for Seward Peninsula; DU = Ducks Unlimited mosaic for interior; YKD = Yukon Delta map; NPS = NPS Arctic Network vegetation map; NHD = NHD SWD Network**

| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
|---|---|---|---|---|---|
| 1 | 105249 | NRCS | Black Spruce | Woodland Black Spruce/Moss | White spruce or Black spruce (Woodland) |
| 2 | 1943 | NRCS | Complex 11-32: Black spruce, and Mixed shrub (tundra) | Open Black Spruce (Mesic) | White spruce or Black spruce (Open-Closed) |
| 3 | 8601 | NRCS | Complex 11-44: Black spruce, and Shrub-lichen (upland) | Open Black Spruce (Mesic) | White spruce or Black spruce (Open-Closed) |
| 4 | 11191 | NRCS | Complex 11-45: Black spruce, and Water sedge-muskeg (bog-fen) | Open Black Spruce (Mesic) | White spruce or Black spruce (Open-Closed) |
| 5 | 2879 | NRCS | Complex 11-60: Black spruce, and Lichen (tussock tundra) | Open Black Spruce (Mesic) | White spruce or Black spruce (Open-Closed) |
| 6 | 5679 | NRCS | Spruce-Lichen/Palsa | Woodland Black Spruce/Lichen (Palsa) | White spruce or Black spruce/Lichen (Woodland-Open) |
| 7 | 72677 | NRCS | Complex 15-45: Spruce-Lichen (palsa), and Water sedge-muskeg (bog-fen) | Woodland Black Spruce/Lichen (Palsa) | White spruce or Black spruce/Lichen (Woodland-Open) |
| 8 | 3155316 | NRCS | White Spruce / Upland | Woodland White Spruce (Upland) | White Spruce or Black spruce (Woodland) |
| 9 | 54481 | NRCS | Complex 11-12: Black spruce, and White spruce (upland) | Open White Spruce (upland) | White spruce or Black spruce (Open-Closed) |
| 10 | 143456 | NRCS | Complex 12-22: White spruce (upland), and Tall shrub (hillside) | Open White Spruce (upland) | White spruce or Black spruce (Open-Closed) |
| 11 | 31799 | NRCS | Complex 12-32: White spruce (upland), and Mixed shrub (tundra) | Open White Spruce (upland) | White spruce or Black spruce (Open-Closed) |
| 12 | 8194 | NRCS | Complex 12-44: White spruce (upland), and Shrub-lichen (upland) | Open White Spruce (upland) | White spruce or Black spruce (Open-Closed) |
| 13 | 6237 | NRCS | Complex 12-60: White spruce (upland), and Lichen (tussock tundra) | Open White Spruce (upland) | White spruce or Black spruce (Open-Closed) |
| 14 | 720300 | NRCS | Spruce-Lichen/Upl Sh | Woodland White Spruce/Lichen (Upland) | White spruce or Black spruce/Lichen (Woodland-Open) |
| 15 | 63019 | NRCS | Complex 11-13: Black spruce, and Spruce-Lichen (upland) | Open White Spruce/Lichen (upland) | White spruce or Black spruce/Lichen (Woodland-Open) |

| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
|---|---|---|---|---|---|
| 16 | 47595 | NRCS | Complex 12-13: White spruce (upland), and Spruce-Lichen (upland) | Open White Spruce/Lichen (upland) | White spruce or Black spruce/Lichen (Woodland-Open) |
| 17 | 17995 | NRCS | Complex 13-11: Spruce-Lichen (upland), and Black spruce | Open White Spruce/Lichen (upland) | White spruce or Black spruce/Lichen (Woodland-Open) |
| 18 | 70519 | NRCS | Complex 13-44: Spruce-Lichen (upland), and Shrub-lichen (upland) | Open White Spruce/Lichen (upland) | White spruce or Black spruce/Lichen (Woodland-Open) |
| 19 | 224756 | NRCS | Mixed Forest/Floodplain | Woodland White Spruce (Floodplain) | White Spruce or Black spruce (Woodland) |
| 20 | 237562 | NRCS | Complex 10-20: Mixed forest (Floodplain), and Tall shrub (floodplain) | Woodland White Spruce (Floodplain) | White Spruce or Black spruce (Woodland) |
| 21 | 10044 | NRCS | Complex 10-21: Mixed forest (Floodplain), and Tall shrub (drainageway) | Woodland White Spruce (Floodplain) | White Spruce or Black spruce (Woodland) |
| 22 | 574301 | NRCS | Complex 10-34: Mixed forest (Floodplain), and Low shrub (floodplain) | Woodland White Spruce (Floodplain) | White Spruce or Black spruce (Woodland) |
| 23 | 7840 | NRCS | Complex 10-66: Mixed forest (Floodplain), and Lichen mat (lowland tundra) | Woodland White Spruce (Floodplain) | White Spruce or Black spruce (Woodland) |
| 24 | 8383 | NRCS | Complex 12-14: White spruce (upland), and Paper birch (upland) | Open White Spruce-Birch (Upland) | White spruce or Black spruce-Deciduous (Open-Closed) |
| 25 | 29600 | NRCS | Paper birch / upl | Closed Birch (upland) | Deciduous (Open-Closed) |
| 26 | 1684393 | NRCS | Tall Shrub/Hillside | Alder (Upland) | Tall Shrub (Open-Closed) |
| 27 | 125831 | NRCS | Complex 22-12: Tall shrub (hillside), and White spruce (upland) | Alder (Upland) | Tall Shrub (Open-Closed) |
| 28 | 19968 | NRCS | Complex 22-32: Tall shrub (hillside), and Mixed shrub (tundra) | Alder (Upland) | Tall Shrub (Open-Closed) |
| 29 | 11740 | NRCS | Complex 22-41: Tall shrub (hillside), and Shrub Meadow (mountain) | Alder (Upland) | Tall Shrub (Open-Closed) |
| 30 | 2145 | NRCS | Complex 22-42: Tall shrub (hillside), and Tussock tundra | Alder (Upland) | Tall Shrub (Open-Closed) |
| 31 | 1662 | NRCS | Complex 22-52: Tall shrub (hillside), and Sedge (wet lake bed) | Alder (Upland) | Tall Shrub (Open-Closed) |
| 32 | 22312 | NRCS | Complex 22-61: Tall shrub (hillside), and Lichen meadow (mountain) | Alder (Upland) | Tall Shrub (Open-Closed) |
| 33 | 2492 | NRCS | Complex 22-65: Tall shrub (hillside), and Lichen slope (upland) | Alder (Upland) | Tall Shrub (Open-Closed) |
| 34 | 891782 | NRCS | Tall Shrub/Floodplain | Alder-Tall Willow (Floodplain) | Tall Shrub (Open-Closed) |

| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
|---|---|---|---|---|---|
| 35 | 886488 | NRCS | Complex 20-34: Tall shrub (floodplain), and Low shrub (floodplain) | Alder-Tall Willow (Floodplain) | Tall Shrub (Open-Closed) |
| 36 | 1512 | NRCS | Complex 20-54: Tall shrub (floodplain), and Sedge (Drainageway) | Alder-Tall Willow (Floodplain) | Tall Shrub (Open-Closed) |
| 37 | 205301 | NRCS | Complex 20-82: Tall shrub (floodplain), and Riverwash | Alder-Tall Willow (Floodplain) | Tall Shrub (Open-Closed) |
| 38 | 194546 | NRCS | Riverwash | Tall willow (Floodplain) | Tall Shrub (Open-Closed) |
| 39 | 2969196 | NRCS | Tall Shrub/Drainagew | Tall Salix planifolia (Water track) | Low Shrub |
| 40 | 1839 | NRCS | Complex 21-13: Tall shrub (drainageway), and Spruce-Lichen (upland) | Tall Salix planifolia (Water track) | Low Shrub |
| 41 | 37152 | NRCS | Complex 21-35: Tall shrub (drainageway), and Low shrub (hillside) | Tall Salix planifolia (Water track) | Low Shrub |
| 42 | 58395 | NRCS | Complex 21-42: Tall shrub (drainageway), and Tussock tundra | Tall Salix planifolia (Water track) | Low Shrub |
| 43 | 431853 | NRCS | Shrub-Lichen Upland | Low Shrub birch/Lichen (upland) | Low Shrub/Lichen |
| 44 | 706022 | NRCS | Complex 42-54: Tussock tundra, and Sedge (Drainageway) | Low Shrub birch/Lichen (upland) | Low Shrub/Lichen |
| 45 | 79221 | NRCS | Complex 44-52: Shrub-lichen (upland), and Sedge (wet lake bed) | Low Shrub birch/Lichen (upland) | Low Shrub/Lichen |
| 46 | 4604 | NRCS | Complex 44-72: Shrub-lichen (upland), and Bald limestone slope | Low Shrub birch/Lichen (upland) | Low Shrub/Lichen |
| 47 | 2087457 | NRCS | Shrub Meadow/Mountain | Low Shrub birch-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 48 | 50214 | NRCS | Complex 21-32: Tall shrub (drainageway), and Mixed shrub (tundra) | Open Low Shrub Birch-Ledum decumbens-Vaccinium uliginosum (upland) | Low Shrub |
| 49 | 126992 | NRCS | Complex 32-42: Mixed shrub (tundra), and Tussock tundra | Open Low Shrub Birch-Ledum decumbens-Vaccinium uliginosum (upland) | Low Shrub |
| 50 | 2557 | NRCS | Complex 32-44: Mixed shrub (tundra), and Shrub-lichen (upland) | Open Low Shrub Birch-Ledum decumbens-Vaccinium uliginosum (upland) | Low Shrub |
| 51 | 64450 | NRCS | Complex 32-52: Mixed shrub (tundra), and Sedge (wet lake bed) | Open Low Shrub Birch-Ledum decumbens-Vaccinium uliginosum (upland) | Low Shrub |
| 52 | 13204 | NRCS | Complex 32-54: Mixed shrub (tundra), and Sedge (Drainageway) | Open Low Shrub Birch-Ledum decumbens-Vaccinium uliginosum (upland) | Low Shrub |
| 53 | 61279 | NRCS | Complex 32-60: Mixed shrub (tundra), and Lichen (tussock tundra) | Open Low Shrub Birch-Ledum decumbens-Vaccinium uliginosum (upland) | Low Shrub |
| 54 | 2078703 | NRCS | Mixed Shrub/Tundra | Open Low Shrub Birch-Ledum decumbens-Vaccinium uliginosum (upland) | Low Shrub |
| 55 | 7249 | NRCS | Complex 35-12: Low shrub (hillside), and White spruce (upland) | Open Low Shrub Birch-Ledum decumbens-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |

| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
|---|---|---|---|---|---|
| 56 | 53781 | NRCS | Complex 35-43: Low shrub (hillside), and Alpine Mountain Meadow (complex) | Open Low Shrub Birch-Ledum decumbens-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 57 | 49914 | NRCS | Complex 35-52: Low shrub (hillside), and Sedge (wet lake bed) | Open Low Shrub Birch-Ledum decumbens-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 58 | 34067 | NRCS | Complex 35-61: Low shrub (hillside), and Lichen meadow (mountain) | Open Low Shrub Birch-Ledum decumbens-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 59 | 4098281 | NRCS | Low Shrub/Hillside | Open Low Shrub Birch-Ledum decumbens-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 60 | 12459 | NRCS | Complex 35-41: Low shrub (hillside), and Shrub Meadow (mountain) | Low Shrub birch-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 61 | 6032 | NRCS | Complex 41-20: Shrub Meadow (mountain), and Tall shrub (floodplain) | Low Shrub birch-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 62 | 426119 | NRCS | Complex 41-32: Shrub Meadow (mountain), and Mixed shrub (tundra) | Low Shrub birch-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 63 | 96085 | NRCS | Complex 41-42: Shrub Meadow (mountain), and Tussock tundra | Low Shrub birch-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 64 | 52160 | NRCS | Complex 41-43: Shrub Meadow (mountain), and Alpine Mountain Meadow (complex) | Low Shrub birch-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 65 | 181075 | NRCS | Complex 41-52: Shrub Meadow (mountain), and Sedge (wet lake bed) | Low Shrub birch-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 66 | 15918 | NRCS | Complex 41-54: Shrub Meadow (mountain), and Sedge (Drainageway) | Low Shrub birch-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 67 | 963 | NRCS | Complex 41-56: Shrub Meadow (mountain), and Breached lake bed | Low Shrub birch-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 68 | 50566 | NRCS | Complex 41-61: Shrub Meadow (mountain), and Lichen meadow (mountain) | Low Shrub birch-Vaccinium uliginosum-Salix planifolia (upland) | Low Shrub |
| 69 | 1241588 | NRCS | Low Shrub/Floodplain | Open Low Shrub Birch-Vaccinium uliginosum-Low Salix planifolia-S. alaxensis (Floodplain) | Low Shrub |
| 70 | 16455 | NRCS | Complex 21-34: Tall shrub (drainageway), and Low shrub (floodplain) | Open Low Shrub Birch-Vaccinium uliginosum-Low Salix planifolia-S. alaxensis (Floodplain) | Low Shrub |
| 71 | 25829 | NRCS | Complex 34-54: Low shrub (floodplain), and Sedge (Drainageway) | Open Low Shrub Birch-Vaccinium uliginosum-Low Salix planifolia-S. alaxensis (Floodplain) | Low Shrub |
| 72 | 3644 | NRCS | Complex 34-56: Low shrub (floodplain), and Breached lake bed | Open Low Shrub Birch-Vaccinium uliginosum-Low Salix planifolia-S. alaxensis (Floodplain) | Low Shrub |
| 73 | 44207 | NRCS | Complex 34-82: Low shrub (floodplain), and Riverwash | Open Low Shrub Birch-Vaccinium uliginosum-Low Salix planifolia-S. alaxensis (Floodplain) | Low Shrub |
| 74 | 40269 | NRCS | Complex 34-42: Low shrub (floodplain), and Tussock tundra | Low Shrub-Tussock Tundra (Upland) | Tussock Tundra (Low Shrub or Herbaceous) |

| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
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| 75 | 152466 | NRCS | Complex 42-34: Tussock tundra, and Low shrub (floodplain) | Low Shrub-Tussock Tundra (Upland) | Tussock Tundra (Low Shrub or Herbaceous) |
| 76 | 7478 | NRCS | Complex 42-43: Tussock tundra, and Alpine Mountain Meadow (complex) | Low Shrub-Tussock Tundra (Upland) | Tussock Tundra (Low Shrub or Herbaceous) |
| 77 | 5440 | NRCS | Complex 42-44: Tussock tundra, and Shrub-lichen (upland) | Low Shrub-Tussock Tundra (Upland) | Tussock Tundra (Low Shrub or Herbaceous) |
| 78 | 919089 | NRCS | Complex 42-55: Tussock tundra, and Cottongrass-water sedge (low center polygons) | Low Shrub-Tussock Tundra (Upland) | Tussock Tundra (Low Shrub or Herbaceous) |
| 79 | 5114 | NRCS | Complex 42-56: Tussock tundra, and Breached lake bed | Low Shrub-Tussock Tundra (Upland) | Tussock Tundra (Low Shrub or Herbaceous) |
| 80 | 7354 | NRCS | Complex 42-57: Tussock tundra, and Sedge (wet lake bed) | Low Shrub-Tussock Tundra (Upland) | Tussock Tundra (Low Shrub or Herbaceous) |
| 81 | 333017 | NRCS | Complex 42-60: Tussock tundra, and Lichen (tussock tundra) | Low Shrub-Tussock Tundra (Upland) | Tussock Tundra (Low Shrub or Herbaceous) |
| 82 | 36388 | NRCS | Complex 42-80: Tussock tundra, and Lava bed | Low Shrub-Tussock Tundra (Upland) | Tussock Tundra (Low Shrub or Herbaceous) |
| 83 | 503575 | NRCS | Dryas Limestone Slop | Dryas (Non-acidic, Upland) | Dwarf shrub |
| 84 | 6247 | NRCS | Complex 71-52: Dryas limestone slope, and Sedge (wet lake bed) | Dryas (Non-acidic, Upland) | Dwarf shrub |
| 85 | 2479280 | NRCS | Lichen Granitic Slop | Dryas-Lichen (upland) | Dwarf shrub Lichen |
| 86 | 2125395 | NRCS | Lichen-Meadow/Mountain | Dryas-Lichen (upland) | Dwarf shrub Lichen |
| 87 | 37781 | NRCS | Complex 61-32: Lichen meadow (mountain), and Mixed shrub (tundra) | Dryas-Lichen (upland) | Dwarf shrub Lichen |
| 88 | 318004 | NRCS | Complex 61-43: Lichen meadow (mountain), and Alpine Mountain Meadow (complex) | Dryas-Lichen (upland) | Dwarf shrub Lichen |
| 89 | 73909 | NRCS | Complex 61-44: Lichen meadow (mountain), and Shrub-lichen (upland) | Dryas-Lichen (upland) | Dwarf shrub Lichen |
| 90 | 58232 | NRCS | Complex 61-52: Lichen meadow (mountain), and Sedge (wet lake bed) | Dryas-Lichen (upland) | Dwarf shrub Lichen |
| 91 | 8631 | NRCS | Complex 61-64: Lichen meadow (mountain), and Lichen-sedge meadow (upland) | Dryas-Lichen (upland) | Dwarf shrub Lichen |
| 92 | 4380 | NRCS | Complex 61-72: Lichen meadow (mountain), and Bald limestone slope | Dryas-Lichen (upland) | Dwarf shrub Lichen |
| 93 | 65384 | NRCS | Complex 61-74: Lichen meadow (mountain), and Dryas-Lichen (ridges) | Dryas-Lichen (upland) | Dwarf shrub Lichen |
| 94 | 29888 | NRCS | Complex 70-41: Lichen granitic slope (alpine), and Shrub Meadow (mountain) | Dryas-Lichen (upland) | Dwarf shrub Lichen |

| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
|---|---|---|---|---|---|
| 95 | 11246 | NRCS | Complex 70-43: Lichen granitic slope (alpine), and Alpine Mountain Meadow (complex) | Dryas-Lichen (upland) | Dwarf shrub Lichen |
| 96 | 39507 | NRCS | Complex 70-61: Lichen granitic slope (alpine), and Lichen meadow (mountain) | Dryas-Lichen (upland) | Dwarf shrub Lichen |
| 97 | 2614213 | NRCS | Alpine Mountain Meadow (complex) | Dwarf shrub (upland) | Dwarf shrub |
| 98 | 2129 | NRCS | Complex 43-22: Alpine Mountain Meadow (complex), and Tall shrub (hillside) | Dwarf shrub (upland) | Dwarf shrub |
| 99 | 10980 | NRCS | Complex 43-32: Alpine Mountain Meadow (complex), and Mixed shrub (tundra) | Dwarf shrub (upland) | Dwarf shrub |
| 100 | 47129 | NRCS | Complex 43-35: Alpine Mountain Meadow (complex), and Low shrub (hillside) | Dwarf shrub (upland) | Dwarf shrub |
| 101 | 144195 | NRCS | Complex 43-52: Alpine Mountain Meadow (complex), and Sedge (wet lake bed) | Dwarf shrub (upland) | Dwarf shrub |
| 102 | 1313 | NRCS | Complex 43-55: Alpine Mountain Meadow (complex), and Cottongrass-water sedge (low center polygons) | Dwarf shrub (upland) | Dwarf shrub |
| 103 | 7519 | NRCS | Complex 43-71: Alpine Mountain Meadow (complex), and Dryas limestone slope | Dwarf shrub (upland) | Dwarf shrub |
| 104 | 22086 | NRCS | Complex 44-22: Shrub-lichen (upland), and Tall shrub (hillside) | Dwarf shrub (upland) | Dwarf shrub |
| 105 | 1838019 | NRCS | Cottongrass-Water Sedge | Carex aquatilis (Low Centered Polygons) | Herbaceous (Wet) |
| 106 | 16352 | NRCS | Complex 34-55: Low shrub (floodplain), and Cottongrass-water sedge (low center polygons) | Carex aquatilis (Low Centered Polygons) | Herbaceous (Wet) |
| 107 | 5039 | NRCS | Complex 52-55: Sedge (wet lake bed), and Cottongrass-water sedge (low center polygons) | Carex aquatilis (Low Centered Polygons) | Herbaceous (Wet) |
| 108 | 971732 | NRCS | Complex 55-42: Cottongrass-water sedge (low center polygons), and Tussock tundra | Carex aquatilis (Low Centered Polygons) | Herbaceous (Wet) |
| 109 | 31223 | NRCS | Complex 55-57: Cottongrass-water sedge (low center polygons), and Sedge (wet lake bed) | Carex aquatilis (Low Centered Polygons) | Herbaceous (Wet) |
| 110 | 2740 | NRCS | Complex 56-55: Breached lake bed, and Cottongrass-water sedge (low center polygons) | Carex aquatilis (Low Centered Polygons) | Herbaceous (Wet) |
| 111 | 5110 | NRCS | Water Sedge-Muskeg/Bog-fen | Carex aquatilis/Sphagnum (Peatland) | Herbaceous (Wet) |
| 112 | 151168 | NRCS | Sedge/Drainageway | Sedge (Wet) | Herbaceous (Wet) |
| 113 | 3093749 | NRCS | Sedge/Wet Lake Bed | Sedge (Wet) | Herbaceous (Wet) |
| 114 | 319309 | NRCS | Sedge/Wet Meadow | Sedge (Wet) | Herbaceous (Wet) |
| 115 | 137444 | NRCS | Complex 52-32: Sedge (wet lake bed), and Mixed shrub (tundra) | Sedge (Wet) | Herbaceous (Wet) |
| 116 | 3193 | NRCS | Complex 52-34: Sedge (wet lake bed), and Low shrub (floodplain) | Sedge (Wet) | Herbaceous (Wet) |

| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
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| 117 | 42817 | NRCS | Complex 52-35: Sedge (wet lake bed), and Low shrub (hillside) | Sedge (Wet) | Herbaceous (Wet) |
| 118 | 176534 | NRCS | Complex 52-41: Sedge (wet lake bed), and Shrub Meadow (mountain) | Sedge (Wet) | Herbaceous (Wet) |
| 119 | 37219 | NRCS | Complex 52-43: Sedge (wet lake bed), and Alpine Mountain Meadow (complex) | Sedge (Wet) | Herbaceous (Wet) |
| 120 | 351291 | NRCS | Complex 52-54: Sedge (wet lake bed), and Sedge (Drainageway) | Sedge (Wet) | Herbaceous (Wet) |
| 121 | 6541 | NRCS | Complex 52-56: Sedge (wet lake bed), and Breached lake bed | Sedge (Wet) | Herbaceous (Wet) |
| 122 | 70695 | NRCS | Complex 52-60: Sedge (wet lake bed), and Lichen (tussock tundra) | Sedge (Wet) | Herbaceous (Wet) |
| 123 | 64864 | NRCS | Complex 52-61: Sedge (wet lake bed), and Lichen meadow (mountain) | Sedge (Wet) | Herbaceous (Wet) |
| 124 | 4068 | NRCS | Complex 52-72: Sedge (wet lake bed), and Bald limestone slope | Sedge (Wet) | Herbaceous (Wet) |
| 125 | 2086 | NRCS | Complex 56-57: Breached lake bed, and Sedge (wet lake bed) | Sedge (Wet) | Herbaceous (Wet) |
| 126 | 1728 | NRCS | Complex 57-34: Sedge (wet lake bed), and Low shrub (floodplain) | Sedge (Wet) | Herbaceous (Wet) |
| 127 | 536760 | NRCS | Breached Lake Bed | Graminoid (Wet) | Herbaceous (Wet) |
| 128 | 667747 | NRCS | Marsh/Tidal | Graminoid Marsh (Tidal) | Tidal Marsh |
| 129 | 28670 | NRCS | Complex 34-51: Low shrub (floodplain), and Marsh (tidal) | Graminoid Marsh (Tidal) | Tidal Marsh |
| 130 | 8210 | NRCS | Complex 51-52: Marsh (tidal), and Sedge (wet lake bed) | Graminoid Marsh (Tidal) | Tidal Marsh |
| 131 | 74322 | NRCS | Dunes/Beach | Leymus (Coastal) | Herbaceous (Mesic-Dry) |
| 132 | 24041 | NRCS | Complex 50-52: Dunes (Beach), and Sedge (wet lake bed) | Leymus (Coastal) | Herbaceous (Mesic-Dry) |
| 133 | 11449911 | NRCS | Tussock tundra | Low Shrub-Tussock Tundra (Upland) | Tussock Tundra (Low Shrub or Herbaceous) |
| 134 | 2820988 | NRCS | Lichen/Tussock Tundra | Tussock Tundra/Lichen | Tussock Tundra (Low Shrub or Herbaceous) |
| 135 | 21845 | NRCS | Complex 21-60: Tall shrub (drainageway), and Lichen (tussock tundra) | Tussock Tundra/Lichen | Tussock Tundra (Low Shrub or Herbaceous) |
| 136 | 18944 | NRCS | Complex 60-20: Lichen (tussock tundra), and Tall shrub (floodplain) | Tussock Tundra/Lichen | Tussock Tundra (Low Shrub or Herbaceous) |

| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
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| 137 | 120369 | NRCS | Complex 60-32: Lichen (tussock tundra), and Mixed shrub (tundra) | Tussock Tundra/Lichen | Tussock Tundra (Low Shrub or Herbaceous) |
| 138 | 47234 | NRCS | Complex 60-34: Lichen (tussock tundra), and Low shrub (floodplain) | Tussock Tundra/Lichen | Tussock Tundra (Low Shrub or Herbaceous) |
| 139 | 99768 | NRCS | Complex 60-42: Lichen (tussock tundra), and Tussock tundra | Tussock Tundra/Lichen | Tussock Tundra (Low Shrub or Herbaceous) |
| 140 | 1055826 | NRCS | Complex 60-54: Lichen (tussock tundra), and Sedge (Drainageway) | Tussock Tundra/Lichen | Tussock Tundra (Low Shrub or Herbaceous) |
| 141 | 216358 | NRCS | Complex 60-55: Lichen (tussock tundra), and Cottongrass-water sedge (low center polygons) | Tussock Tundra/Lichen | Tussock Tundra (Low Shrub or Herbaceous) |
| 142 | 4264 | NRCS | Complex 60-56: Lichen (tussock tundra), and Breached lake bed | Tussock Tundra/Lichen | Tussock Tundra (Low Shrub or Herbaceous) |
| 143 | 7555 | NRCS | Complex 43-21: Alpine Mountain Meadow (complex), and Tall shrub (drainageway) | Lichen (Lava bed) | Lichen |
| 144 | 9433 | NRCS | Complex 60-80: Lichen (tussock tundra), and Lava bed | Lichen (Lava bed) | Lichen |
| 145 | 80144 | NRCS | Complex 80-60: Lava bed, and Lichen (tussock tundra) | Lichen (Lava bed) | Lichen |
| 146 | 321167 | NRCS | Lava bed | Lichen (Mafic) | Lichen |
| 147 | 3720 | NRCS | Complex 41-80: Shrub Meadow (mountain), and Lava bed | Lichen (Mafic) | Lichen |
| 148 | 13098 | NRCS | Lichen Mat/Lowland Tundra | Lichen (upland) | Lichen |
| 149 | 6086 | NRCS | Lichen-sedge meadow (upland) | Lichen (upland) | Lichen |
| 150 | 249485 | NRCS | Lichen-Slope/Upland | Lichen (upland) | Lichen |
| 151 | 4064 | NRCS | Complex 64-43: Lichen-sedge meadow (upland), and Alpine Mountain Meadow (complex) | Lichen (upland) | Lichen |
| 152 | 929 | NRCS | Complex 66-20: Lichen mat (lowland tundra), and Tall shrub (floodplain) | Lichen (upland) | Lichen |
| 153 | 48838 | NRCS | Complex 66-54: Lichen mat (lowland tundra), and Sedge (Drainageway) | Lichen (upland) | Lichen |
| 154 | 1619 | NRCS | Complex 66-55: Lichen mat (lowland tundra), and Cottongrass-water sedge (low center polygons) | Lichen (upland) | Lichen |
| 155 | 356465 | NRCS | Lichen-Sedge/Coastal | Lichen-sedge (coastal tundra) | Lichen |
| 156 | 8885 | NRCS | Complex 63-43: Lichen-sedge (coastal tundra), and Alpine Mountain Meadow (complex) | Lichen-sedge (coastal tundra) | Lichen |
| 157 | 17455 | NRCS | Complex 63-52: Lichen-sedge (coastal tundra), and Sedge (wet lake bed) | Lichen-sedge (coastal tundra) | Lichen |
| 158 | 250992 | NRCS | Complex 63-54: Lichen-sedge (coastal tundra), and Sedge (Drainageway) | Lichen-sedge (coastal tundra) | Lichen |
| 159 | 1822013 | NRCS | Bald Limestone Slope | Sparse Dryas | Sparse Vegetation |

| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
|---|---|---|---|---|---|
| 160 | 1537 | NRCS | Complex 72-12: Bald limestone slope, and White spruce (upland) | Sparse Dryas | Sparse Vegetation |
| 161 | 12320 | NRCS | Complex 72-22: Bald limestone slope, and Tall shrub (hillside) | Sparse Dryas | Sparse Vegetation |
| 162 | 737116 | NRCS | Barren | Sparse Dryas | Sparse Vegetation |
| 163 | 797807 | NRCS | Burned Forest | Fire scar (Burned forest) | Fire Scar |
| 164 | 7107 | NRCS | Complex 90-22: Burned forest, and Tall shrub (hillside) | Fire scar (Burned forest) | Fire Scar |
| 165 | 3317596 | NRCS | Burned Tundra | Fire scar (Burned tundra) | Fire Scar |
| 167 | 130162 | NRCS | Lagoon | Salt Water | Salt water |
| 168 | 3660 | YKD | Open Needleleaf Lichen | Open White spruce or Black spruce/Lichen | White spruce or Black spruce/Lichen (Woodland-Open) |
| 169 | 1016510 | YKD | Open Needleleaf Other | Open White spruce or Black spruce | White spruce or Black spruce (Open-Closed) |
| 170 | 856197 | YKD | Closed Deciduous - general [Closed Deciduous (Mixed Deciduous Species)/Closed Mixed Deciduous] | Closed Deciduous | Deciduous (Open-Closed) |
| 171 | 547499 | YKD | Closed Mixed Needleleaf/Deciduous | Closed White spruce-Birch | White spruce or Black spruce-Deciduous (Open-Closed) |
| 172 | 608 | YKD | Open Mixed Needleleaf/Deciduous | Open White Spruce-Birch | White spruce or Black spruce-Deciduous (Open-Closed) |
| 173 | 14934 | YKD | Woodland Needleleaf Lichen | Woodland White spruce or Black spruce/Lichen | White spruce or Black spruce/Lichen (Woodland-Open) |
| 174 | 981119 | YKD | Woodland Needleleaf Other | Woodland White spruce or Black spruce | White spruce or Black spruce (Woodland) |
| 175 | 5747042 | YKD | Tall Shrub - general | Alder-Tall Willow | Tall Shrub (Open-Closed) |
| 176 | 2176228 | YKD | Low Shrub - general | Low Shrub birch-Low Willow | Low Shrub |
| 177 | 68283 | YKD | Low Shrub Sweetgale (or Wet Low Shrub) | Myrica gale (Peatland) | Low Shrub |
| 178 | 837014 | YKD | Alpine Dwarf Shrub Lichen | Dwarf shrub-Lichen | Dwarf shrub Lichen |
| 180 | 2142288 | YKD | Mesic Dwarf Shrub Lichen (Mesic Dwarf Birch-Ericaceous Shrub Lichen) | Dwarf shrub birch-Dwarf Ericaceous-Lichen | Dwarf shrub Lichen |
| 181 | 30165 | YKD | Mesic Dwarf Shrub Other (Mesic Dwarf Birch-Ericaceous Shrub) | Dwarf shrub birch-Ericaceous | Dwarf shrub |
| 183 | 2317501 | YKD | Dwarf Shrub Peatland | Dwarf shrub-Sphagnum (Peatland plateau) | Dwarf shrub |
| 184 | 3947102 | YKD | Dwarf Shrub Lichen Peatland | Dwarf shrub-Lichen-Sphagnum (Peatland plateau) | Dwarf shrub Lichen |
| 185 | 141635 | YKD | Dwarf Shrub/Wet Graminoid Mosaic | Mosaic of: Dwarf shrub-Sphagnum (Peatland) and Sedge (Wet) | Herbaceous (Wet) |

| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
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| 188 | 64274 | YKD | Moss/Graminoid Peatland | Sedge/Sphagnum (Peatland) | Herbaceous (Wet) |
| 189 | 1863 | YKD | Mesic/Dry Graminoid Meadow | Graminoid (Mesic) | Herbaceous (Mesic-Dry) |
| 190 | 615491 | YKD | Wet Graminoid | Sedge (Wet) | Herbaceous (Wet) |
| 191 | 676244 | YKD | Freshwater Marsh (Emergent) [Fresh Marsh (Emergent)] | Herbaceous Marsh | Herbaceous (Marsh) |
| 192 | 129135 | YKD | Lower Coastal Salt Marsh | Carex ramenskii (Tidal) | Tidal Marsh |
| 193 | 80255 | YKD | Upper Coastal Brackish Meadow | Wet Sedge-Carex rariflora (Upper Tidal) | Tidal Marsh |
| 195 | 1015532 | YKD | Clear Water | Clear Water | Freshwater |
| 196 | 681688 | YKD | Turbid Water | Turbid Water | Freshwater |
| 197 | 63244 | YKD | Sparse Vegetation | Dwarf shrub >20%, Bareground >50% | Dwarf shrub |
| 198 | 39432 | YKD | Rock/Gravel | Bareground (rock-gravel; <20% vegetation) | Bareground |
| 199 | 45685 | YKD | Non-Vegetated Soil (Sandbars/Mudflats) | Bareground (Sandbars/Mudflats) | Bareground |
| 200 | 5291 | YKD | Urban | Urban | Urban |
| 201 | 38983 | YKD | Snow/Ice | Ice | Snow-Ice |
| 202 | 318834 | YKD | Cloud | Cloud | Cloud |
| 203 | 267529 | YKD | Shadow | Cloud Shadow | Cloud |
| 204 | 10164 | YKD | Burn | Fire Scar | Fire Scar |
| 205 | 8640 | YKD | Peatland Dwarf Shrub - Regenerating Burn | Dwarf shrub-Sphagnum (Peatland) | Herbaceous (Wet) |
| 206 | 81191 | YKD | Dwarf Shrub Other (lowlands & uplands - Phase 2) | Dwarf Shrub | Dwarf Shrub |
| 207 | 332251 | YKD | Dwarf Shrub Lichen (lowlands & uplands - Phase 2) | Dwarf shrub-Lichen | Dwarf Shrub Lichen |
| 210 | 94001 | DU | Closed Needleleaf | Closed White spruce or Black spruce | White spruce or Black spruce (Open-Closed) |
| 211 | 11169974 | DU | Open Needleleaf | Open White spruce or Black spruce | White spruce or Black spruce (Open-Closed) |
| 212 | 1582720 | DU | Open Needleleaf - Lichen | Open White spruce or Black spruce/Lichen | White spruce or Black spruce/Lichen (Woodland-Open) |
| 213 | 6073792 | DU | Woodland Needleleaf | Woodland White spruce or Black spruce | White spruce or Black spruce (Woodland) |
| 214 | 522190 | DU | Woodland Ndl. - Lichen | Woodland White spruce or Black spruce/Lichen | White spruce or Black spruce/Lichen (Woodland-Open) |
| 217 | 1404562 | DU | Closed Mixed Needleleaf/Deciduous | Closed White spruce or Black spruce-Deciduous | White spruce or Black spruce-Deciduous (Open-Closed) |
| 218 | 3027692 | DU | Open Mixed Needleleaf/Deciduous | Open White spruce or Black spruce-Deciduous | White spruce or Black spruce-Deciduous (Open-Closed) |
| 219 | 2520772 | DU | Closed Deciduous | Closed Deciduous | Deciduous (Open-Closed) |
| 220 | 5046 | DU | Closed Aspen | Closed Aspen | Deciduous (Open-Closed) |

| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
|---|---|---|---|---|---|
| 221 | 594917 | DU | Closed Birch | Closed Birch | Deciduous (Open-Closed) |
| 223 | 38139 | DU | Close Willow | Close Willow | Deciduous (Open-Closed) |
| 224 | 819066 | DU | Open Deciduous | Open Deciduous | Deciduous (Open-Closed) |
| 225 | 22042 | DU | Open Aspen | Open Aspen | Deciduous (Open-Closed) |
| 226 | 358702 | DU | Open Birch | Open Birch | Deciduous (Open-Closed) |
| 228 | 33642 | DU | Open Willow | Open Tall willow | Tall Shrub (Open-Closed) |
| 229 | 5182113 | DU | Tall Shrub | Tall Shrub | Tall Shrub (Open-Closed) |
| 230 | 5574677 | DU | Low Shrub | Low Shrub birch-Low Willow | Low Shrub |
| 231 | 411189 | DU | Low shrub - Lichen | Low shrub - Lichen | Low Shrub/Lichen |
| 232 | 3666133 | DU | Low Shrub-Tussock Tundra | Low Shrub-Tussock Tundra | Tussock Tundra (Low Shrub or Herbaceous) |
| 233 | 2847451 | DU | Dwarf Shrub | Dwarf Shrub | Dwarf shrub |
| 234 | 1653149 | DU | Dwarf Shrub-Lichen | Dwarf shrub-Lichen | Dwarf Shrub Lichen |
| 235 | 873430 | DU | Low Shrub - Willow/Alder | Alder-Low willow | Low Shrub |
| 240 | 686417 | DU | Wet Graminoid | Graminoid (Wet) | Herbaceous (Wet) |
| 241 | 1375 | DU | Wet Forb | Forb (Wet) | Herbaceous (Wet) |
| 242 | 294660 | DU | Wet Sedge | Sedge (Wet) | Herbaceous (Wet) |
| 244 | 388835 | DU | Lichen | Lichen | Lichen |
| 245 | 315622 | DU | Moss | Herbaceous-Moss (Wet) | Herbaceous (Wet) |
| 247 | 3510 | DU | Mesic/Dry Sedge Meadow | Sedge (Mesic) | Herbaceous (Mesic-Dry) |
| 248 | 16209 | DU | Mesic/Dry Grass Meadow | Grass (Mesic) | Herbaceous (Mesic-Dry) |
| 249 | 769357 | DU | Mesic/Dry Graminoid | Graminoid (Mesic) | Herbaceous (Mesic-Dry) |
| 250 | 27090 | DU | Mesic/Dry Forb | Forb (Mesic) | Herbaceous (Mesic-Dry) |
| 252 | 2305284 | DU | Tussock Tundra | Tussock Tundra | Tussock Tundra (Low Shrub or Herbaceous) |
| 253 | 573586 | DU | Tussock Tundra - Lichen | Tussock Tundra/Lichen | Tussock Tundra (Low Shrub or Herbaceous) |
| 254 | 12956 | DU | Aquatic Bed | Pondlily | Herbaceous (Aquatic) |
| 255 | 211033 | DU | Emergent | Forb(wet) | Herbaceous (Wet) |
| 258 | 972358 | DU | Clear Water | Clear Water | Freshwater |
| 259 | 838258 | DU | Turbid Water | Turbid Water | Freshwater |
| 260 | 2671 | DU | Snow/Ice | Ice | Snow-Ice |
| 262 | 16563 | DU | Saltwater | Salt Water | Salt water |
| 263 | 555999 | DU | Sparse Vegetation | Herbaceous (Mesic) >20%, Bareground >50% | Herbaceous (Mesic-Dry) |
| 264 | 145842 | DU | Rock/Gravel | Bareground (rock-gravel; <20% vegetation) | Bareground |
| 265 | 95661 | DU | Non-vegetated Soil | Bareground (<20% vegetation) | Bareground |
| 267 | 48 | DU | Other - Driftwood Piles | Bareground (Driftwood Piles) | Bareground |

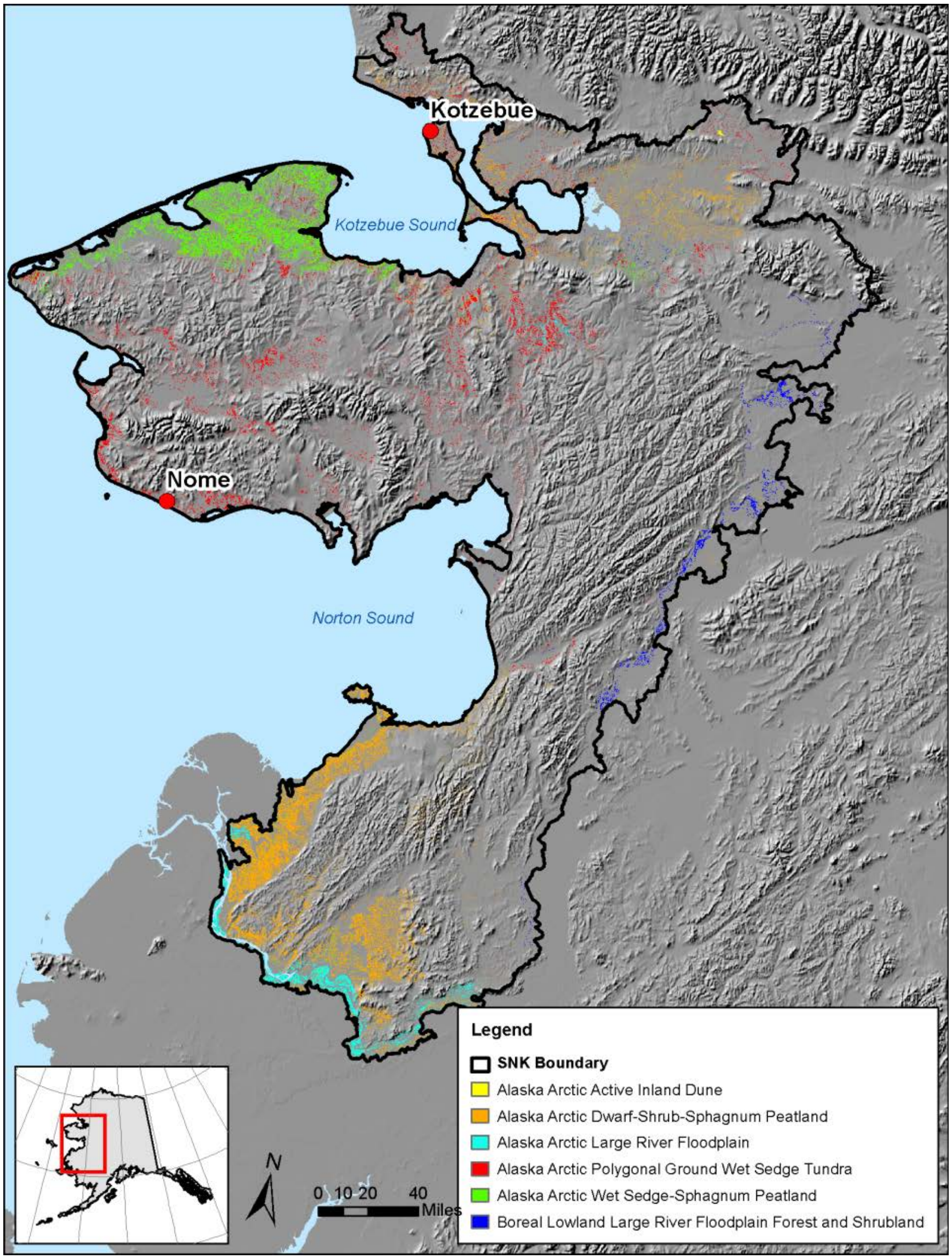
| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
|---|---|---|---|---|---|
| 268 | 1669 | DU | Sand | Bareground (Sandbars/Mudflats) | Bareground |
| 269 | 326 | DU | Urban/Developed | Urban | Urban |
| 271 | 566833 | DU | Cloud | Cloud | Cloud |
| 272 | 193089 | DU | Cloud Shadow | Cloud Shadow | Cloud |
| 273 | 345629 | DU | Terrain Shadow | Terrain Shadow | Unclassified |
| 274 | 27310 | DU | Fire Scar | Fire Scar | Fire Scar |
| 290 | 19 | NPS | Alpine Lake | Clear Water | Freshwater |
| 291 | 25046 | NPS | Alpine Rocky Circumneutral Wet Sedge Meadow | Sedge (Wet) | Herbaceous (Wet) |
| 292 | 89663 | NPS | Alpine Rocky Dry Acidic Barrens | Lichen (Upland acidic) | Lichen |
| 293 | 244139 | NPS | Alpine Rocky Dry Dryas Dwarf Shrub | Dryas-lichen (Acidic, upland) | Dwarf shrub Lichen |
| 294 | 239641 | NPS | Alpine Rocky Dry Alkaline Barrens | Dwarf Shrub (Non-acidic, Alpine, 44% bareground) | Dwarf shrub |
| 296 | 60602 | NPS | Alpine Rocky Moist Ericaceous Dwarf Shrub | Dwarf shrub (upland) | Dwarf shrub |
| 297 | 117943 | NPS | Coastal Water | Salt Water | Salt water |
| 298 | 134723 | NPS | Coastal Loamy Wet Brackish Sedge-Grass Meadow | Carex ramenskii (Tidal) | Tidal Marsh |
| 299 | 152549 | NPS | Lowland Acidic Ericaceous Shrub Bog | Sedge/Sphagnum (Peatland) | Herbaceous (Wet) |
| 300 | 597657 | NPS | Lowland Circumacidic Sedge Fen | Carex chordorrhiza-Carex aquatilis (Peatland) | Herbaceous (Wet) |
| 301 | 465582 | NPS | Lowland Lake | Clear Water | Freshwater |
| 302 | 2381193 | NPS | Lowland Moist Dwarf Birch-Ericaceous-Willow Low Shrub | Low Shrub birch-Low Willow | Low Shrub |
| 303 | 199921 | NPS | Lowland Organic-rich Wet Acidic Black Spruce Forest | Open Black Spruce (Mesic) | White spruce or Black spruce (Open-Closed) |
| 304 | 523760 | NPS | Lowland Organic-rich Wet Circumacidic Alder Tall Shrub | Alder (Upland) | Tall Shrub (Open-Closed) |
| 305 | 228481 | NPS | Lowland Organic-rich Wet Circumacidic Willow Low Shrub | Low Salix planifolia ssp. pulchra (Upland) | Low Shrub |
| 306 | 483770 | NPS | Riverine Water | Fresh Water | Freshwater |
| 307 | 9687 | NPS | Riverine Gravelly Dry Alkaline Dryas Dwarf Shrub | Dryas (Non-acidic, Floodplain) | Dwarf shrub |
| 308 | 46219 | NPS | Riverine Gravelly Moist Circumalkaline Barrens | Sparse Vegetation (Floodplain) | Sparse Vegetation |
| 309 | 69940 | NPS | Riverine Gravelly-loamy Moist Circumalkaline Poplar Forest | Open Balsam Poplar (Floodplain) | Deciduous (Open-Closed) |
| 310 | 23969 | NPS | Riverine Gravelly-loamy Moist Circumalkaline White Spruce-Poplar Forest | Open White Spruce-Balsam Poplar (Floodplain) | White spruce or Black spruce-Deciduous (Open-Closed) |
| 311 | 308182 | NPS | Riverine Gravelly-loamy Moist Circumalkaline White Spruce-Willow Forest | Open White Spruce (Floodplain) | White spruce or Black spruce (Open-Closed) |
| 312 | 116375 | NPS | Riverine Gravelly-loamy Moist Circumalkaline Willow Low Shrub | Low Salix lanata ssp. richardsonii (Floodplain) | Low Shrub |
| 313 | 504960 | NPS | Riverine Loamy Moist Alder or Willow Tall Shrub | Alder-Tall Willow (Floodplain) | Tall Shrub (Open-Closed) |

| Value | Count | Source Map | Source Map Class | Detailed_L | Coarse_Lc_ |
|---|---|---|---|---|---|
| 314 | 584261 | NPS | Riverine Loamy Moist Circumacidic Birch-Willow Low Shrub | Low Shrub birch-Salix planifolia (Floodplain) | Low Shrub |
| 315 | 727152 | NPS | Riverine Loamy Wet Circumacidic Wet Sedge Meadow | Sedge (Wet) (Floodplain) | Herbaceous (Wet) |
| 316 | 411682 | NPS | Upland Loamy Moist Circumalkaline Willow Low Shrub | Low Salix lanata ssp. richardsonii (Upland) | Low Shrub |
| 317 | 4616222 | NPS | Upland Organic-rich Moist Acidic Dwarf Birch-Tussock Shrub | Low Shrub-Tussock Tundra (Upland) | Tussock Tundra (Low Shrub or Herbaceous) |
| 318 | 1834307 | NPS | Upland Moist Dwarf Birch-Ericaceous-Willow Low Shrub | Low Shrub birch-Low Willow | Low Shrub |
| 319 | 354046 | NPS | Upland Rocky-loamy Moist Alkaline Sedge-Dryas Meadow | Dryas (Non-acidic, Upland) | Dwarf shrub |
| 320 | 836009 | NPS | Upland Rocky-loamy Moist Circumacidic Alder-Willow Tall Shrub | Alder (Upland) | Tall Shrub (Open-Closed) |
| 321 | 127998 | NPS | Upland Rocky-loamy Moist Circumacidic Birch Forest | Open Birch (Upland) | Deciduous (Open-Closed) |
| 322 | 186377 | NPS | Upland Rocky-loamy Moist Circumacidic Spruce-Birch Forest | Open White Spruce-Birch (Upland) | White spruce or Black spruce-Deciduous (Open-Closed) |
| 323 | 1583167 | NPS | Upland Rocky-loamy Moist White Spruce Forest | Open White Spruce (upland) | White spruce or Black spruce (Open-Closed) |
| 324 | 51688 | NPS | Upland Sandy Dry Acidic White Spruce-Lichen Woodland | Woodland White Spruce/Lichen (Upland) | White spruce or Black spruce/Lichen (Woodland-Open) |
| 325 | 21550 | NPS | Upland Sandy Dry Alkaline Barrens | Sparse Vegetation (Sanddunes) | Bareground |
| 326 | 9286 | NPS | Coastal Barrens | Bareground (Tide flat) | Bareground |
| 327 | 14780 | NPS | Coastal Dry Crowberry Dwarf Shrub | Empetrum nigrum-Lichen (Acidic, Coastal) | Dwarf shrub Lichen |
| 328 | 45931 | NPS | Lowland Moist Sedge-Dryas Meadow | Dryas | Dwarf shrub |
| 329 | 3310 | NPS | Coastal Dry Dunegrass Meadow | Leymus (Coastal) | Herbaceous (Mesic-Dry) |
| 332 | 706 | NPS | Snow | Snow | Snow-Ice |
| 334 | 14370 | NRCS | Unclassified-Swanson-74 | Unclassified | Unclassified |
| 335 | 7119 | YKD | Terrain Shadow | Terrain Shadow | Unclassified |
| 336 | 398019 | NHD | Small and disconnected | Freshwater | Freshwater |
| 337 | 1014776 | NHD | Large and connected | Freshwater | Freshwater |
| 338 | 130631 | NHD | Small and connected | Freshwater | Freshwater |
| 339 | 119030 | NHD | Large and disconnected | Freshwater | Freshwater |
| 340 | 55624 | NHD | Estuary | Freshwater | Freshwater |

In the SNK REA terrestrial coarse-filter CE map, sixteen of the twenty-eight classes were directly cross-walked from the AKNHP Land Cover mosaic class, and the classes were simply renamed to a NatureServe ecological system, based on a review of the AKNHP land cover map class conceptual model descriptions (see Table B-2).

The distributions of six SNK terrestrial CE ecological system classes were all, or partially, delineated from LandFire Existing Vegetation Type (EVT) data (see http://www.landfire.gov/vegetation.php). The following six LandFire EVT classes were burned into the SNK terrestrial CE dataset: Arctic Active Inland Dunes, Arctic Dwarf-Shrub-Sphagnum Peatland, Arctic Polygonal Ground Wet Sedge Tundra, Arctic Wet Sedge-Sphagnum Peatland, Arctic Large River Floodplain, and Western North American Boreal Lowland Large River Floodplain (Figure B-5). Wherever these LandFire EVT classes occurred within the SNK REA, their distribution replaced the AKNHP Land Cover mosaic class on the map.

**Figure B-5. Distribution of five Landfire Existing Vegetation Type (EVT) classes burned into the coarse-filter terrestrial ecological system map.**

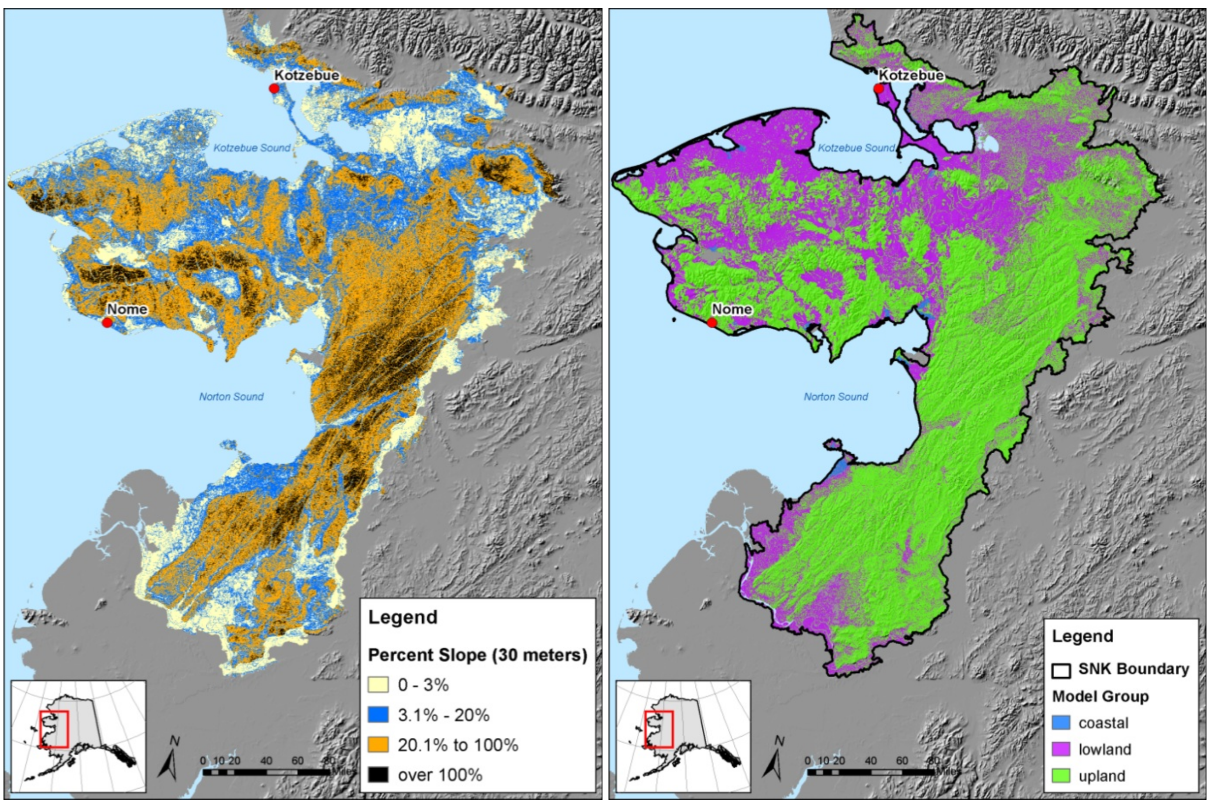



The Alaska 60 meter National Elevation Dataset (NED) was used to model percent slope (Figure B-6). Slope was used to parse out six terrestrial coarse-filter classes: AKNHP White Spruce or Black Spruce (Woodland) on <3% slope was selected and renamed to Boreal Black Spruce Dwarf-Tree Peatland; AKNHP White or Black Spruce (Woodland) on >3% slope was selected renamed to Boreal Black or White Spruce Forest and Woodland; AKNHP Tall Shrub (open-Closed) on <20% slope was selected and renamed to Mesic-Wet Willow Shrubland; AKNHP Tall Shrub (open-Closed) on >20% slope was selected and renamed to Arctic Mesic Alder; AKNHP Bareground and AKNHP Herbaceous Mesic-Dry within 300 meters of the coast on <100% slope was selected renamed to Arctic Marine Beach and Beach Meadow; and all AKNHP Land Cover classes within 300 meters of the coast on >100% slope (i.e., coastal cliffs) was selected and renamed to Bedrock Cliff, Talus, and Block Fields.

Coastal cliffs were also delineated using the slope map. Only a few scattered pixels had very steep slopes (i.e., over 200%). A 100% slope threshold (45 degree slope) more consistently parsed out the larger areal extent of coastal cliffs. The geographic extent of coastal cliffs throughout the SNK REA was reviewed/confirmed in Kessel's (1989) Birds of the Seward Peninsula, Alaska: Their Biogeography, Seasonality and Natural History publication, which provides a detailed description of coastal cliffs on the Seward Peninsula (pages 17-19).

The SNK terrestrial coarse-filter CEs are grouped into lowland, upland, or coastal model group types, based on their relative elevation position in the landscape. There are fourteen upland classes which represent 62% of the total area of the ecoregion, eight lowland classes which represent 33% of total area, and two coastal classes which represent 0.6% of the ecoregion. In addition, there are three "other" classes (freshwater, salt water and urban) which represent 4% of ecoregion and one "unknown" class (Unclassified) which represents 0.6% of the ecoregion (see Table B-2 and Figure B-6).

**Figure B-6. Percent slope map derived from the Alaska 60 meter National Elevation Dataset (NED) (left) and upland, lowland and coastal model group map (right).**



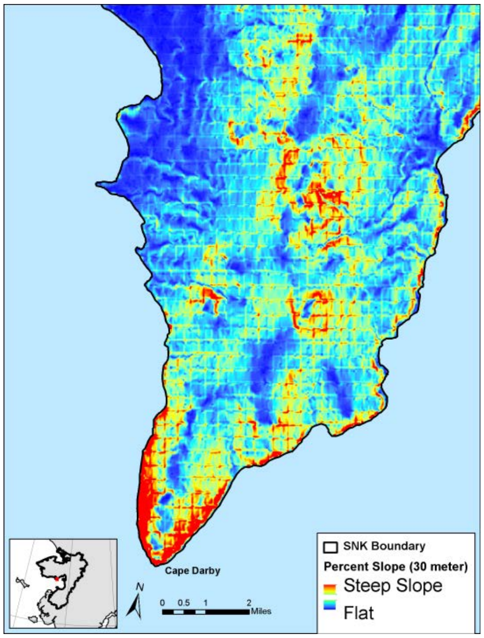

### *B-1.1.1.1 Uncertainty and Limitations*

Users of the SNK terrestrial coarse-filter data layer should note the following caveats about the original AKNHP Land cover mosaic source data, the Alaska 60 meter NED, and the LandFire Existing Vegetation Type data.

The SNK terrestrial coarse-filter map layer was derived primarily from the AKNHP Land Cover Mosaic, which was derived from five source datasets of varying classification accuracy, time period (ground condition), spatial resolution, and classification resolution (see Figure B-2 and the AKNHP land cover mosaic map metadata). The documented classification accuracy of the source land cover datasets used to produce the AKNHP land cover mosaic range from 80% to 90% (see the AKNHP land cover mosaic map metadata). These are unusually high assessed accuracy values, for this type of mapped data, and may reflect some bias in the method of assessment. The time period of the imagery used to produce the four land cover source datasets ranges from 1979 to 2011. Three of the four land cover datasets reflect fairly recent ground conditions, 2007 or sooner (Figure B-2). The Natural Resources Conservation Service (NRCS) vegetation map is derived from source imagery dating from 1979-1984. It is possible that land cover in this mapped geography may have changed over the past thirty years. The NRCS vegetation map is also a vector dataset of large, contiguous polygons ranging from 1 to 216,488 acres in size, with a median size of 466 acres; whereas the other three land cover datasets are all raster with a significantly finer resolution (30 meter pixel). The classification resolution among the four source land cover datasets is also significantly different, ranging from 40 to 79 classes (Figure B-2). Cross-walking land cover classifications from maps with varying classification resolutions generally means that the map with the coarsest resolution, in this case the Natural Resources Conservation Service map having 40 classes, tends to limit the level of classification of the final land cover map (e.g. the AKNHP land cover mosaic has 26 classes). The final SNK terrestrial coarse-filter ecological system map reflects these variations in classification accuracy, time period (ground condition), spatial resolution, and classification resolution of the original source data. The spatial and classification differences can be seen as visual discontinuities between classes and spatial distribution of classes along the boundaries of the original source land cover datasets.

The Alaska 60 meter NED has significant discontinuities in elevation values between adjacent pixels which produced artifacts, a regular blocky gridded pattern, when modeling the derivative percent slope data (see Figure B-7). However, since the percent slope map was reclassified into general slope maps with two classes (i.e., <3 percent slope and >3 percent slope) when parsing out the different coarse-filter types, the effects of these blocky artifacts is less significant than if the slope map had been parsed into a much larger number of classes for analysis.

**Figure B-7. Blocky/gridded artifacts in the percent slope map derived from the Alaska 60 meter National Elevation Dataset.**




The LandFire EVT data has very low published assessed accuracy in Alaska – 23% overall. Accuracy values for individual EVT classes varied. However, the accuracy assessment was based on an extremely small and geographically limited set of samples and may not reflect the true accuracy of the LandFire EVT map. For the several Landfire EVT classes used in the final map, the general distribution patterns reflect expected patterns based on the concepts for those ecosystems. They represent biodiversity patterns (peatlands, dunes, polygonal wet sedge tundra and floodplains) in the SNK that are important components of the ecoregion’s dynamics. Given these considerations, the value of having them represented in the spatial coarse-filter map provides some benefit to the users. Future work by the LandFire Program is aiming to improve the mapping and accuracy across Alaska.

## B-1.1.2 Aquatic Coarse Filter CEs

**SNK MQ113:** Where are the important aquatic resources, such as spawning grounds and other fish habitats? (herring spawning grounds and areas used by waterfowl?)

**SNK MQ 114:** What is the condition of these various aquatic systems?

### *B-1.1.2.1 Headwater Streams*

Headwater streams were defined as all first and second order streams. In order to obtain accurate results from the stream order tool in Spatial Analyst, a raster stream network was created using the terrain processing tools in ArcHydro by following the steps included in Comprehensive Terrain Preprocessing Using Arc Hydro Tools (Djokic 2008). The terrain preprocessing steps are included in the model for headwater streams and described in the Processing Methods. Upon completion of the stream network, the stream order tool in spatial analyst was run to assign Strahler stream order to each stream.

The headwater streams model contains all of the steps used to create the headwater streams dataset. Detailed descriptions of the terrain preprocessing steps are provided below. The 60 m National Elevation Dataset for the State of Alaska was clipped to the project boundary as a first step before implementing any terrain processing steps. In addition, the NHD required merging and clipping to the project area boundary so that it could be used in the DEM reconditioning step. The terrain pre-processing steps were carried out in the following order:

1. Fill sinks. Sinks are areas where water flows, but does not exit and are often an artifact of DEM construction. Sinks were filled so that all water on the landscape could be directed to the stream channel.
2. DEM reconditioning. The DEM is reconditioned by burning in the linear stream features to ensure that the elevations in the DEM match the existing known stream network captured in the National Hydrography Dataset (NHD). The stream buffer is the number of cells around the linear feature class around which smoothing will occur and was set at 5 cells. The drop or raise is the number (in elevation units) that the DEM will be adjusted within the buffer width, which was set at 10 cells. All features in the flowlines feature class in the NHD classified with ftype = 460 (stream or river) or 558 (artificial path) were exported from the NHD stream dataset and used to recondition the DEM. In addition, stream segments with uninitialized flow were removed to avoid creating unnecessary sinks disconnected from the stream network.
3. Fill sinks. Sinks are filled a second time in case any are created during the DEM reconditioning step.
4. Flow direction. This tool attributes each cell in the DEM with a flow direction based on the elevation of its neighboring cells. The flow direction values are 1, 2, 4, 8, 16, 32, 64, and 128 depending on the direction that the cell flows into.
5. Flow accumulation. Flow accumulation is the total number of cells that drain to each cell in the raster. It can also be weighted to calculate watershed metrics.
6. Stream definition. The initiation of streams were defined as having a watershed area of 0.5 km2 to best match the first order streams included in the National Hydrography Dataset. Stream densities varied throughout the project boundary in the NHD and it is not known if this is due to real differences in watershed geomorphology that affect stream density or an artifact of mapping accuracy. Generally, the raster stream network underestimated streams in the southern portion of the REA study area and overestimated them in the northern portion, as compared to the NHD.

Upon completion of the stream network, the stream order tool in spatial analyst was used to attribute stream order to the stream raster dataset. Headwater streams were extracted from the stream order dataset using map algebra and are defined as all first and second order streams.

#### *B-1.1.2.2 Low-gradient Streams*

Low-gradient streams were defined as streams of third order or higher with gradient less than two percent. A raster stream network was created using ArcHydro's terrain preprocessing tools and a detailed description of the steps are included in the metadata and model for headwater streams. The stream network was separated into three habitat types: headwater streams (1$^{st}$ and 2$^{nd}$ order streams), low gradient streams (3$^{rd}$ order and higher with gradient less than 2%), and rivers (3$^{rd}$ order and higher with gradient greater than 2%). Stream gradient was calculated in a 3 x 3 cell window for the stream network following the steps in Nagel (2005) and included in the model for low gradient streams.

In order to calculate the stream gradient for each 60 m stream pixel in the stream raster dataset, both rise and run were calculated in a 3x3 window following the steps in the low gradient stream model and described below.

1. Use extract by mask to get elevations for the stream network. [Note: the stream network methods are described in the headwater streams metadata and model.]

2. Use focal statistics to obtain the minimum and maximum elevations in a 3x3 window for the stream network. Subtract the minimum from the maximum to get the rise and convert to meters since the National Elevation Dataset z values are in feet.
3. The run calculation depends on whether the three stream cells in the 3x3 processing window are all in a row, all diagonal, or two adjacent and one diagonal. The total number of cells in the 3x3 window, the total vertical cells, and the total horizontal cells are all required to calculate the run. A detailed raster calculator statement is then required to obtain the run for each stream cell (see the model). For three stream cells in a row, the run is 120 m; for three stream cells diagonal to one another, the run is 170 meters; and for two adjacent cells and one diagonal, the run is 145 meters.
4. Convert rise and run to floats and calculate the stream gradient as rise/run x 100.
5. Low gradient streams were extracted from the stream network by selecting 3rd order and higher steams with stream gradient less than 2%. [Note: steps to create stream order dataset can be found in the headwater steams metadata and model.]

#### *B-1.1.2.3 Rivers (High Gradient Rivers)*

Rivers were identified as third order or higher streams with gradient greater than two percent. A raster stream network was created using ArcHydro's terrain preprocessing tools and a detailed description of the steps are included in the metadata and model for headwater streams. The final stream order dataset was also created in the headwater stream model. A detailed description of the steps to calculate gradient for the stream network can be found in the metadata and model for low gradient streams. The stream network was separated into three habitat types: headwater streams (1$^{st}$ and 2$^{nd}$ order streams), low gradient streams (3$^{rd}$ order and higher with gradient less than 2%), and rivers (3$^{rd}$ order and higher with gradient greater than 2%).

The steps used to select rivers from the stream network are included in the model for rivers. A raster calculator statement was used to select pixels from the stream network that represented 3rd order or higher streams with gradient greater than 2%. Steps to create the stream order dataset can be found in the headwater streams model and metadata and steps to complete the stream gradient dataset can be found in the low gradient streams metadata and model.

#### *B-1.1.2.4 Estuaries*

The NOAA Environmental Sensitivity Index (ESI) for Northwest Arctic and Western Alaska contains shoreline types that were used to create the estuary line file. The ESI data was selected over the National Wetlands Inventory data because the NWI only covered approximately half of the SNK REA shoreline and was much older than the ESI data, which was created in 2002. The steps for creating the estuary shapefile for the study area are included in the ModelBuilder model called Estuary. The steps include merging the ESI line feature classes from the Northwest Arctic and Western Alaska geodatabases, adding a new field called "tena", using the left expression to calculate the "tena" field with the left three characters from the ESI attribute field, selecting all features classified as 10A (Salt- and brackish-water marsh) using the "tena" field, copying all 10A shorelines into a new shapefile, selecting the 10A shorelines from the new shapefile that are within a 1.5 mile buffer of the project boundary, copying those features to a new shapefile, and projecting the new shapefile to the NAD83 Alaska Albers coordinate system. Many of the ESI shorelines were classified using multiple shoreline types in combination, which made it necessary to create a new field with just the 10A descriptor to ensure that all salt- and brackish-water marshes were included in the final estuary dataset. The ESI shorelines could not be selected without using a buffer because the ESI shoreline did not exactly match the project boundary shoreline.

#### *B-1.1.2.5 Lakes: Large and Connected; Large and Disconnected; Small and Connected; Small and Disconnected*

The waterbody feature classes in the NHD geodatabases for the project area were used to identify and classify lakes for the final lakes dataset. Small and large lakes were differentiated based on the definition used in Arp and Jones (2008) to differentiate small (< 0.1 km2) from medium and large lakes (> 0.1 km2) in the Geography of Alaska Lake Districts. Lakes that intersected the streams dataset created from processing the 60 m NED were classified as connected (see the headwater streams description for details on how the stream network was created from the DEM).

The steps followed to create the lakes dataset can be found in the model called lakes. The steps included merging the waterbody feature classes from the six NHD geodatabases, clipping the lakes to the project area, adding a field called "laketype", adding a field called "area_km2", calculating the area for all lakes in the area_km2 field, and deleting lakes of ftype=466, which are swamps, not lakes. The laketype field was populated by selecting lakes greater than 0.1 km2 that intersected the streams shapefile and attributing them as "large and connected," selecting lakes greater than 0.1 km2 that did not intersect the streams shapefile and attributing them as "large and disconnected", selecting lakes less than 0.1 km2 that intersected the streams shapefile and attributing them as "small and connected," and selecting lakes less than 0.1 km2 that did not intersect the streams shapefile and attributing them as "small and disconnected".

#### *B-1.1.2.6 Hot Springs*

The NOAA National Geophysical Data Center Thermal Springs Database was accessed at http://www.ngdc.noaa.gov/nndc/servlet/ShowDatasets?dataset=100006&search_look=1&display_look=1 and queried for the State of Alaska. The resulting Excel spreadsheet with hot springs locations was added to ArcMap and plotted using the latitude and longitude fields and exported to the shapefile NGDC_thermal_springs. The remaining steps can be found in the ModelBuilder model called "Hotsprings" and include selecting the hot springs in the NGDC_thermal_springs shapefile that are within the project boundary, copying those features to a new shapefile, and projecting the new shapefile to the NAD83 Alaska Albers coordinate system.

### B-1.1.3 Species Assemblages

Distributions were mapped for three species assemblages: marine mammal haul-out sites, important waterfowl breeding sites, and seabird colonies.

#### *B-1.1.3.1 Marine Mammal Haul-Out Sites*

Four species distributions were used to model marine mammal haul-out sites: bearded seal, ringed seal, spotted seal and walrus. For bearded seal, ringed seal and spotted seal, haul-outs and concentration areas were hand selected from Audubon's Alaska 2010 Arctic Marine Synthesis polygon dataset. For Walrus and Spotted Seal haul-out and concentration area represented by points were also selected and buffered by 5km to take into consideration use of habitat in immediate vicinity of haul-out sites. The AK GAP occurrence data for bearded seal, ringed seal, spotted seal and walrus and queried, based on life stage, and points were selected on or near Seward Peninsula and buffered by 5km. All four datasets were then combined to produce a marine mammal haul-out sites special assemblage distribution map.

#### *B-1.1.3.2 Important Waterfowl Breeding Sites*

The distribution of important waterfowl breeding sites was modeled from five source datasets: The Nature Conservancy Alaska Conservation Blueprint (2005), ADF&G Most Environmentally Sensitive Areas (MESA) map (2001), Audubon Important Bird Areas, Alaska GAP ( AK GAP) Occurrence Database, and National Hydrography Database.

Duck and geese distributions were selected from the TNC Conservation Blueprint which digitized wetland vegetation types using the CAVM (circumpolar arctic vegetation map). All waterfowl habitat areas were selected from the ADF&G MESA. All waterfowl areas that were deemed important to individual species or suites of species having state, national or global significance were selected from the Audubon IBA maps. These areas are representative of waterfowl IBAs only and do not include important shorebird stopover areas, which are also a major IBA type on the Seward Peninsula. Occurrence data for eighteen waterfowl species (12,343 point sites) were selected from AK GAP. All NHD lake and pond polygons within 2 kilometers of these GAP occurrence sites were selected and then buffered by .5 kilometers. All of the above subsets were then merged to create the important waterfowl breeding site species assemblage distribution map.

#### *B-1.1.3.3 Seabird Colonies*

Seabird colony sites were mapped from occurrence data in the North Pacific Seabird Colony database. Occurrences for twenty species (103 point sites) were selected from the North Pacific Seabird Colony database and buffered by 2 kilometers (so that terrestrial boundaries would be sure to be picked up when intersected with 10 digit HUC map) to produce the seabird colonies species assemblage distribution map.

### B-1.1.4 Landscape Species

#### *B-1.1.4.1 Mammals and Birds*

Species distribution maps for mammals and birds were developed by the Alaska Gap (AK GAP) program (http://aknhp.uaa.alaska.edu/zoology/akgap/). These predicted habitat models are preliminary results provided by the AK GAP program and will be updated. They were provided by AK GAP in their initial draft form for use in the SNK REA. As is described in more detail later in this section, only models with an area under curve (AUC) of 0.75 or better were considered acceptable and used in this REA. However, it is possible and likely that with further review and refinement of the models, the accuracy of the predicted habitat distributions may be further improved. These models represented the best available information on CEs at the time of the REA; once the models are finalized and published, BLM may want to obtain these final versions, for general reference as well as any step-down planning or to be able to re-assess MQs relating to the species distributions. Predicted distributions were modeled for all sixteen identified landscape bird and mammal species (Table B-4). Because the AK GAP program is tasked with developing habitat models for a large number of vertebrate species, including the six local bird species identified for the SNK REA, predicted distributions for those local six species have been included in this REA as well (rather than using existing locality data from the Alaska Natural Heritage Program).

**Table B-4. Alaska GAP distribution maps for local, landscape, and subsistence species.**

| Species | CE Group | Taxonomic Group |
|---|---|---|
| 1. Emperor Goose | Local | Bird |
| 2. Hudsonian Godwit | Local | Bird |
| 3. King Eider | Local | Bird |
| 4. Kittlitz's Murrelet | Local | Bird |
| 5. McKay's Bunting | Local | Bird |
| 6. Spectacled Eider | Local | Bird |
| 7. Alaskan Hare | Landscape | Mammal |
| 8. Arctic Peregrine Falcon | Landscape | Bird |
| 9. Bar-Tailed Godwit | Landscape | Bird |
| 10. Black Scoter | Landscape | Bird |
| 11. Bristle-Thighed Curlew | Landscape | Bird |
| 12. Common Eider | Landscape | Bird |

| Species | CE Group | Taxonomic Group |
|---|---|---|
| 13. King Eider | Landscape | Bird |
| 14. Red Knot | Landscape | Bird |
| 15. Yellow-Billed Loon | Landscape | Bird |
| 16. Beaver | Landscape/Subsistence | Mammal |
| 17. Black Bear | Landscape/Subsistence | Mammal |
| 18. Brown Bear | Landscape/Subsistence | Mammal |
| 19. Caribou | Landscape/Subsistence | Mammal |
| 20. Moose | Landscape/Subsistence | Mammal |
| 21. Muskox | Landscape/Subsistence | Mammal |
| 22. Cackling Goose | Landscape/Subsistence | Bird |

#### B-1.1.4.1.1 Data Collection

Occurrence data were acquired from over 650 unique data sources, resulting in a dataset of approximately 1.6 million records for 435 species. Records were summarized in a common format and attributed with 30 common fields, including: record ID, primary data source, secondary data source, species Latin name, species common name, infra-species designation, date of most recent observation, other observation dates, life history stage (when available), latitude and longitude coordinates of the geographic location of the observation (including projection, datum, accuracy and precision), observer name and affiliation, reliability of taxon identification, data sensitivity, and observation (point) type. Positional accuracy (if not provided) was estimated based on the record's mapping protocol using standards established by the Natural Heritage Network (http://www.natureserve.org/prodServices/standardsMethods.jsp). All records were stored in a geodatabase that was queried as needed for analysis and modeling.

#### B-1.1.4.1.2 Data Filtering

For migratory species, all occurrences outside the designated modeling season were removed from the dataset. For avian species, the primary season of interest was the breeding season in which case all non-breeding season occurrences were eliminated. Breeding season was defined as such: for breeding waterfowl, May through August, for all other breeding birds, June, July and August. Further filtering restrictions included year - only data from 1990 or newer were included, and accuracy - data with accuracy rating of M (minutes) and S (seconds) were accepted, while accuracy of D (degrees) and U (unknown) were eliminated.

Preliminary models were run using all occurrence data that met the above criteria. These preliminary datasets were then reviewed to identify species with highly autocorrelated data, which can sometimes bias environmental niche models (Jimenez-Valverde and Lobo 2006, Johnson and Gillingham 2008). Dense clusters of occurrences resulting from oversampling were thinned by applying a stratified sampling method using 12-digit HUCs (Hydrologic Units Codes) to spatially separate occurrences. At least two, and up to ten, occurrences were randomly selected from each HUC to be included in the modeling procedure. The number of occurrences used depended on the number of overall occurrence data points available for, and the results of further iterations of, modeling.

Preliminary models for species that had poor results and few occurrence points from the aforementioned data filtering process were re-run using alternative data selection procedures. The first data selection method removed the year data restriction and included data from years prior to 1990 as long as they met the other filtering restrictions. The other method removed the seasonal restriction if the species was found within Alaska for the entire year. This method was only used if the prior models for the species did not meet expert review criteria.

### B-1.1.4.1.3 Environmental Data Collection and Processing

Environmental predictor layers were re-projected to Alaska Albers Equal Conical projection and resampled to 60 m cell size, such that there projection, extent, cell size, and alignment were consistent. These processes were performed in ArcGIS 10.0.

All models were run using the same 20 environmental layers (Table B-5).

**Table B-5. Twenty environmental predictors used in all AK GAP species distribution models.**

| | Environmental Predictor Layer |
|---|---|
| 1 | Distance to coast |
| 2 | Freeze Days |
| 3 | Thaw Days |
| 4 | Distance to Glaciers |
| 5 | Distance to Lentic Water |
| 6 | Distance to Permafrost |
| 7 | Elevation |
| 8 | Geology |
| 9 | Distance to Infrastructure |
| 10 | Sea Ice - December |
| 11 | Sea Ice - June |
| 12 | Soils |
| 13 | Mean Temperature - Jan. |
| 14 | Mean Temperature - Feb. |
| 15 | Mean Temperature - Mar. |
| 16 | Mean Temperature - Apr. |
| 17 | Mean Temperature - May |
| 18 | Mean Temperature - Sept. |
| 19 | Mean Temperature - Nov. |
| 20 | Mean Temperature - Dec. |

Spatial overlays of environmental data were performed in the Geospatial Modeling Environment (www.spatialecology.com). The results of the overlay were converted into a Background SWD (samples with data) file. The SWD file format is very useful for modeling in Maxent, especially when environmental grids are very large. This technique can be used in place of an ordinary samples file. The difference is only that the program doesn't need to look in the environmental layers to get values for the variables at the sample points. The environmental layers are thus only used to get "background" pixels – pixels where the species hasn't necessarily been found. The file "background.csv" has 10,000 background data points in it.

### B-1.1.4.1.4 Model Generation and Validation

Maxent version 3.3.1 (http://www.cs.princeton.edu/~schapire/maxent/) was used to produce the species distribution models. Maxent allows for tuning for a limited number of model parameters, controlled by adjusting settings in the software. Generally, the default settings were used for each parameter. However, after an initial run using all the defaults, we ran secondary models on select species and adjusted the regularization multiplier to improve model performance and prevent over-fitting of the input data.

All models were produced using the 20 environmental variables presented in Table B-5. Thirty percent of the occurrence data were held back to test the model. Models were validated using k-fold cross-validation techniques, which withhold random subsets of the presence localities to test the model as it is built.

AK GAP used area under the curve (AUC) statistics derived from receiver operating characteristics analyses, which is automatically calculated by Maxent, to estimate performance. Models with an AUC of 0.75 and higher were considered acceptable, while models with AUCs lower than 0.75 were rejected.

#### B-1.1.4.1.5 Model Display

Model outputs include an ASCII file which was converted to a continuous raster grid for import into ArcGIS. Each cell in the raster contains a probability value that represents the probability of occurrence for that particular species. For these models, a binary threshold was applied that divided the continuous output into two categories: predicted presence and predicted absence. AK GAP applied the threshold rule that maximizes the sum of training sensitivity (true positive rate) plus estimated training specificity (true negative rate), and is automatically generated as part of the model output. The final modeled output was then clipped to the species known and suspected range within the state – thus, limiting predictions to areas of the state that are believed to be part of the species range.

### *B-1.1.4.2 Fish*

Distributions for ten fish species were mapped or modeled within the ecoregion: Chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*Oncorhynchus keta*), pink salmon (*Oncoyhynchus gorbuscha*), sheefish (*Stendous leucichthys*), sockeye salmon (*Oncorhynchus nerka*), Arctic char (*Salvelinus alpinus*), coho salmon (*Oncorhynchus kisutch*), Alaska blackfish (*Dallia pectoralis*), Dolly Varden (*Salvelinus malma*), and Arctic grayling (*Thymallus arcticus*). The Arctic grayling model was rejected because it didn't perform well.

Several fish species lacked data to perform distribution mapping and are considered data gaps: Arctic lamprey (*Lampetra japponica*), Pacific lamprey (*Lampetra tridentata*), broad whitefish (*Coregonus nasus*), humpback whitefish (*Coregonus pidschian*), round whitefish (*Prosopium cylindraceum*), Bering cisco (*Coregonus laurettae*), rainbow smelt (*Osmerus mordax*), and pike (*Esox lucius*).

#### B-1.1.4.2.1 Chinook salmon, Chum salmon, Pink salmon, Sheefish, and Sockeye salmon

Distributions for five fish species were mapped using the Alaska Department of Fish and Game's Anadromous Waters Catalog (AWC) Species and Life Stages data set.

The AWC metadata describes the AWC data set as follows:

> The Alaska Department of Fish and Game's (ADF&G) Anadromous water bodies data is derived from the ADF&G's GIS shapefiles for the "Catalog of Waters Important for Spawning, Rearing or Migration of Anadromous Fishes" (referred to as the "Catalog") and the "Atlas to the Catalog of Waters Important for Spawning, Rearing or Migration of Anadromous Fishes" (referred to as the "Atlas"). It is produced for general visual reference and to aid users in generating various natural resource analyses and products. The shapefiles depict the known anadromous fish bearing lakes and streams within Alaska (from the mouth to the known upper extent of species usage). [The AWC] incorporates data from a variety of sources including: USGS Digital Line Graph (DLG) and National Hydrography Dataset (NHD) hydrography data; Alaska Department of Natural Resources hydrography layer; and ADF&G shapefiles for the "Atlas" and "Catalog". ADF&G updates the Anadromous Streams data regularly. Note that stream numbers, locations, extent

of cataloged habitat or species utilization of a given stream may change from year to year. Data for the shapefiles are current as of the 2010 revision of the "Atlas to the Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes" and the "Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes" effective June 1, 2011. Three data layers were downloaded to cover the project area: Arctic, Interior, and West regions.

The Species and Life Stages portion of the data has the same coverage as the Anadromous Waters Catalog, except that it has additional attribute fields identifying species and life stages for individual stream segments. There are 23 species in the dataset and three life stages: present (p), spawning (s), and rearing (r). It was received from Skip Repetto, a GIS analyst at ADF&G with the following caveat: "This is a value-added representation of the AWC and has not been error-checked completely, so use at your own risk; the actual AWC takes precedence."

Records for all three life stages (present, rearing, spawning) for each individual species were selected and extracted from this data set to create distributions for the five fish species listed above.

#### B-1.1.4.2.2 Arctic char

Arctic char (*Salvelinus alpinus*) was mapped using BLM's lake survey data. Arctic char is a local fish species restricted to lakes of the Kigluaik Mountains. It is a BLM Sensitive Species and some work has been conducted in lakes of the Kigluaik Mountains to study its population sizes and distribution. Lakes confirmed to have Arctic char include Gold Run, Crater, Snow Creek, Lower Fall Creek, and Middle Fall Creek Lakes (personal communication Dave Parker, BLM). Lakes confirmed to have Arctic char were selected from the National Hydrography Dataset and exported to create a polygon shapefile that indicates the known distribution of Arctic char in the Kigluaik Mountains.

#### B-1.1.4.2.3 Coho salmon, Alaska blackfish, Dolly Varden and Arctic grayling

Distributions for four fish species were modeled by the AKNHP using a combination of classification tree analyses and GIS processing: Coho salmon, Alaska blackfish, Dolly Varden, and Arctic grayling. As noted above, the grayling model was rejected, but methods are retained here for reference. The methods are generally similar among the four species, but thresholds vary between species.

***<u>Coho salmon</u>***

The distribution model for coho salmon (*Oncorhynchus kisutch*) was developed using presence-absence data from the ADF&G Alaska Freshwater Fish Inventory Database (AFFID) and GIS-generated landscape variables in a classification tree analysis. The final tree had two splits based on two different landscape variables and was pruned based on the minimum error using 10 fold cross-validation on 1000 permutations of the data (McCune and Grace 2002). The model misclassification rate was 13.1% and the kappa was 0.54, indicating moderate model performance (Manel et al. 2001). Coho salmon presence was predicted to occur in stream reaches with watershed area greater than 30.23 km2 and mean topographic wetness (TW) less than 11.8. Model application in GIS resulted in a distribution map totaling approximately 5,700 km of potential habitat for coho salmon in the REA study area. A second descriptive model using the stream reach variables included in the AFFID resulted in a tree with the same variables and splits as the prediction model. There are two factors that limit the model's ability to accurately predict potential coho salmon habitat across the study area: 1) the field data points from the AFFID are heavily biased to low order streams because one of the main objectives of the surveys in the study area was to maximize the mapped anadromous fish habitat included in the Anadromous Waters Catalog, and 2) the field data points do not represent random locations and thus may have other biases that affect the ability of the model to predict potential fish habitat in unsampled areas. A probabilistic sampling study conducted in the Western Alaska REA study area would be the best tool to test the accuracy of this model for predicting potential fish habitat.

***Processing Methods***

Four fish species had existing point data from three field projects included in ADF&G's Alaska Freshwater Fish Inventory Database (AFFID) that overlapped the SNK REA study area: Alaska blackfish (*Dallia pectoralis*), Arctic grayling (*Thymallus arcticus*), coho salmon (*Oncorhynchus kisutch*), and Dolly Varden (*Salvelinus malma*).

Latitude and longitude were used to project the AFFID data points for Coho salmon in ArcGIS. Points were converted to raster cells and moved using the Spatial Analyst/Hydrology/Snap pour point tool using a 120m snap distance to place them on the stream network. All raster locations were manually checked and if the point had been moved to a junction between a headwater and a larger river, the actual stream sampling site was confirmed using field notes, stream name, or wetted width. After reconciliation between AFFID locations and the stream network, the landscape variables generated in GIS were extracted to the AFFID data points using the Spatial Analyst/Extraction/Extract multi-values to points tool.

Landscape variables were calculated in GIS as predictors of fish presence or absence using classification tree models. The steps used to create each predictor variable are included in individual models and descriptions follow.

Lake density was defined as the proportion of area in the watershed covered by lakes. The steps included converting the lakes polygon shapefile (created from the NHD, see the lakes metadata and model) into a raster dataset, running a weighted flow accumulation to get the total lake area in the watershed for each stream cell, dividing by the flow accumulation to obtain lake density, and extracting lake density using the stream network. [Note: the flow direction, flow accumulation, and stream network dataset methods are all described in the headwater streams metadata and model.]

1. Mean topographic wetness (TW) was calculated for each stream cell based on all cells in the watershed with a higher elevation. The TW calculation is based on both watershed area and local slope: $TW = \ln(A/\tan\beta)$; A – watershed area, $\beta$ – local slope. The topographic wetness is an index used to quantify the control of topography on hydrologic processes and predict local wetness. The steps to calculate the mean TW are described below.
    a. Use the slope tool in Spatial Analyst to calculate slope in degrees from the National Elevation Dataset 60 m DEM and convert the slope to radians.
    b. Calculate the tangent of the slope in radians for all cells greater than zero and add 0.001 to cells with slope of zero to avoid having zero values in the denominator for the TW calculation.
    c. Calculate watershed area by multiplying the flow accumulation by 3600 (60 m x 60 m) after adding one to avoid cells of zero at the watershed boundary.
    d. Calculate the TW for all cells in the study area by taking the natural log of the watershed area divided by the tangent of the slope in radians.
    e. Run a weighted flow accumulation to add up the TW for all cells in the watershed above each cell in the study area.
    f. Calculate the average TW by dividing the weighted flow accumulation by the watershed area and extract the data for the stream network.
2. Mean gradient was calculated for each stream cell based on all cells in the watershed with a higher elevation. The steps to calculate mean gradient include running a weight flow accumulation to add up the gradient for all cells in the watershed with a higher elevation,

dividing the weighted flow accumulation by the flow accumulation grid to get mean gradient, and extracting the data for the stream network.

3. Stream gradient was calculated for each stream cell using a 3x3 window following the methods in the low gradient streams metadata and model. The stream gradient raster was created as part of the low gradient streams model.
4. Stream order was calculated for the stream network using the stream order tool in spatial analyst. The stream order raster was created as part of the headwater stream model.
5. Watershed area was calculated by multiplying the flow accumulation grid by 3600 based on the 60 m cell size and dividing by 1,000,000 to convert to area in square kilometers. The stream network was used to extract the upstream watershed area for each cell.
6. Elevation was generated by using the stream network to extract elevations from the National Elevation Dataset 60 m DEM.

For each fish species, three models were constructed and analyzed. The first model included stream reach variables from the AFFID and GIS-generated landscape variables as predictors of presence-absence using a classification tree (for a complete list of variables see Table B-6). The results of this model were used strictly for description of the relationships between fish presence and habitat attributes at the combined stream reach and landscape level. The second classification tree model only used landscape variables as predictors of fish presence-absence so that results could be used for mapping fish distribution in GIS. Classification trees were initially overfit by setting the stopping rule at a complexity parameter of 0.01. Trees were pruned using cross-validation: the data were split into 10 groups and 90% of the data was used to predict the remaining 10%. Cross-validation was performed on 1000 permutations of the data and the prediction errors were plotted against tree size. Trees were pruned to the least number of splits that fell within one standard error of the minimum cross-validated error; or, when the null model fell within one standard error, to the minimum cross-validated error. A third model was run using a random forest analysis to help evaluate the performance of the classification tree prediction model. Random forests produce more accurate classifications as they include many classification trees and average the results (Cutler et al. 2007). The drawback of random forest is the lack of an explicit listing of tree splits and break points that can be used for distribution mapping in GIS; thus, classification trees were used for the final prediction models.

Prediction model performance was compared using the misclassification rate (number of samples misclassified / total number of samples) and Cohen's kappa, which corrects for chance when comparing agreement between predicted and actual class assignments (as compared to the percent correctly classified). Prediction models were accepted with kappa greater than 0.4 (for both the classification tree and random forest models), indicating moderate to very high model performance (Manel et al. 2001).

Classification trees and random forest models were run using the R statistical software (Version 2.14.1) and mvpart and randomForest libraries, respectively (De'Ath 2011, Liaw and Wiener 2002). A script with all of the R functions was provided as a separate document.

**Table B-6. Landscape variables used to model coho salmon distribution.**

| Variable name | Type | Source | Method | Units |
|---|---|---|---|---|
| Water temperature | Continuous | AFFID | Collected using handheld meter. | Celsius |
| pH | Continuous | AFFID | Collected using handheld meter. | pH units |
| Dissolved oxygen | Continuous | AFFID | Collected using handheld meter. | mg/L |
| NTU | Continuous | AFFID | Collected using turbidimeter. | NTU units |
| Stream gradient | Continuous | AFFID | Collected using clinometer. | % |
| Wetted width | Continuous | AFFID | Collected using fiberglass tape or laser range finder (large rivers). | meters |
| Wetted depth | Continuous | AFFID | Collected using a graduated rod or combination sonar and clinometers (large rivers). | meters |
| Velocity | Continuous | AFFID | Collected using flow meter. | m/s |
| Clarity | Class | AFFID | Clear, low turbidity, high turbidity, ferric, humic, and muddy | NA |
| Conductivity | Continuous | AFFID | Collected using handheld meter. | uS/cm |
| Substrate | Class | AFFID | Dominant substrate class: boulder, cobble, gravel, sand/silt/clay, or organics | NA |
| Boulders | Class | AFFID | Presence-absence, were boulders selected in one of three substrate classes? | NA |
| Organics | Class | AFFID | Presence-absence, were organics selected in one of three substrate classes? | NA |
| Viereck class | Class | AFFID | Combined right and left bank Viereck Level III classes to Viereck Level II vegetation communities to reduce variation in number of classes (22 total). | NA |
| Canopy height | Continuous | AFFID | Average of left and right bank canopy height (0-5 meters) | meters |
| Rosgen class | Class | AFFID | Rosgen (1994) major stream types: Aa, A, B, C, D, E, F, or G. | NA |
| Lake density | Continuous | ArcGIS | Density of lake area in watershed, lakes are from NHD. | Proportion |
| Mean TW | Continuous | ArcGIS | Mean topographic wetness for watershed. TW is an index of topographic control on hydrologic processes used to predict local wetness. | NA |
| Mean watershed gradient | Continuous | ArcGIS | Mean gradient in watershed. | % |
| Stream gradient | Continuous | ArcGIS | Stream gradient at sample site. | % |
| Stream order | Class | ArcGIS | Stream Strahler order calculated from stream network. | NA |
| Watershed area | Continuous | ArcGIS | Watershed area based on flow accumulation grid. | $km^2$ |
| Elevation | Continuous | ArcGIS | Elevation from NED 60m DEM. | feet |

***Alaska blackfish***

The distribution model for Alaska blackfish (*Dallia pectoralis*) was developed using presence-absence data from the ADF&G Alaska Freshwater Fish Inventory Database (AFFID) and the Alaska Natural Heritage Program (AKNHP) in addition to GIS-generated landscape variables in a classification tree analysis. The final tree had two splits based on two different landscape variables and was pruned based on the one standard error rule using 10 fold cross-validation on 1000 permutations of the data (McCune and Grace 2002). The model misclassification rate was 5.3% and the kappa was 0.60, indicating substantial model performance (Manel et al. 2001). Alaska blackfish presence was predicted to occur in stream reaches with elevations less than 158.5 feet and lake density greater than 0.003%. Model application in GIS resulted in a distribution map totaling approximately 32,700 km of potential habitat for Alaska Blackfish in the REA study area. A descriptive model using stream reach variables from the AFFID was not constructed for Alaska blackfish because one third of the presence data points originated from AKNHP where stream reach data was not available. There are two factors that limit the model's ability to accurately predict potential Alaska blackfish habitat across the study area: 1) the field data points from the AFFID are heavily biased to low order streams because one of the main objectives of the surveys in the study area was to maximize the mapped anadromous fish habitat included in the Anadromous Waters Catalog and 2) the field data points do not represent random locations and thus may have other biases that affect the ability of the model to predict potential fish habitat in unsampled areas. A probabilistic sampling study conducted in the Western Alaska REA study area would be the best tool to test the accuracy of this model for predicting potential fish habitat.

***Processing Methods***

Four fish species had existing point data from three field projects included in ADF&G's Alaska Freshwater Fish Inventory Database (AFFID) that overlapped the SNK REA study area: Alaska blackfish (*Dallia pectoralis*), Arctic grayling (*Thymallus arcticus*), coho salmon (*Oncorhynchus kisutch*), and Dolly Varden (*Salvelinus malma*). Alaska blackfish also had presence data points from the Alaska Natural Heritage Program (AKNHP).

Latitude and longitude were used to project the AFFID data points in ArcGIS. The AKNHP data points were provided as a shapefile for the entire state and clipped to the REA study area. Points were converted to raster cells and manually snapped to the stream network. After reconciliation between AFFID and AKNHP point locations and the stream network, the landscape variables generated in GIS were extracted to the data points using the Spatial Analyst/Extraction/Extract multi-values to points tool.

Landscape variables were calculated in GIS as predictors of fish presence or absence using classification tree models. The steps used to create each predictor variable are included in individual models and descriptions follow.

1. Lake density was defined as the proportion of area in the watershed covered by lakes. The steps included converting the lakes polygon shapefile (created from the NHD, see the lakes metadata and model) into a raster dataset, running a weighted flow accumulation to get the total lake area in the watershed for each stream cell, dividing by the flow accumulation to obtain lake density, and extracting lake density using the stream network. [Note: the flow direction, flow accumulation, and stream network dataset methods are all described in the headwater streams metadata and model.]
2. Mean topographic wetness (TW) was calculated for each stream cell based on all cells in the watershed with a higher elevation. The TW calculation is based on both watershed area and local slope: $TW = \ln(A/\tan\beta)$; A – watershed area, β – local slope. The topographic wetness is an

index used to quantify the control of topography on hydrologic processes and predict local wetness. The steps to calculate the mean TW are described below.

   a. Use the slope tool in Spatial Analyst to calculate slope in degrees from the National Elevation Dataset 60 m DEM and convert the slope to radians.
   b. Calculate the tangent of the slope in radians for all cells greater than zero and add 0.001 to cells with slope of zero to avoid having zero values in the denominator for the TW calculation.
   c. Calculate watershed area by multiplying the flow accumulation by 3600 (60 m x 60 m) after adding one to avoid cells of zero at the watershed boundary.
   d. Calculate the TW for all cells in the study area by taking the natural log of the watershed area divided by the tangent of the slope in radians.
   e. Run a weighted flow accumulation to add up the TW for all cells in the watershed above each cell in the study area.
   f. Calculate the average TW by dividing the weighted flow accumulation by the watershed area and extract the data for the stream network.

3. Mean gradient was calculated for each stream cell based on all cells in the watershed with a higher elevation. The steps to calculate mean gradient include running a weight flow accumulation to add up the gradient for all cells in the watershed with a higher elevation, dividing the weighted flow accumulation by the flow accumulation grid to get mean gradient, and extracting the data for the stream network.
4. Stream gradient was calculated for each stream cell using a 3x3 window following the methods in the low gradient streams metadata and model. The stream gradient raster was created as part of the low gradient streams model.
5. Stream order was calculated for the stream network using the stream order tool in spatial analyst. The stream order raster was created as part of the headwater stream model.
6. Watershed area was calculated by multiplying the flow accumulation grid by 3600 based on the 60 m cell size and dividing by 1,000,000 to convert to area in square kilometers. The stream network was used to extract the upstream watershed area for each cell.
7. Elevation was generated by using the stream network to extract elevations from the National Elevation Dataset 60 m DEM.

For Alaska blackfish, two models were constructed and analyzed. The first model was a classification tree analysis, which used landscape variables as predictors of fish presence-absence so that results could be used for mapping fish distribution in GIS (for a complete list of variables see Table B-7). Classification trees were initially overfit by setting the stopping rule at a complexity parameter of 0.01. Trees were pruned using cross-validation: the data were split into 10 groups and 90% of the data was used to predict the remaining 10%. Cross-validation was performed on 1000 permutations of the data and the prediction errors were plotted against tree size. Trees were pruned to the least number of splits that fell within one standard error of the minimum cross-validated error. A second model was run using a random forest analysis to help evaluate the performance of the classification tree prediction model. Random forests produce more accurate classifications as they include many classification trees and average the results (Cutler et al. 2007). The drawback of random forest is the lack of an explicit listing of tree splits and break points that can be used for distribution mapping in GIS; thus, classification trees were used for the final prediction models.

Prediction model performance was compared using the misclassification rate (number of samples misclassified / total number of samples) and Cohen's kappa, which corrects for chance when comparing agreement between predicted and actual class assignments (as compared to the percent correctly classified). Prediction models were accepted with kappa greater than 0.4 (for both the classification tree and random forest models), indicating moderate to very high model performance (Manel et al. 2001).

Classification trees and random forest models were run using the R statistical software (Version 2.14.1) and mvpart and randomForest libraries, respectively (De'Ath 2011, Liaw and Wiener 2002). A script with all of the R functions has been provided as a separate document.

**Table B-7. Landscape variables used to model Alaska blackfish distribution.**

| Variable name | Type | Source | Method | Units |
|---|---|---|---|---|
| Lake density | Continuous | ArcGIS | Density of lake area in watershed, lakes are from NHD. | Proportion |
| Mean TW | Continuous | ArcGIS | Mean topographic wetness for watershed. TW is an index of topographic control on hydrologic processes used to predict local wetness. | NA |
| Mean watershed gradient | Continuous | ArcGIS | Mean gradient in watershed. | % |
| Stream gradient | Continuous | ArcGIS | Stream gradient at sample site. | % |
| Stream order | Class | ArcGIS | Stream Strahler order calculated from stream network. | NA |
| Watershed area | Continuous | ArcGIS | Watershed area based on flow accumulation grid. | $km^2$ |
| Elevation | Continuous | ArcGIS | Elevation from NED 60m DEM. | feet |

***Dolly Varden***

The distribution model for Dolly Varden (*Salvelinus malma*) was developed using presence-absence data from the ADF&G Alaska Freshwater Fish Inventory Database (AFFID) and GIS-generated landscape variables in a classification tree analysis. The final tree had two splits based on two different landscape variables and was pruned based on the one standard error rule using 10 fold cross-validation on 1000 permutations of the data (McCune and Grace 2002). The model misclassification rate was 23.2% and the kappa was 0.53, indicating moderate model performance (Manel et al. 2001). Dolly varden presence was predicted to occur in two settings: 1) stream reaches with mean gradient in the watershed greater than or equal to 14.96% and 2) stream reaches with mean gradient less than 14.96%, at elevations greater than or equal to 722 feet. Model application in GIS resulted in a distribution map totaling approximately 48,200 km of potential habitat for Dolly Varden in the REA study area. A second model, used for descriptive purposes, which included the stream reach variables from the AFFID and pruned according to the one standard error rule, resulted in a tree with one split based on water clarity. In this model, Dolly Varden occurred in streams with clear or highly turbid water. Dolly Varden were only found in four sites with highly turbid water and field notes indicate that flooding on the Seward Peninsula in August 2004 was the cause. There are two factors that limit the model's ability to accurately predict potential Dolly Varden habitat across the study area: 1) the field data points from the AFFID are heavily biased to low order streams because one of the main objectives of the surveys in the study area was to maximize the mapped anadromous fish habitat included in the Anadromous Waters Catalog and 2) the field data points do not represent random locations and thus may have other biases that affect the ability of the model to predict potential fish habitat in unsampled areas. A probabilistic sampling study conducted in the Western Alaska REA study area would be the best tool to test the accuracy of this model for predicting potential fish habitat.

***Processing Methods***

Four fish species had existing point data from three field projects included in ADF&G's Alaska Freshwater Fish Inventory Database (AFFID) that overlapped the SNK REA study area: Alaska blackfish (*Dallia pectoralis*), Arctic grayling (*Thymallus arcticus*), coho salmon (*Oncorhynchus kisutch*), and Dolly Varden (*Salvelinus malma*).

Latitude and longitude were used to project the AFFID data points in ArcGIS. Points were converted to raster cells and moved using the Spatial Analyst/Hydrology/Snap pour point tool using a 120m snap distance to place them on the stream network. All raster locations were manually checked and if the point had been moved to a junction between a headwater and a larger river, the actual stream sampling site was confirmed using field notes, stream name, or wetted width. After reconciliation between AFFID locations and the stream network, the landscape variables generated in GIS were extracted to the AFFID data points using the Spatial Analyst/Extraction/Extract multi-values to points tool.

Landscape variables were calculated in GIS as predictors of fish presence or absence using classification tree models. The steps used to create each predictor variable are included in individual models and descriptions follow.

1. Lake density was defined as the proportion of area in the watershed covered by lakes. The steps included converting the lakes polygon shapefile (created from the NHD, see the lakes metadata and model) into a raster dataset, running a weighted flow accumulation to get the total lake area in the watershed for each stream cell, dividing by the flow accumulation to obtain lake density, and extracting lake density using the stream network. [Note: the flow direction, flow accumulation, and stream network dataset methods are all described in the headwater streams metadata and model.]
2. Mean topographic wetness (TW) was calculated for each stream cell based on all cells in the watershed with a higher elevation. The TW calculation is based on both watershed area and local slope: $TW = \ln(A/\tan\beta)$; A – watershed area, β – local slope. The topographic wetness is an index used to quantify the control of topography on hydrologic processes and predict local wetness. The steps to calculate the mean TW are described below.
    a. Use the slope tool in Spatial Analyst to calculate slope in degrees from the National Elevation Dataset 60 m DEM and convert the slope to radians.
    b. Calculate the tangent of the slope in radians for all cells greater than zero and add 0.001 to cells with slope of zero to avoid having zero values in the denominator for the TW calculation.
    c. Calculate watershed area by multiplying the flow accumulation by 3600 (60 m x 60 m) after adding one to avoid cells of zero at the watershed boundary.
    d. Calculate the TW for all cells in the study area by taking the natural log of the watershed area divided by the tangent of the slope in radians.
    e. Run a weighted flow accumulation to add up the TW for all cells in the watershed above each cell in the study area.
    f. Calculate the average TW by dividing the weighted flow accumulation by the watershed area and extract the data for the stream network.
3. Mean gradient was calculated for each stream cell based on all cells in the watershed with a higher elevation. The steps to calculate mean gradient include running a weight flow accumulation to add up the gradient for all cells in the watershed with a higher elevation, dividing the weighted flow accumulation by the flow accumulation grid to get mean gradient, and extracting the data for the stream network.

4. Stream gradient was calculated for each stream cell using a 3x3 window following the methods in the low gradient streams metadata and model. The stream gradient raster was created as part of the low gradient streams model.
5. Stream order was calculated for the stream network using the stream order tool in spatial analyst. The stream order raster was created as part of the headwater stream model.
6. Watershed area was calculated by multiplying the flow accumulation grid by 3600 based on the 60 m cell size and dividing by 1,000,000 to convert to area in square kilometers. The stream network was used to extract the upstream watershed area for each cell.
7. Elevation was generated by using the stream network to extract elevations from the National Elevation Dataset 60 m DEM.

For each fish species, three models were constructed and analyzed. The first model included stream reach variables from the AFFID and GIS-generated landscape variables as predictors of presence-absence using a classification tree (see Table B-8 for a complete list of variables). The results of this model were used strictly for description of the relationships between fish presence and habitat attributes at the combined stream reach and landscape level. The second classification tree model only used landscape variables as predictors of fish presence-absence so that results could be used for mapping fish distribution in GIS. Classification trees were initially overfit by setting the stopping rule at a complexity parameter of 0.01. Trees were pruned using cross-validation: the data were split into 10 groups and 90% of the data was used to predict the remaining 10%. Cross-validation was performed on 1000 permutations of the data and the prediction errors were plotted against tree size. Trees were pruned to the least number of splits that fell within one standard error of the minimum cross-validated error. A third model was run using a random forest analysis to help evaluate the performance of the classification tree prediction model. Random forests produce more accurate classifications as they include many classification trees and average the results (Cutler et al. 2007). The drawback of random forest is the lack of an explicit listing of tree splits and break points that can be used for distribution mapping in GIS; thus, classification trees were used for the final prediction models.

Prediction model performance was compared using the misclassification rate (number of samples misclassified / total number of samples) and Cohen's kappa, which corrects for chance when comparing agreement between predicted and actual class assignments (as compared to the percent correctly classified). Prediction models were accepted with kappa greater than 0.4 (for both the classification tree and random forest models), indicating moderate to very high model performance (Manel et al. 2001).

Classification trees and random forest models were run using the R statistical software (Version 2.14.1) and mvpart and randomForest libraries, respectively (De'Ath 2011, Liaw and Wiener 2002). A script with all of the R functions has been provided as a separate document.

**Table B-8. Landscape variables used to model Dolly Varden distribution.**

| Variable name | Type | Source | Method | Units |
|---|---|---|---|---|
| Water temperature | Continuous | AFFID | Collected using handheld meter. | Celsius |
| pH | Continuous | AFFID | Collected using handheld meter. | pH units |
| Dissolved oxygen | Continuous | AFFID | Collected using handheld meter. | mg/L |
| NTU | Continuous | AFFID | Collected using turbidimeter. | NTU units |
| Stream gradient | Continuous | AFFID | Collected using clinometer. | % |
| Wetted width | Continuous | AFFID | Collected using fiberglass tape or laser range finder (large rivers). | meters |

| Variable name | Type | Source | Method | Units |
|---|---|---|---|---|
| Wetted depth | Continuous | AFFID | Collected using a graduated rod or combination sonar and clinometers (large rivers). | meters |
| Velocity | Continuous | AFFID | Collected using flow meter. | m/s |
| Clarity | Class | AFFID | Clear, low turbidity, high turbidity, ferric, humic, and muddy | NA |
| Conductivity | Continuous | AFFID | Collected using handheld meter. | uS/cm |
| Substrate | Class | AFFID | Dominant substrate class: boulder, cobble, gravel, sand/silt/clay, or organics | NA |
| Boulders | Class | AFFID | Presence-absence, were boulders selected in one of three substrate classes? | NA |
| Organics | Class | AFFID | Presence-absence, were organics selected in one of three substrate classes? | NA |
| Viereck class | Class | AFFID | Combined right and left bank Viereck Level III classes to Viereck Level II vegetation communities to reduce variation in number of classes (22 total). | NA |
| Canopy height | Continuous | AFFID | Average of left and right bank canopy height (0-5 meters) | meters |
| Rosgen class | Class | AFFID | Rosgen (1994) major stream types: Aa, A, B, C, D, E, F, or G. | NA |
| Lake density | Continuous | ArcGIS | Density of lake area in watershed, lakes are from NHD. | Proportion |
| Mean TW | Continuous | ArcGIS | Mean topographic wetness for watershed. TW is an index of topographic control on hydrologic processes used to predict local wetness. | NA |
| Mean watershed gradient | Continuous | ArcGIS | Mean gradient in watershed. | % |
| Stream gradient | Continuous | ArcGIS | Stream gradient at sample site. | % |
| Stream order | Class | ArcGIS | Stream Strahler order calculated from stream network. | NA |
| Watershed area | Continuous | ArcGIS | Watershed area based on flow accumulation grid. | $km^2$ |
| Elevation | Continuous | ArcGIS | Elevation from NED 60m DEM. | feet |

#### B-1.1.5 Local Species: Birds and Rare Plants

Local species observations were obtained from element occurrence records from the Alaska Natural Heritage Program. (For an overview and detail of Natural Heritage Program methodology, see http://www.natureserve.org/prodServices/heritagemethodology.jsp.) Twenty-two rare local plants (Table B-9) were summarized by 5$^{th}$-level watersheds using the element occurrence records.

Distributions for all six local bird species were modeled by the Alaska GAP program as described previously for the landscape bird and mammal species.

The distribution of Arctic char, a local fish species in the Kigluaik Mountains, was mapped using BLM's lake survey data and the National Hydrography Dataset as described previously.

**Table B-9. List of rare plant species CEs summarized for SNK REA.** Four plant species grayed out were not assessed because they were later determined to not be documented within the SNK ecoregion.

| Scientific Name | Common Name |
|---|---|
| 1. *Artemisia globularia* ssp. *lutea* | a Boreal Wormwood subspecies |
| 2. *Artemisia senjavinensis* | Arctic Sage |
| 3. *Cardamine microphylla* ssp. *blaisdellii* | Littleleaf Bittercress |
| 4. *Carex heleonastes* | Hudson Bay Sedge |
| 5. *Claytonia arctica* | Arctic Springbeauty |
| 6. *Douglasia alaskana* | Alaska Rockjasmine |
| 7. *Douglasia beringensis* | Arctic Dwarf-primrose |
| 8. *Gentianopsis detonsa* ssp. *detonsa* | Sheared Gentian |
| 9. *Lupinus kuschei* | Yukon Lupine |
| 10. *Oxytropis arctica* var. *barnebyana* | Barneby's Locoweed |
| 11. *Oxytropis kokrinensis* | Kokrines Oxytrope |
| 12. *Papaver walpolei* | Walpole's Poppy |
| 13. *Parrya nauruaq* | Naked-stemmed Wallflower |
| 14. *Potentilla stipularis* | Circumpolar Cinquefoil |
| 15. *Primula tschuktschorum* | Chukchi Primrose |
| 16. *Puccinellia wrightii* ssp. *wrightii* | a Wright's Arctic Grass subspecies |
| 17. *Ranunculus auricomus* | Goldilocks Buttercup |
| 18. *Ranunculus chamissonis* | Glacier Buttercup |
| 19. *Ranunculus glacialis* var. 1 | a Glacier Buttercup subspecies |
| 20. *Rumex krausei* | Krause's Sorrel |
| 21. *Smelowskia johnsonii* | Johnson's False Candytuft |
| 22. *Taraxacum carneocoloratum* | Pink Dandelion |
| 23. *Puccinellia vahliana* | Vahl's Alkali Grass |
| 24. *Potentilla rubricaulis* | Rocky Mountain Cinquefoil |
| 25. *Saussurea* cf. *triangulata* | a Saw-Wort |
| 26. *Symphyotrichum yukonense* | Yukon Aster |

## B-1.2 Bioclimatic Envelope Modeling for CEs

Climate change is the change agent for which *potential* effects relating to CE distributions were readily modeled at the level of individual CEs. The following section discusses the bioclimate envelope modeling that was conducted for a subset of terrestrial CEs and two invasive species with some additional technical detail that was not included in the main body of the report.

### B-1.2.1 Background and Model Approach

Forecasting the impacts of climate change on species current distributions begins with the selection of an appropriate subset of species that occur in the SNK region. Not all species are suitable for bioclimatic envelope modeling. Generalist species with broad ecological niches often lead to spatial over-prediction by niche modeling algorithms. Species with very narrow niches that are largely determined by non-climate factors, such as plant species dependent on a particular soil type, or birds associated with coastal cliff nesting sites where oceanic climate regimes prevail, are also poor candidates for robust performance by ecological niche modeling algorithms. For many species of management concern whose ranges are at least partly defined by climate, the availability of sufficient distribution data that is broadly representative of the species known range is a crucial consideration. Species distribution algorithms require sufficient input data on known distributions to correlate observations with climatic or environmental parameters to produce a robust modeled distribution. The Alaska GAP program compiled species observation records within Alaska for use in its distribution modeling; these data were also used for the bioclimate modeling in this REA. The geographic coverage of this data was one of the limiting factors determining which species could be modeled. Finally, modeling efforts are limited by available spatial climate data. This is particularly true for modeling future distributions, which requires downscaled spatial climate data from global circulation models. The downscaled climate data used for this study, provided by SNAP, is limited to Alaska and western Canada, which restricted our ability to model pan-Arctic taxa. Our selection of species was guided by their importance as a species of management concern, the likelihood of climate as at least a partial driver of their distributions, the available distribution data, and the spatial extent of available downscaled future climate data. Table B-10 lists the species that received bioclimate envelope models.

**Table B-10. Species CEs and invasive species CAs chosen for bioclimate envelope modeling with model parameters. Months listed are associated with the climate variables monthly maximum temperature, minimum temperature, and total precipitation. Baseline climate data is used to define the current climate envelope for a species.**

| CEs/CAs | Species | Months | Baseline | Future Time Slices |
|---|---|---|---|---|
| Mammals CE | Alaskan hare | 1-12 | 1901-1981 | 2020s, 2050s |
| Birds | Arctic peregrine falcon | 6,7,8 | 1901-1981 | 2020s, 2050s |
| | Hudsonian godwit | 6,7,8 | 1901-1981 | 2020s, 2050s |
| | Bristle-thighed curlew | 6,7,8 | 1901-1981 | 2020s, 2050s |
| | Bar-tailed godwit | 6,7,8 | 1901-1981 | 2020s, 2050s |
| Subsistence | Caribou: winter habitat of WACH | 10,11,12,1,2,3,4 | 1991-2009 | 2020s, 2050s |
| Invasive CAs | White sweet clover | 1-12 | 1901-1981 | 2020s, 2050s |
| | Orange hawkweed | 1-12 | 1901-1981 | 2020s, 2050s |

In order to forecast how climate change may result in geographic shifts of the suitable climatic conditions for a species, its 'bioclimatic envelope' must first be defined. Species distribution models, also called ecological niche models, perform this task by correlating known localities of a species' current range with current climatic conditions to generate a species' multidimensional bioclimatic 'envelope' or 'niche'. The species' identified n-dimensional bioclimatic envelope can then be projected into 21$^{st}$ century climate scenarios, resulting in a map of the future spatial extent of the species current bioclimatic niche. Of course, climactic conditions such as air temperature and precipitation levels are not the sole defining characteristics of species occupied range. Some species, for example, may be limited or facilitated by the presence of particular vegetation communities, or by other habitat characteristics such as topography or soil type, etc. Nonetheless, climatic conditions play a broad role in determining the suitability of habitat for most species, and they have indirect influence on those other factors, such as the extent of certain vegetation communities or the characteristics of local hydrology, that in turn influence habitat selection for species. Thus, there is value for management in anticipating the geographic changes in bioclimatic suitability that climate change may bring: Managers can gain an improved understanding of the relative risk climate change may pose to the current geographic distribution of suitable bioclimate for species of management concern. In order to predict how climate change may shift the suitable climatic conditions for a species or vegetation class, first its bioclimatic niche is identified by correlating its current range with current climatic conditions. The species' identified bioclimatic niche can then be projected into the future using downscaled Global Circulation Models (GCMs) to predict where its climate niche will occur at different time slices in 21st century climate scenarios.

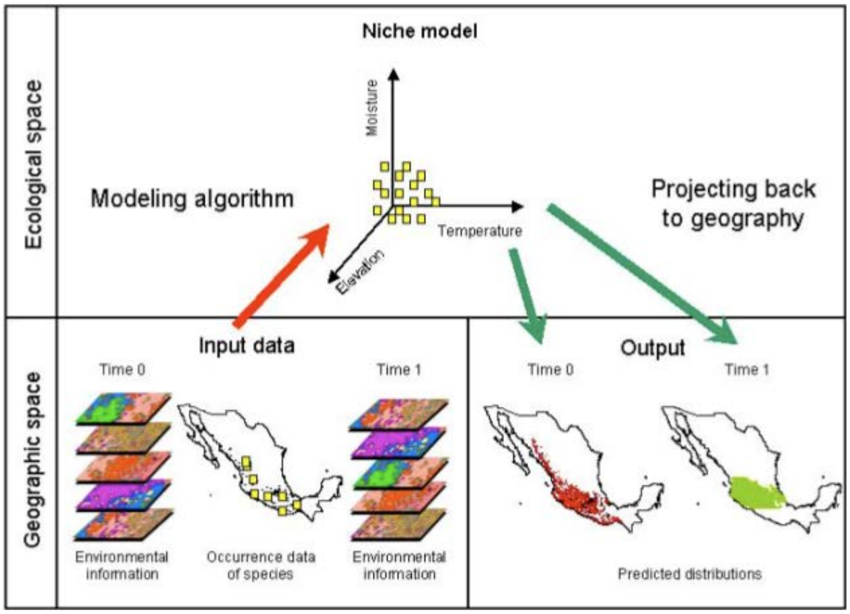
This information can serve as one of many inputs in developing an understanding of how climate change might affect a given species of management interest, and offers a basic building block for a myriad of studies that include vulnerability assessment, prediction of extinction risk, analysis of future conservation priorities, and species range shifts.

The species distribution modeling algorithm MaxEnt (Phillips et al. 2006, Phillips and Dudik 2008) was used in conjunction with spatial climate data from SNAP to model current and future bioclimate of conservation elements in the SNK region. Maxent is a correlative niche model that uses the principle of maximum entropy to estimate a set of functions that relate environmental variables and species known occurrences in order to approximate species' niche and potential geographic distribution (Figure B-8). Maxent was chosen because of its established performance with presence-only data relative to alternative niche modeling techniques, and its built-in capacity to deal with multi-colinearity in the environmental variables (Elith et al. 2006, Elith and Leathwick 2009). Maxent is a machine learning algorithm related to Bayesian theory that considers redundant information without penalizing models by over-fitting, eliminating the need to apply any type of variable reduction technique before running the models. Maxent calculates a surface of probability across geographic space, where each cell has a value of the probability that a species niche will occur there at a given time. Maxent focuses on how the environment where the species is known to occur relates to the environment across the rest of the study area (the "background"). The model does not identify either the species occupied niche or fundamental niche; rather the model identifies only that part of the niche defined by the observed records (Phillips et al. 2006, Elith et al. 2011).

Niche models were generated using the CRU 2km resolution (1901-1981) monthly data to define the current niche of a species, which was then used to estimate future range shifts using the SNAP climate projections of downscaled spatial climate surfaces from five different GCMs (see section A-4.1 for further details on SNAP spatial climate data). The five GCMs used for this study were selected for downscaling by SNAP after a comparative analysis among all IPCC 4th assessment climate models, choosing those that performed best in Alaska and the Arctic. Using an ensemble, or multiple GCMs, allows exploration of a range of possible climatic futures. In this way, the assessment team attempted to represent a sample of possible futures, providing an indication of the degree of agreement across a range of global climate models, which offers one metric for assessing uncertainty. Two time slices were explored: 2020s (2020-2029) and 2050s (2050-2059). This will complete a time series from 20th century baseline to mid 21st century based on monthly average temperature and monthly total precipitation.

The species distribution modeling algorithm MaxEnt (Phillips et al. 2006, Phillips and Dudik 2008) was used in conjunction with the historical CRU dataset and the SNAP Climate Projections (both at 2km resolution) to model current and future bioclimate of conservation elements in the SNK region. Each time slice (2020s and 2050s) was run independently with each of five different GCMs.

**Figure B-8. The process used in this study defines certain aspects of a species' niche in environmental space by relating observed species occurrence to environmental variables. The process does not identify a species' realized or fundamental niche, but rather only the part of the niche defined by the occurrence data provided. In this case, the process defines a potential suitable bioclimate, which can then be projected into the future under various climate change scenarios. (Adapted from Martinez-Meyer, 2005.)**




### *B-1.2.1.1 Threshold Selection*

In order to translate the raw Maxent probability distribution into binary estimates of species presence or absence, a specific threshold needs to be selected, a necessary post-processing step when using an ensemble approach. The threshold used in this analysis is the "equal training sensitivity plus specificity" threshold. This threshold maximizes the agreement between observed and predicted distributions, a choice that has proven to produce the most accurate predictions under a range of conditions (Jimenes-Valverde and Lobo 2007; Lobo et al. 2007; Liu et al. 2005). This is done by finding a balance between **sensitivity** and **specificity** on a receiver operating characteristic (ROC). **Sensitivity** measures *the proportion of actual presences which are correctly identified* as such (true positive) and **specificity** measures *the proportion of absences which are correctly identified* (true negative). The receiver operating characteristic (ROC) is a plot of the true positive rate vs. the false positive (sensitivity vs. specificity). The threshold chosen for this analysis is one at which the sensitivity and specificity are equal.

### *B-1.2.1.2 Model Evaluation*

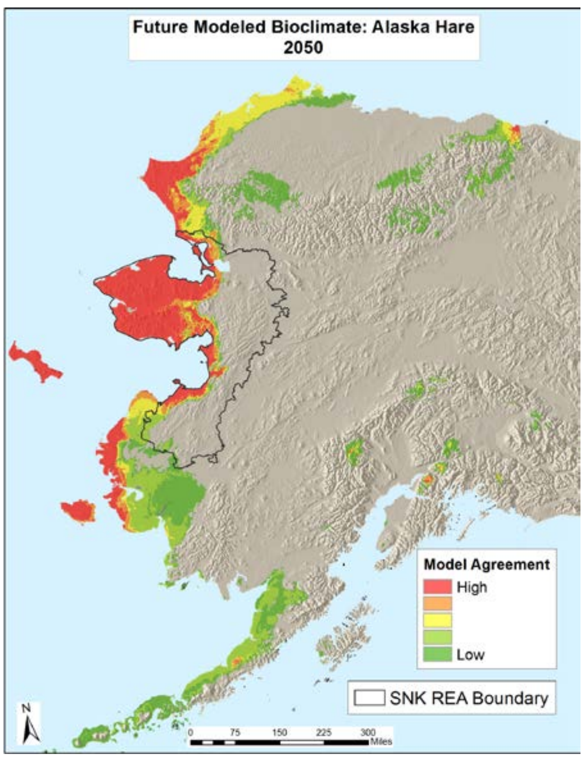
Model evaluation was performed using the area under the curve (AUC) of the receiver operating characteristic (ROC) plot analysis (Fielding and Bell, 1997). Twenty percent of occurrence points for a given conservation element were withheld from the model to be used as independent test data in calculating the AUC. The AUC is a widely accepted, threshold-independent metric of species distribution model performance (Marmion et al., 2009; Warren et al., 2010) that provides an overall picture of how well the data fits the model and has previously been used in comprehensive SDM evaluations (Elith et al., 2006).

#### B-1.2.1.3 Ensemble Approach

The ensemble approach focuses on the degree of agreement among multiple GCMs. Various GCMs predict different outcomes for future climatic conditions, even when provided the same input data, because each model accounts for the interactions of various elements of the oceanic-atmospheric system differently. Therefore, an ensemble approach, wherein multiple GCMs are run using the same input data and emissions scenarios and their results are compared, averaged, or otherwise aggregated, is increasingly accepted as the preferred method for applying climate projections for a variety of purposes (Tebaldi et al. 2011).

Each time slice (2020s and 2050s) was run independently with each of five different GCMs. The probability outputs were then converted to presence-absence and then combined using an additive function. Adding all model outputs creates a single layer of suitable bioclimate with values indicating the number of models in agreement. Therefore, each time slice for a given species has five values, with 5 being the highest level of agreement (all five GCMs agree on a species predicted suitable bioclimate in a given pixel) and 1 being the lowest (only one GCM predicts suitable bioclimate in a given pixel). This approach supports an assessment of multi-model agreement in projections of bioclimatic shifts. The results of each independent model run were part of the deliverables to the BLM, as well as change summary layers.

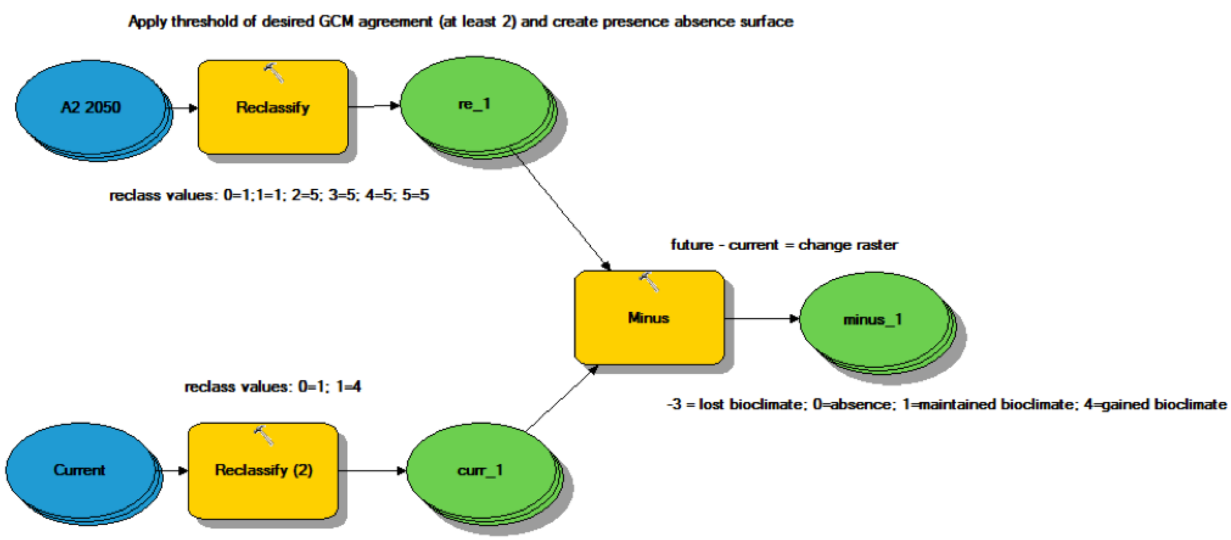
**Figure B-9. An example of an ensemble model output for Alaskan hare. Areas in red are pixels where 5 out of 5 models agree there will be suitable bioclimate in 2050.**




#### B-1.2.1.4 Evaluating Model Results: Creating a Change Summary Layer

In order to summarize change in the spatial extent of the bioclimate envelope for a species, a change layer was created by calculating the difference between the modeled current climate envelope and the midcentury (2050s) modeled future envelope. As shown in Figure B-10, the first step in this calculation was to reclassify the A2 2050 outputs to a presence/absence layer (absence = 1, presence = 5). For any given pixel, agreement of at least 2 GCMs was required to qualify for the change summary. Current layers, which were already classified as presence/absence, were reclassified for the change summary to coded values (0 = 1 and 1= 4). The last step was subtracting the current from the future which created a surface with the coded values: -3 = contraction, 0 = absence, 1 = overlap, 4 = expansion. Pixels with "contraction" are areas where suitable bioclimate was currently present, but in 2050, either none or only one climate models predict this climate envelope will no longer be present in that pixel. "Overlap" identifies areas where two or more GCMs project that the future climate envelope overlaps with the current envelope, indicating that these areas are projected to be *climatically* suitable under both current and future climate regimes. "Expansion" identifies pixels that are not *currently* climatically suitable, but may be suitable in the midcentury future. Expansion is essentially showing a potential geographic shift in future suitable *climate* conditions for a species.

**Figure B-10. Change summary layer model. This model shows how A2 2050 and current projected outputs were reclassified in order to calculate the difference and code values to identify overlap, contraction, and expansion.**




## B-1.3 Methods for Modeling Ecological Status Indicators

### B-1.3.1 Terrestrial CEs

Based on the conceptual models for CEs, major stressors in the SNK ecoregion, and data availability, several indicators of ecological integrity were proposed and considered. Ultimately, only one indicator had sufficient data to be applied at the level of individual terrestrial CEs in this assessment: the index of landscape condition. This indicator provides information on the effect of development change agents (e.g., roads) on the Landscape Context of the CEs.

Fire is an important ecological process influencing the composition, structure, and successional dynamics of many of the terrestrial CEs in the SNK ecoregion. AKNHP staff evaluated whether fire could inform the ecological status assessment for *individual* coarse-filter CEs. Because fire is a natural process, it is not considered to have a positive or negative impact on CEs, but is simply one of the key ecological processes shaping the composition and structure of vegetative communities. In the SNK ecoregion, it is unclear whether fire regimes in various ecosystems may be functioning significantly outside of their natural range of variation. This consideration, in combination with data availability, were the determining factors for not assessing a fire-related indicator for *individual* CEs. (Broad trends in projected fire frequency and its effects on four coarse vegetation types across the SNK were evaluated separately; see the section on fire modeling using ALFRESCO in Appendix A.)

Insect and disease outbreaks are also driving ecological processes. As with fire, there is not a clear indication that these processes are operating outside their natural range of variability; assuming they are functioning within their natural range, the effects of these processes on CEs is neutral. In addition, data available for insect and disease outbreaks in this ecoregion and modeling approaches were not sufficient to conduct a detailed assessment of insects and disease in relation to the ecological status of individual CEs. Therefore, this factor was not addressed in the CE status assessments, either.

As an indicator of ecosystem condition, an invasive plants index was originally considered to be a tractable measure of ecological status. However, a detailed review of the data and attempts to apply the methods for calculating the index led to the conclusion that while the data are of good quality, they are insufficient to draw conclusions about the condition of the entirety of each of the CEs. Therefore, with AMT review and agreement, this indicator was dropped. However, the invasive plant observation data are summarized and discussed in the Current Conditions chapter.

#### *B-1.3.1.1 Rank Factor: Landscape Context*

##### B-1.3.1.1.1 KEA: Landscape Condition

***Landscape Condition Index***

Ecological condition refers to the state of the physical, chemical, and biological characteristics of natural ecosystems, and their interacting processes. Many human land uses affect ecological condition, (e.g., through vegetation removal or alteration, stream diversion or altered natural hydrology, introduction of non-native and invasive species, etc.). Landscape condition assessments apply principles of landscape ecology with mapped information to characterize ecological condition for a given area (e.g., USEPA 2001, Sanderson et al. 2002). Since human land uses – such as built infrastructure for transportation or urban/developed areas, and land cover such as for agriculture or other vegetation alteration – are increasingly available in mapped form, they can be used to spatially model inferences about ecological condition.

Maps of this nature can be particularly helpful for identifying relatively unaltered landscape blocks or for making inferences about the relative ecological integrity of natural habitats on the ground. They can also be used for screening ecological reference sites (i.e., a set of sites where anthropogenic stressors range from low to high). Ecological condition within reference sites is often further characterized in the field to determine how ecological processes respond to specific stressors, but spatial models can provide a very powerful starting point on which to build (Faber-Langendoen et al. 2006, 2012). Knowledge from reference sites may then apply to surroundings for many types of environmental decisions.

Nearly all studies documenting ecological effects of land use features on ecosystems are quite context-specific (e.g., Knight, et al. 1993, Gelbard and Belnap 2003), thereby limiting their applicability to more generalized modeling. However, some researchers have developed more generalized models with less context-specific inputs and applications in mind. That is, they use generalizations about the relative ecological effects of human land uses to transparently construct the spatial model, and then use field-based observations to calibrate and validate the model relative to their intended use. For example, Brown and Vivas (2005) scored 25 common land use classes along a continuum of estimated "energy intensity values" (i.e., energy input for their development and maintenance); from a lowest-intensity land use of "pine plantations" to a highest-intensity use of "central business district (average 4 stories)." This initial scoring enabled development of a "Landscape Development Index" varying from 1.00 to 10.00. These indices were applied to land use map classes to generate an inference of land use intensity in Florida. The result was validated using selected field-based observations.

The **Landscape Condition Model** builds on this and the growing body of published methods and software tools for ecological effects assessment and spatial modeling, all aiming to characterize relative ecological condition of landscapes (e.g., Knick and Rotenberry 1995, Forman and Alexander 1998, Trombulak and Frissel 1999, Theobald 2001, Seiler 2001, Sanderson et al. 2002, Riitters and Wickham 2003, Brown and Vivas 2005, Hansen et al. 2005, Leu et al. 2008, Comer and Hak 2009, Theobald 2010, Rocchio and Crawford 2011). The intent of this model is to use regionally available spatial data to transparently express user knowledge regarding the relative effects of land uses on natural ecosystems and habitats. Team members' knowledge of the SNK ecoregion forms the basis of stressor selection and relative weightings. Outside of the SNK ecoregion, independent data sets from the western United States have been used to evaluate and validate the model as a whole.

**Technical Description for the Landscape Condition Model:** Table B-11 lists the data sets and parameters for this model. Mapped information for development-related change agents available for the SNK ecoregion was compiled and converted to raster format at 30 meter resolution for use in this model. These data sets are discussed in detail in the Development section of Appendix A, as well as summarized in the Development sections in the Current and Future Conditions chapters. Within the condition model, no attempt was made to depict ecological stressors that act at spatially broad scales, such as air pollutants or climate change.

**Table B-11. Site impact and distance decay scores used in the SNK Landscape Condition Model, 2010.**

| Development Change Agent | Site Impact Score | Relative Site Impact | Distance Decay Score | Relative Distance Decay |
|---|---|---|---|---|
| community | 0.2 | High Impact | 0.5 | Moderate |
| road | 0.5 | Moderate Impact | 0.5 | Moderate |
| railroad (abandoned) | 0.9 | Low Impact | 0.7 | Moderate |
| trail | 0.9 | Low Impact | 0.7 | Moderate |
| landing strip/airport | 0.7 | Low Impact | 0.6 | Moderate |
| military | 0.8 | Low Impact | 0.5 | Moderate |
| mine | 0.2 | High Impact | 0.5 | Moderate |
| contaminated site | 0.2 | High Impact | 0.1 | Very Gradual |

**Landscape Condition Model Parameters and Process Steps:** Each input data layer is summarized to a 30m grid and, *where the land use occurs*, assigned a **site impact score** between 0.05 and 0.9 (Table B-11) reflecting presumed ecological stress or impact. Values close to 1.0 imply relatively little ecological impact from the land use. For example, trails are assumed to have a relatively low site impact compared with the development associated with Nome, Kotzebue, and other communities; trails are therefore assigned an impact score of 0.7, reflecting their lesser impact, while communities are assigned an intensity score of 0.2, reflecting their greater impact.

In the first modeling step, distinct data layers are produced for each of the individual development inputs, reflecting the *site impact* scores applied to pixels where the given land use occurs, and a value of 1 for all other pixels. Euclidian distance for each input layer is then populated for each 30 meter cell with a distance (in 30 meter increments) extending away from each pixel with an impact score <1 (Table B-11).

A second model parameter represents a **distance decay** function, expressing a decreasing ecological impact with increasing distance away from the mapped location of each feature. Similar to site impact, **distance decay scores** are assigned to each of the development classes. The ecological impacts of a high-volume interstate highway would be expected to be present a much greater distance away from the highway than the impacts of an unpaved, local road. Again, values closer to 0 represent a gradual decay extending over a greater distance, and values closer to 1 representing a more abrupt decay extending over a shorter distance. In the SNK, most features were assumed to have a relatively moderate decay.

In the second step, distinct data layers are produced for each of the individual development inputs, reflecting a distance decay function applied to pixels extending out from the pixel where the given land use occurs. Mathematically, this step applies the following formula that characteristically describes a “bell curve” shape that falls towards plus/minus infinity:

$$f(d) = \left(1 - \frac{d^2}{h^2}\right)^2, d < r$$

where *d* = Euclidian distance (in meters, as measured in 30m increments), and *h* equals the distance decay score (from 0.05 – 1.0). In this formula, *r* = the maximum distance across the model analysis area, so the value for *d* must be less than *r*. Applying this formula, grid cells will have scores approaching r – 1.

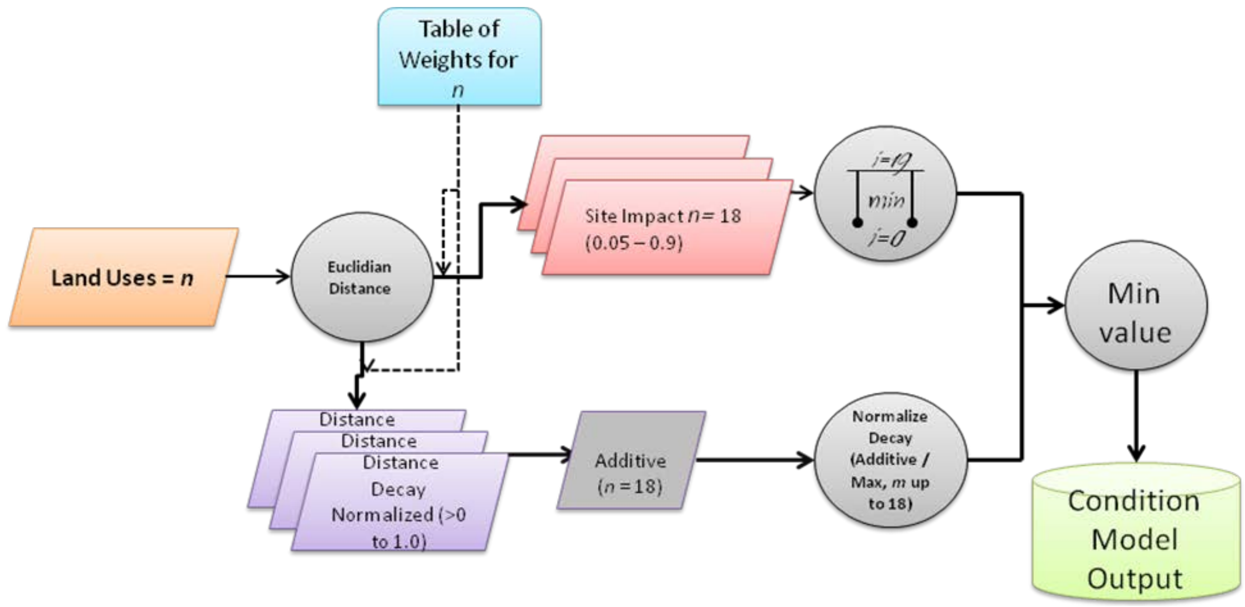
Those features given a high decay score (*h* values approaching 1.0) result in a surface where the impact value dissipates within a relatively short distance. Those features given a low decay score (*h* values approaching 0.0) create a surface where the per-pixel impact value dissipates more gradually with distance away from the impacting feature. Note that given this formula, per-pixel values will actually never reach *r*, but will only approach *r*. Each layer is then normalized by dividing 1 by the per pixel value; this results in a grid with values >0 to 1.0.

**Combining Input Layers:** Figure B-11 summarizes all processing steps, beginning with the selection of individual input layers for land use features. Querying the table of weights (the site intensity and distance decay scores), per-pixel values for **site impact** apply to all pixels overlapping the land use layer. Where more than one land-use feature occurs in a given 30m grid cell, the **minimum site impact score** of all applicable features is applied to each grid cell (**site impact minimum** between 0.05 and 0.9).

Then, the distance decay formula utilizes per pixel Euclidian distance and the distance decay formula to create a per-pixel value for each land use feature layer. As noted above, the result is a grid of >0 to 1.0 values. All 30m grids are then combined additively resulting in a grid of values between >0 to *n* (*n* up to 18 for this model). Because the resulting grid has the potential to include grid cell values greater than 1.0 the overall model is normalized against the maximum value *n.* The final grid represents a layer of > 0 to 1.0.

Finally, the site impact and distance decay minimum values for each 30m grid cells are compared and the lowest number is carried forward to the final landscape condition surface. The combined result is a continuous raster surface of Landscape Condition values falling between >0 and 1.0.

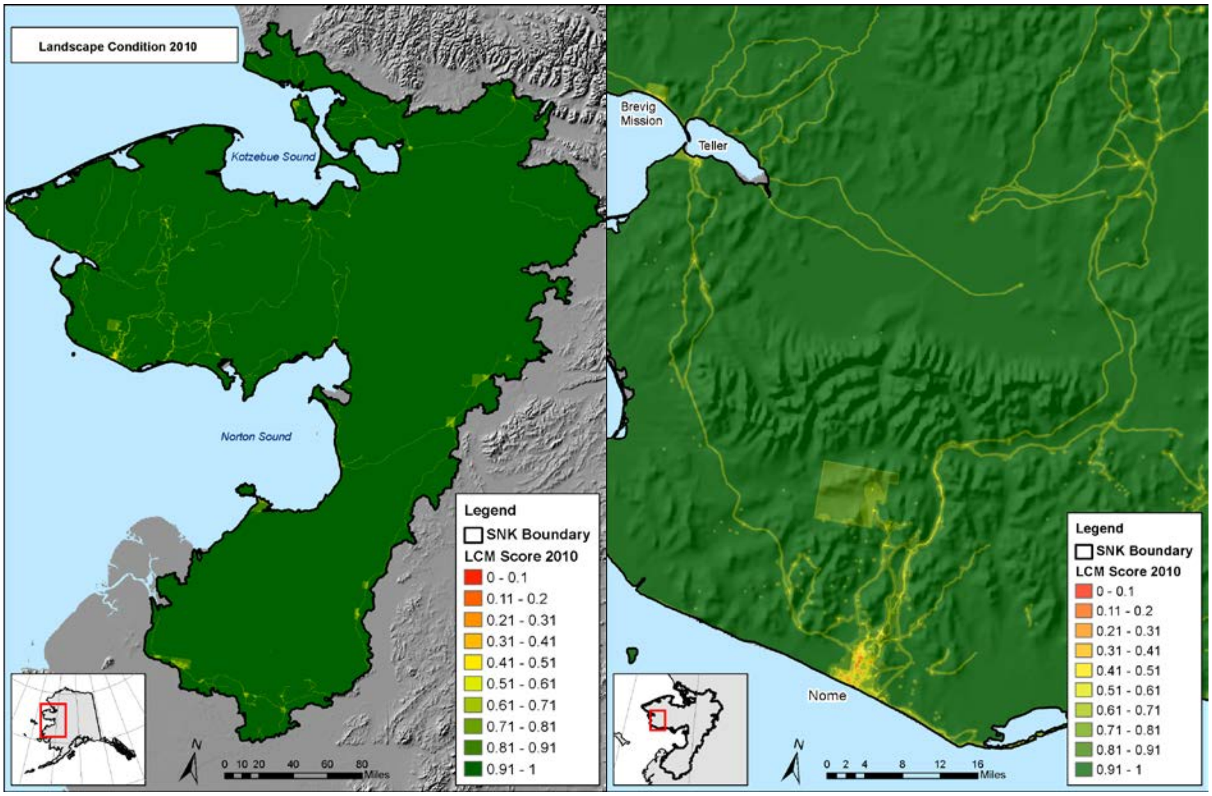
**Figure B-11. Landscape condition model: inputs and processing steps.**




There are some inter-related limitations to this modeling approach. The lack of comprehensive literature quantifying the on-site and distance effects of various anthropogenic land uses or infrastructure on individual CEs (or logical groupings of CEs) found in this ecoregion necessitated the use of expert opinion to assign impact and decay scores. The scores applied in this model are based upon the criteria used in Natural Heritage Methodology to rank an element occurrence in the context of the surrounding landscape. For instance, a dirt road is given a site intensity of 0.7 and distance decay 0.5 (200m), while an interstate highway, if it were present in this ecoregion, would be given a site intensity of 0.05 and a distance decay of 0.05 (2000m) (Table B-11). In addition, different CEs may experience relatively different impacts from a given land use, but again, literature is generally not available to quantify those differences and translate them into CE-specific intensity or decay scores. However, within the scope of a rapid assessment, it was not possible to develop individual condition models for each CE. Therefore, the assigned impact and decay scores are general and were applied to all CEs. Finally, there are minor data limitations for the SNK; footprints for some land uses were modeled or derived and may not accurately reflect the extent of the land use. The discussion of development change agents in Appendix A summarizes these footprint accuracy issues. While there may be local inaccuracies, development is sufficiently limited in the SNK ecoregion that it is unlikely to substantially affect a CE's overall landscape condition.

**Applying the Landscape Condition Model in CE Status Assessments:** The resulting model of current landscape condition is shown in Figure B-12. This was the primary indicator used to assess current ecological status for terrestrial CEs. It was also used as one of the indicators of current ecological status for aquatic CEs. An average of landscape condition was calculated for terrestrial CEs within the 2 x 2 km grid cell reporting units, based on the set of condition values for each of the CE's 30 meter pixels present within a given 2 x 2 km grid cell. The average is calculated based on the actual distribution of the terrestrial CE within the 2 x 2 km reporting unit, and is applied to the entire 2 x 2 unit for that CE. For aquatic CEs, the surrounding landscape condition is assumed to have downstream effects on the CEs that are present within the HUC. Therefore, the average condition value was calculated for each HUC and applied to each of the aquatic CEs present within the HUC. An aquatic CE may have a very limited spatial extent within a HUC, but the average condition of the HUC is assumed to have downstream impacts on it, regardless of its size within the HUC.

**Figure B-12. SNK Landscape Condition Model (LCM), 2010 (left) and zoom map of Nome area (right). Note: In all maps of ecological status, the dark green end of the color ramp represents the best condition or ecological status for this indicator (least impacted), while the red end of the color ramp represents the lowest condition (most impacted).**




Landscape condition, using the landscape condition model, was not proposed to be modeled for future time periods for this REA due to a lack of readily available data or models of projected footprints. The lack of readily available data is presumably partly a result of the fact that future development in this ecoregion is expected to be very limited in geographic extent, and the fact that the known potential developments (a new port, roads to support the Ambler mining district) are political and economic decisions, and spatial data regarding their proposed footprints hasn't been made available. Unlike scientific uncertainty associated with various other models in this REA, the high levels of uncertainty regarding the choice of multiple alternatives for proposed roads, ports, and other development in the SNK ecoregion stem entirely from the politics and economics surrounding these decisions. Projected expansion of development has been modeled for the coterminous United States only (Bierwagen et al. 2009, Spatially Explicit Regional Growth Model, SERGoM); comparable data are not available for Alaska. (Population in the SNK as a whole is projected to increase from ~18,000 to ~28,000 by 2060, primarily in larger communities; while this is a proportionally large increase, the additional development footprint will be small relative to the ecoregion extent.) Some native communities are expected to relocate as climate change impacts cause substantial shoreline erosion in their current locations; however, the proposed locations are still uncertain, with the exception of Shishmaref. Potential footprints for renewable energy were modeled as any area with adequate renewable potential within 25 miles of a community. However, the scale of these projects is highly localized; the actual footprints, if developed, will be orders of magnitude smaller than the potential area where they might be built. The uncertainty surrounding various proposed roads, ports, and other infrastructure is detailed in Appendix A, in the discussion of change agents. With these data gaps and high levels of uncertainty regarding the locations of proposed developments, a meaningful projection of future landscape condition could not be developed.

### B-1.3.2 Aquatic CEs

Five of the original nine proposed indicators of aquatic ecological status had data that could be used for ecological status assessments of aquatic CEs. The landscape condition model or index, described above, was used as an indication of the landscape context for all aquatic CEs, as well as the terrestrial CEs.

| **Rank Factor: Landscape Context** |
|---|
| **Key Ecological Attribute: Landscape Context/Surrounding Land Use Context** |
| **Indicator: Landscape Condition Index** |
| **Indicator: Placer Mine Ditches** |
| **Key Ecological Attribute: Connectivity** |
| **Indicator: Index of Fish Passage (Culverts)** |
| **Rank Factor: Condition** |
| **Key Ecological Attribute: Water Quality** |
| **Indicator: Alaska Pollution Discharge Elimination Permits** |
| **Indicator: Placer Mines** |

#### *B-1.3.2.1 KEA: Landscape Condition*

##### B-1.3.2.1.1 Index of Placer Mine Ditches

**Definition:** On the Seward Peninsula, a significant number of ditches were excavated to support placer mining. Limited rainfall, ranging from 15 to 30 inches annually in various parts of the Seward Peninsula, necessitated ditches to obtain water for sluicing and other mining operations. Various companies constructed approximately 700 miles of ditch on the Seward Peninsula between 1901 and 1914 (Strang & White, 2004). In addition to quantity of water diverted, the point at which water is diverted from the river may create a blockage which restricts connectivity in the stream network. Data on the current status of the ditches was not available, so the total length of ditches per watershed is a surrogate for the past mining impact in the ecoregion.

**Rationale:** According to Placer Mining Methods and Costs in Alaska (Thomas et al. 1959), miners on the Seward Peninsula led Alaska in the construction of large, long ditches. Earlier accounts reveal that over 400 miles of ditches were constructed with a capacity of 20 cubic feet per second (Henshaw and Parker 1913). The purpose of these ditches was to provide high pressure wash water for hydraulic and dredge mining operations. One of the largest ditches in Alaska, the 50-mile Miocene Ditch, was constructed north of Nome to support hydraulic mining.

Ditches run roughly parallel to the source stream, hugging the slope contour in order to maintain elevation and deliver it to a mine well above the source stream. Ditches required a significant investment to construct and required yearly maintenance in order to function. While some ditches were abandoned once operations ceased, some continue to function. While many ditches were mapped by the USGS and appear in the NHD, there is no record indicating which ditches may still be actively maintained in the ecoregion. Although some ditches may still be used by seasonal placer mines, most ditches appear to be abandoned (Strang & White 2004).

**Methods:** Similar to the Index of Fish Passage (culverts), the total length of ditches was tallied per HUC and applied to all CEs. From the National Hydrography Dataset (1:100,000; data current as of 2005), flowlines labeled "CanalDitch" were subset. The total length of all ditches by HUC was calculated.

The number of ditch kilometers per watershed was converted to a normalized score (between 0 and 1) by the following formula: 1-(indicator value/maximum value) where 0 = worst or highest degree of impact and 1 = best or least impacted score.

#### *B-1.3.2.2 KEA: Connectivity*

##### B-1.3.2.2.1 Index of Fish Passage (culverts)

**Definition:** Changes in perennial stream flow affect the flow of animals and nutrients with longer corridors of unmodified flow providing greater extent of habitat for wildlife and increased buffering capacity to the aquatic resource.

**Rationale:** Culverts, bridges and other man-made blockages in the contributing watershed can have a substantial impact on the hydrologic regime. Specifically culverts limit the movement of water, sediments, nutrients and animals within the aquatic corridor. The culverts dataset represent a recent (2011) assessment of the ability of fish to pass underneath the road network and were ranked by their ability to facilitate fish passage. Poorly designed or inadequately maintained culverts will block or impede fish access to upstream spawning habitat. Improving passage for fishes (especially anadromous) is a goal of the state and federal wildlife agencies. Culverts that severely restrict water flow can provoke erosion in a stream and limit movement of macroinvertebrates.

**Methods:** The culvert dataset obtained from AKDFG was subset to for culverts that had been found to block fish passage or that the status of fish passage was unknown. Some culverts had been constructed or modified to allow fish passage (RGGRating = Green (1)) and were not included in this indicator. The total count of restrictive culverts was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. This metric was not applied to SNK lakes, hot springs or estuary CEs. The number of culverts per watershed was converted to a normalized score (between 0 and 1) by the following formula: 1-(indicator value/maximum value) where 0 = worst or highest degree of impact and 1 = best or least impacted score. Similar to the pollution permits below, this metric was applied to all CEs (except hot springs) regardless of culverts position in the watershed. Like other metrics (with the exception of mines), culverts were not intersected directly with the CE but rather the metric was only applied to the entire watersheds where the CE would be expected to be found. This more conservative approach was thought to be preferable given the high quality of the data.

### B-1.3.3 Rank Factor: Condition

#### *B-1.3.3.1 KEA: Water Quality*

##### B-1.3.3.1.1 Index of Placer Mines

**Definition:** Placer mines represent a significant source of sediment loading in streams in Alaska. Other potential water quality effects are increases in organic matter and potential for acid drainage into the stream network. Existing hard rock mines within the region are Rock Creek, which is currently inactive, and placer mines on the Seward Peninsula.

**Rationale**: Metals, typically gold are found in the deepest reaches of the alluvially deposited gravels. Mining operations can take a variety of forms but all use gravity and water to separate gold from sand

and gravel. Mining operations mechanically strip the overburden and place it aside while the gravels below are sluiced to separate out gold. Process water is passed into ponds where heavier material is settled out. Typically settling ponds are insufficient for removing all suspended solids in process water before it is returned, typically to the same stream from which it was taken. Individual practices and effectiveness of the treatment water vary widely from mine to mine.

The effects of placer mining effluent on downstream water quality and aquatic macroinvertebrate populations are well documented: decreased invertebrate densities (Wagener & Laperriere 1985), increased turbidity and suspended sediment (Bjerklie & LaPerriere 1985), fine sediment and sand deposited in the stream can settle out in the substrate and degrade fish spawning areas (Lloyd et al.1987) and decrease the survival of fish eggs and fish in early stages of development (Reynolds 1985), and otherwise degrade habitat for fish. Weber (1985) demonstrated in central Alaska that the effects of increased siltation from placer mining can persist well beyond the source of effluent, sometimes degrading stream conditions as much as 80-90 km downstream.

**Methods:** A polygon dataset of current active mine footprints in the SNK REA was derived from the USGS Alaska Resource Data File (ARDF). The ARDF is a subset of the National Mineral Resource Data System (MRDS) that has been specifically re-formatted and re-designed to better meet the needs of the local user community. The data are relatively recent and appear to have been updated as recently as 2005.

All placer mines in the ecoregion were assigned a default footprint of five acres. CEs in the ecoregion were transformed from 30m raster cells to vector polygon and buffered by 100m on each side. The CEs and mines were then intersected and each intersection received a value of 1 which was then summarized by HUC. Each intersection event received a value of 1 and the total number of mines was summarized by HUC. The number of diversions per watershed was converted to a normalized score (between 0 and 1) by the following formula: 1-(indicator value/maximum value) where 0 = worst or highest degree of impact and 1 = best or least impacted score.

#### B-1.3.3.1.2 Index of State Impaired Waters

A careful review of the Alaska-wide list of impaired waters for 2010 showed that currently there are no impaired waters documented in the SNK; the list is available at http://dec.alaska.gov/water/wqsar/Docs/2010impairedwaters.pdf. Listings are organized by impairment category, and by regions in Alaska. Only Interior (e.g., Fairbanks), South Central (e.g., Anchorage, Wasilla), and Southeast (e.g., Juneau) have listings of impaired waters.

#### B-1.3.3.1.3 Pollution Permits

**Definition:** While there are no State Listed Water Quality of Impaired Waters (303d) documented in the ecoregion, pollution discharge occurs and is permitted through the Alaska Pollutant Discharge Elimination System (APDES) and administered through the Alaska Department of Environmental Conservation. An APDES permit is required whenever there is a discharge of pollutants to surface water, including the ocean, lakes, rivers, and streams. According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites* (APDES 2012).

**Rationale:** Impaired water quality is a measure of aquatic stress on aquatic life integrity. Pollutants can cause harm or death and may accumulate in upper food chain (fish) tissues; increased sediment loading can reduce oxygen availability and reduce spawning habitat.

**Methods:** The list of APDES permits by community was summed by HUC. The number of permits per watershed was converted to a normalized score (between 0 and 1) by the following formula: 1-(indicator value/maximum value) where 0 = worst or highest degree of impact and 1 = best or least impacted score. Similar to the culverts, this metric was applied to all CEs (except hot springs) regardless of position in the watershed. The metric was only applied to the watersheds where the CE would be expected to be found.

# *B-2 Assessment Findings in Relation to Management Questions*

## B-2.1 Current Distribution and Ecological Status of CEs: Additional Maps

The results of mapping or modeling the current distribution of CEs and assessing ecological status, to address the MQs highlighted here, are largely covered in the Current Conditions chapter of the main report. However, with 65 CEs receiving distribution maps or models and status assessments, distribution and status maps could only be included for a small cross-section of CEs in the main report. This section of this appendix is provided simply to show additional mapped results for terrestrial CEs – distribution and ecological status (based on landscape condition) for each CE. (Terrestrial CEs outnumber aquatic CEs by more than two to one; all examples of aquatic CE distribution and status maps are provided in the Current Conditions chapter in the main report.) The reader is directed to the Current Conditions chapter for the overview and interpretation of these results.

As noted in the Current Conditions chapter, although the management question specifically addressing ecological status (MQ 114) was framed by the AMT around aquatic CEs, the intent of the REAs is to describe the status of all CEs. In the SNK REA, both terrestrial and aquatic CEs received ecological status assessments.

**60**: What is the current distribution of each CE?

**87:** What habitats support terrestrial species of concern (rare plants, rare animals, and subsistence species)?

**114**: What is the condition of these various aquatic systems [aquatic CEs]?

### B-2.1.1 Terrestrial Coarse Filter CEs: Additional Distribution and Ecological Status Maps

**A note on interpreting the maps for terrestrial coarse-filter CEs**: The distribution models are on the left and show the actual modeled distribution or predicted habitat for the CE. Terrestrial coarse-filter CEs are mapped as **30 meter** pixels. However, ecological status is reported using the **2 x 2 kilometer** grid cells for terrestrial CEs; the condition values for the 30 meter pixels of the CE that are present within the 2 x 2 cells are averaged to get a single value for each of the 2 x 2 cells. The status maps on the right reflect condition values summarized to the 2 x 2 km grid cells – but these cells do not reflect the detailed distribution of the CE.

#### *B-2.1.1.1 Lowland*

Current distribution and Landscape Condition Index scores of lowland terrestrial coarse-filter CEs are shown in Figure B-13 through Figure B-17.

**Figure B-13. Arctic Dwarf Shrub-Sphagnum Peatland current distribution and Landscape Condition Index scores.**

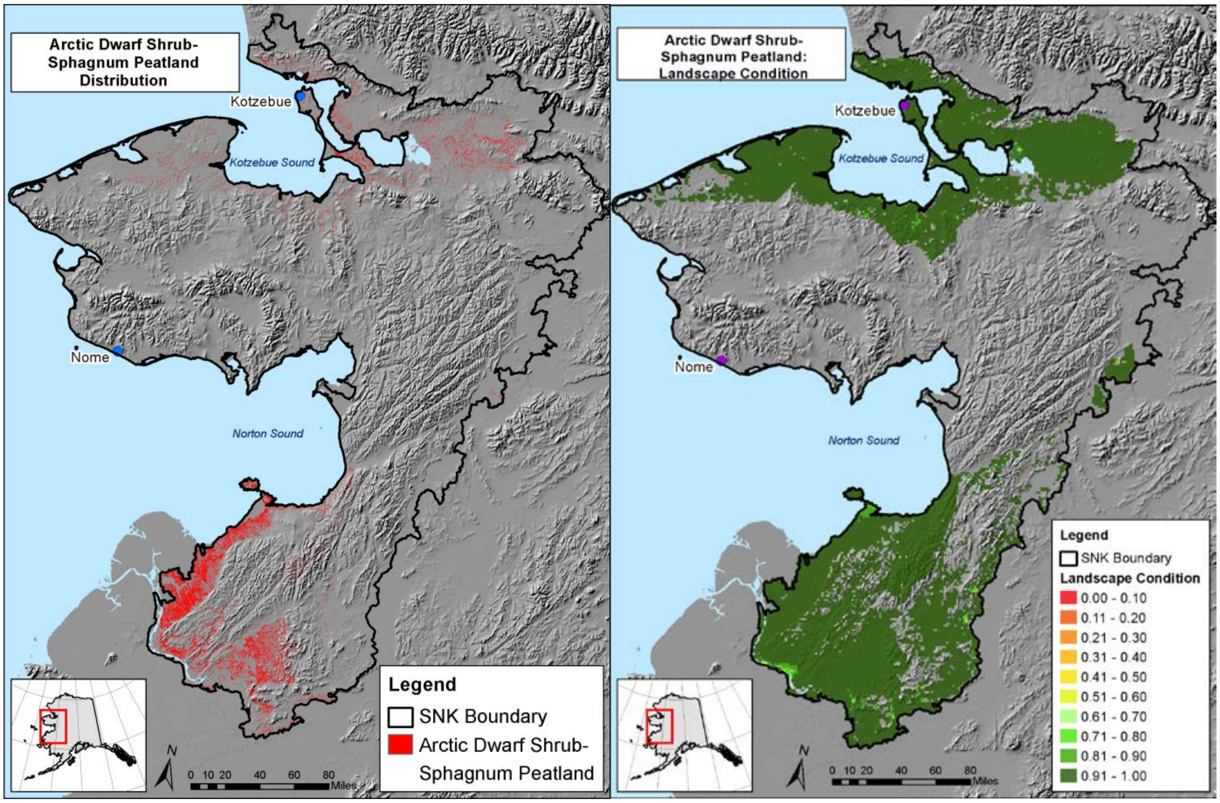



**Figure B-14. Arctic Mesic-Wet Willow Shrubland current distribution and Landscape Condition Index scores.**

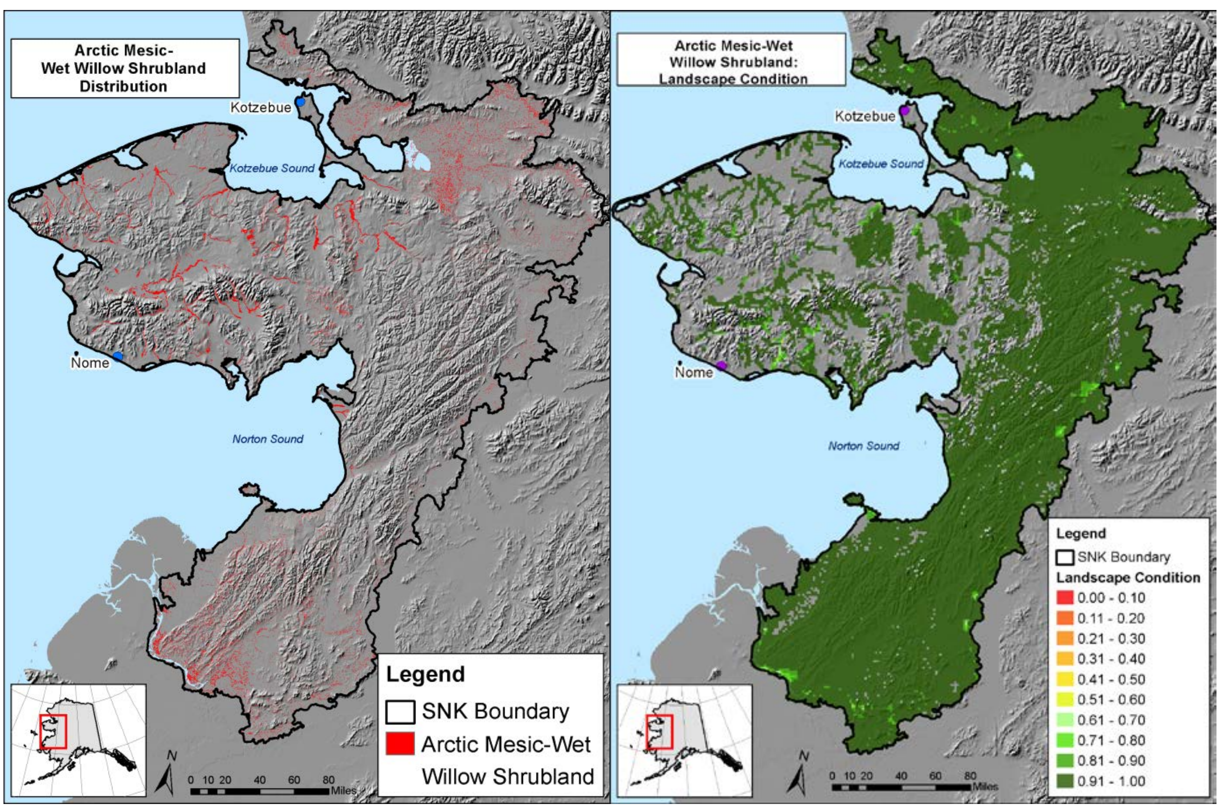


**Figure B-15. Arctic Shrub-Tussock Tundra current distribution and Landscape Condition Index scores.**

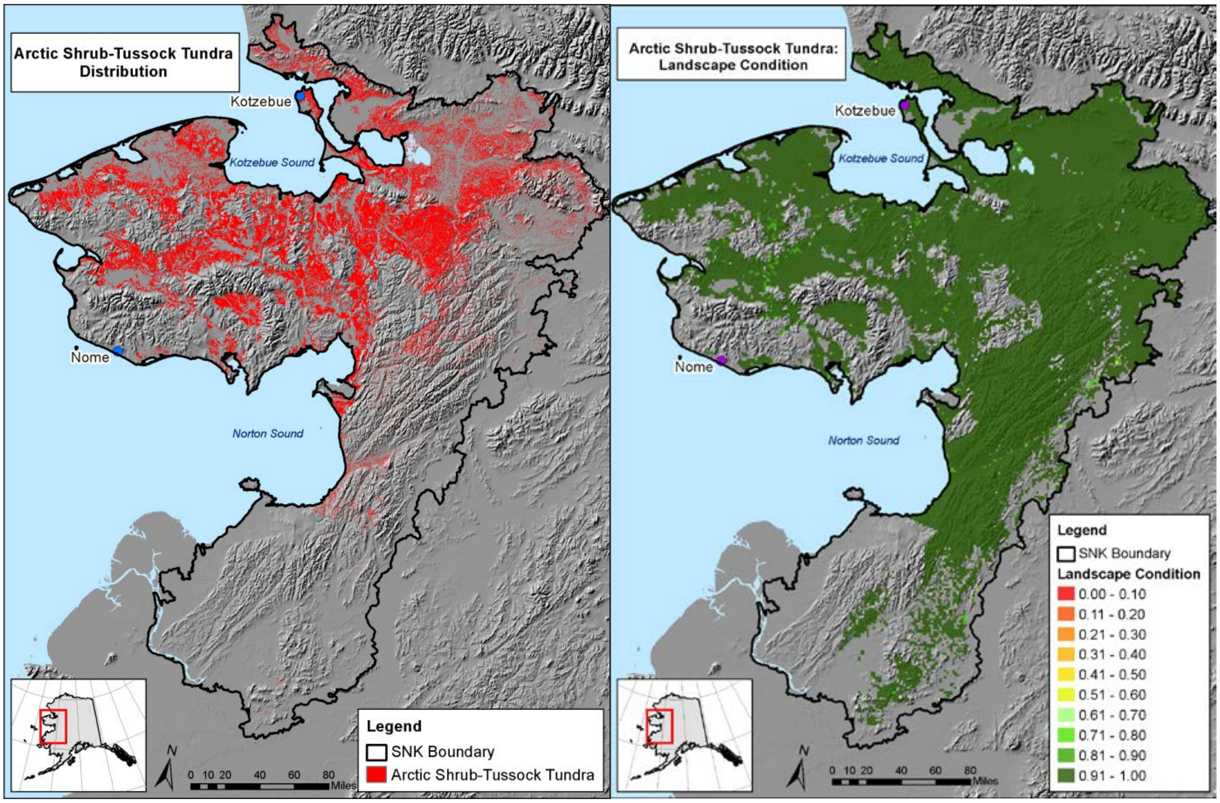



**Figure B-16. Arctic Wet Sedge Tundra current distribution and Landscape Condition Index scores.**

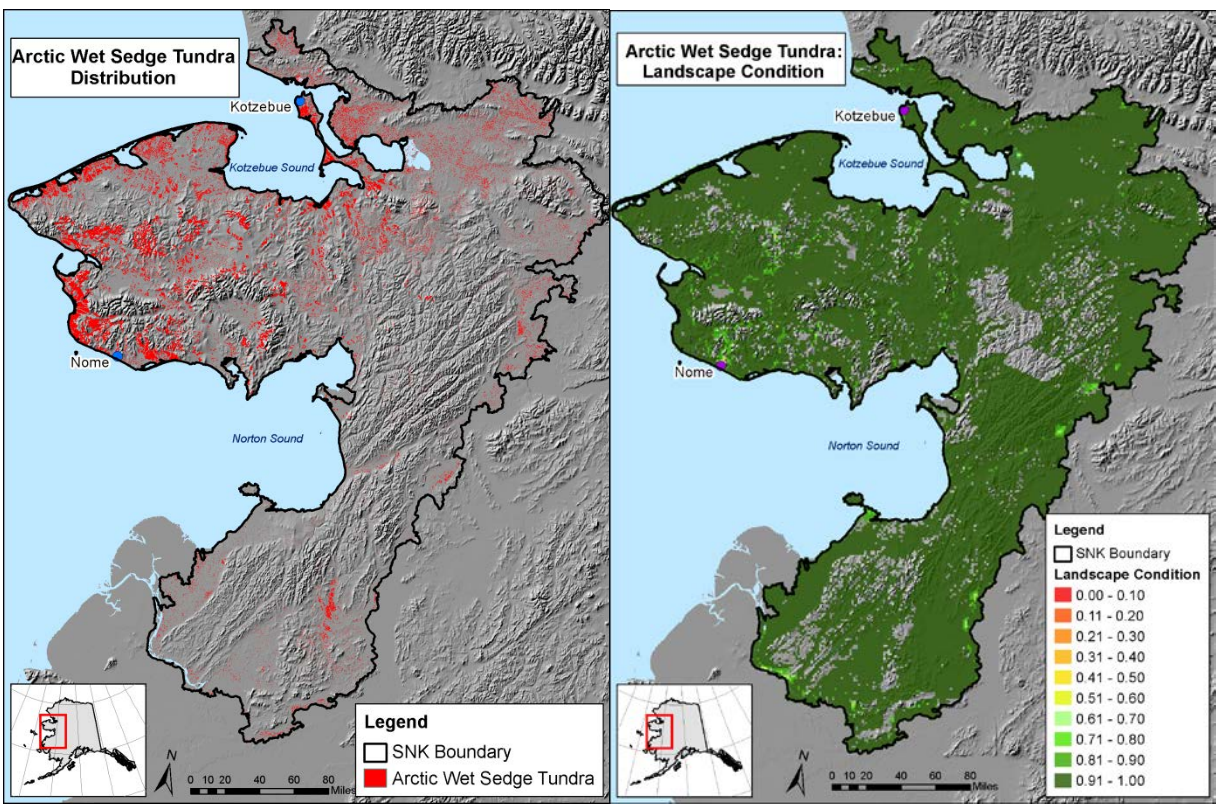
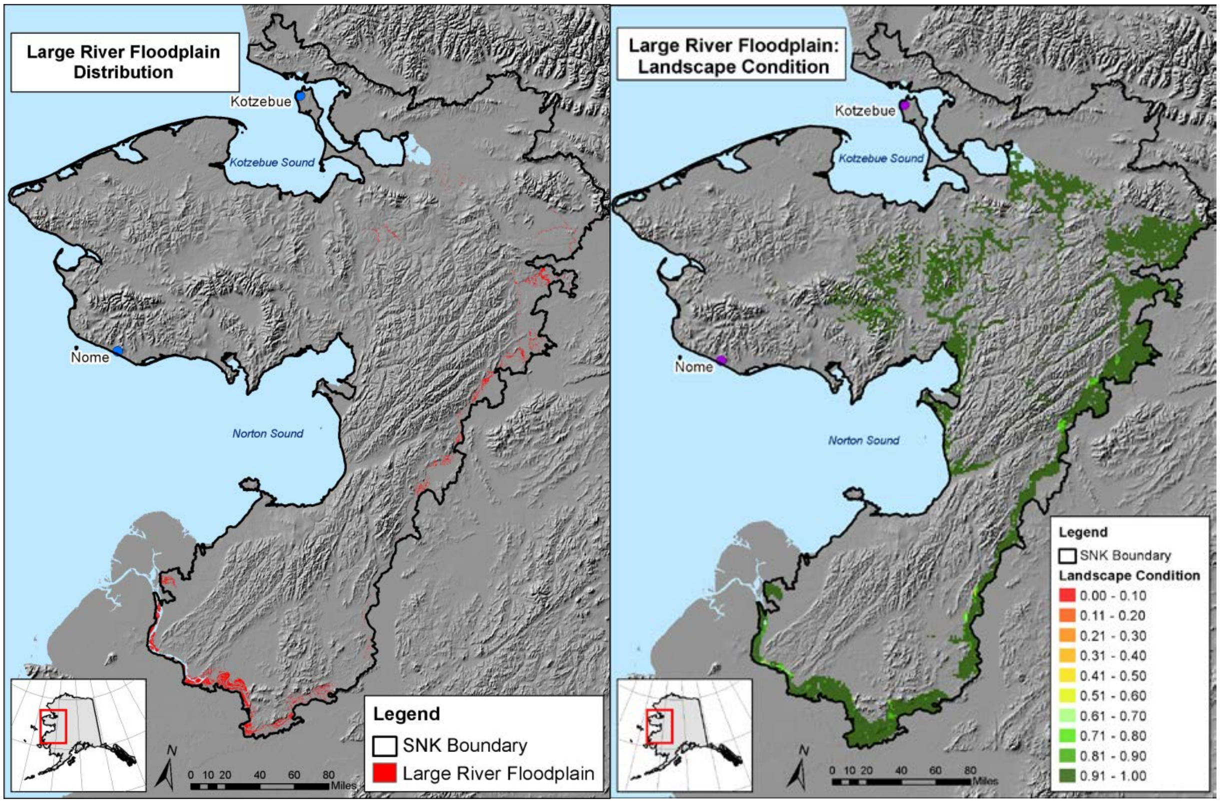


Figure B-17. Large River Floodplain current distribution and Landscape Condition Index scores.




### *B-2.1.1.2 Upland*

Current distribution and Landscape Condition Index scores of upland terrestrial coarse-filter CEs are shown in Figure B-18 through Figure B-26.

**Figure B-18. Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra current distribution and Landscape Condition Index scores.**

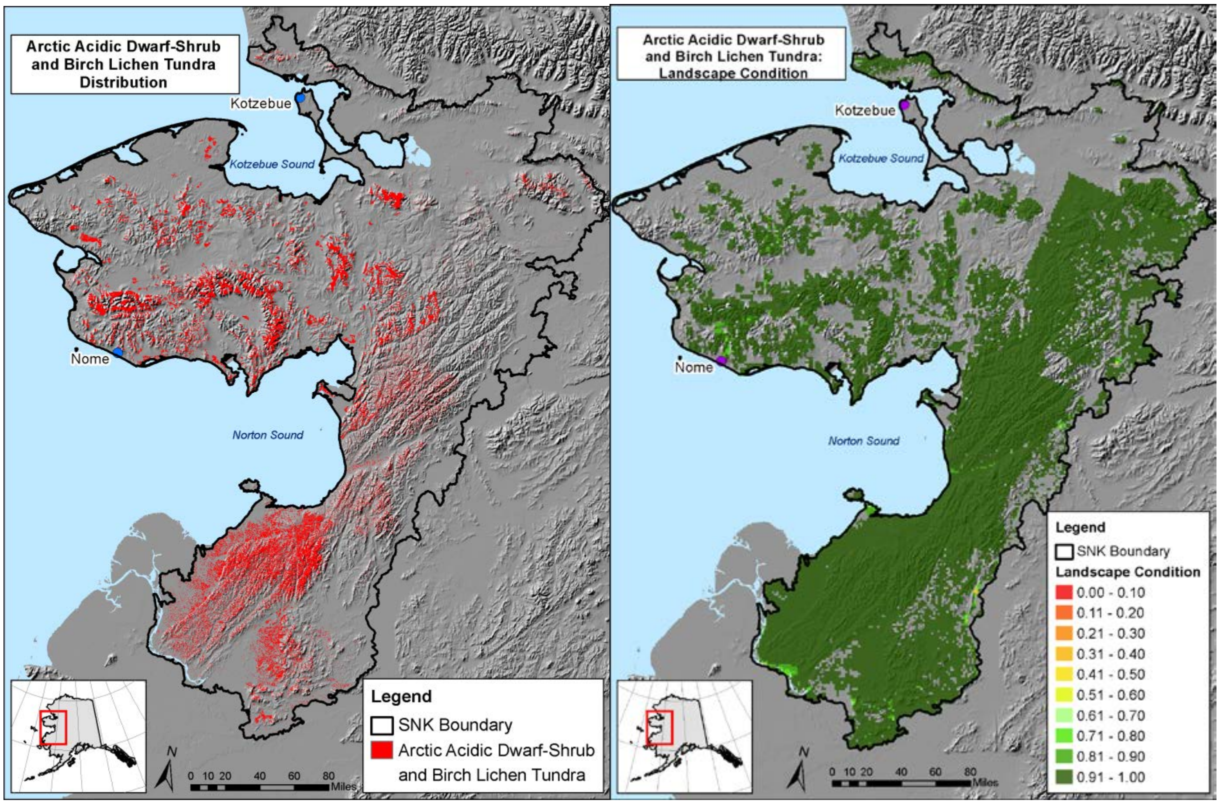



**Figure B-19. Arctic Acidic Sparse Tundra current distribution and Landscape Condition Index scores.**

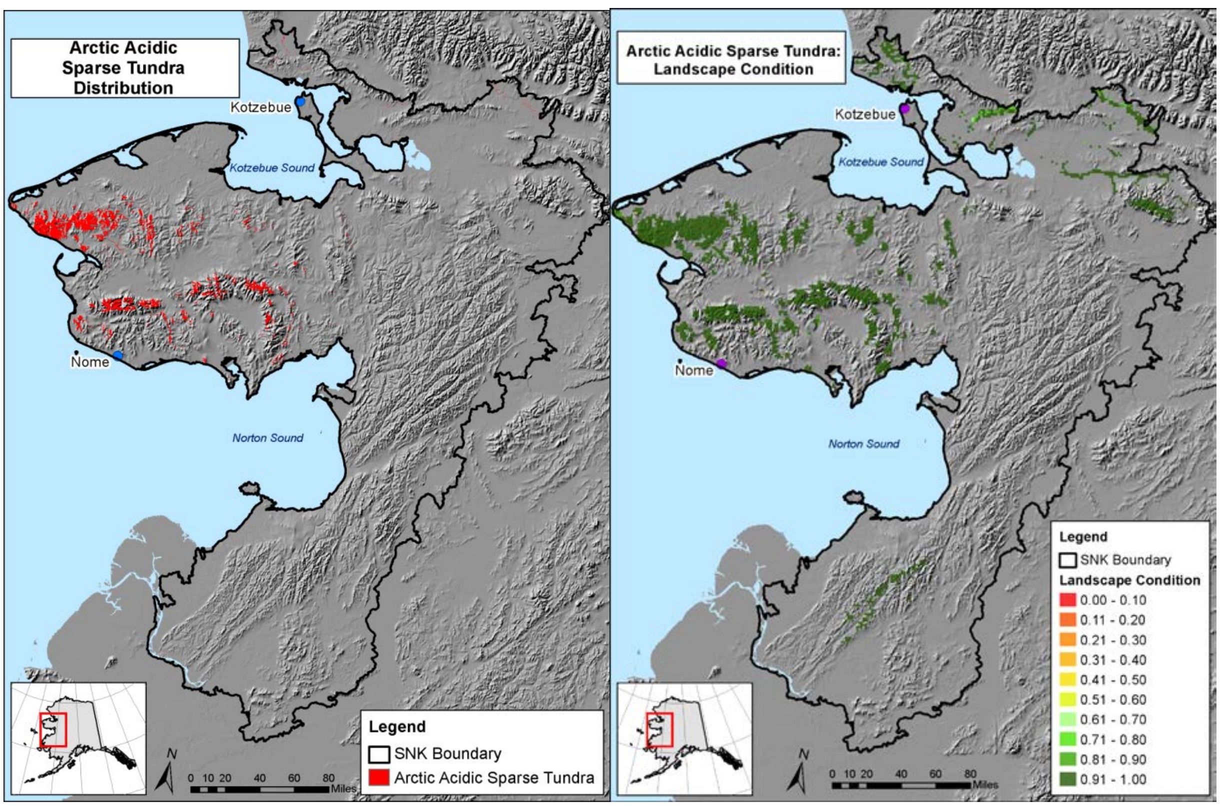


**Figure B-20. Arctic Active Inland Dunes current distribution and Landscape Condition Index scores.**

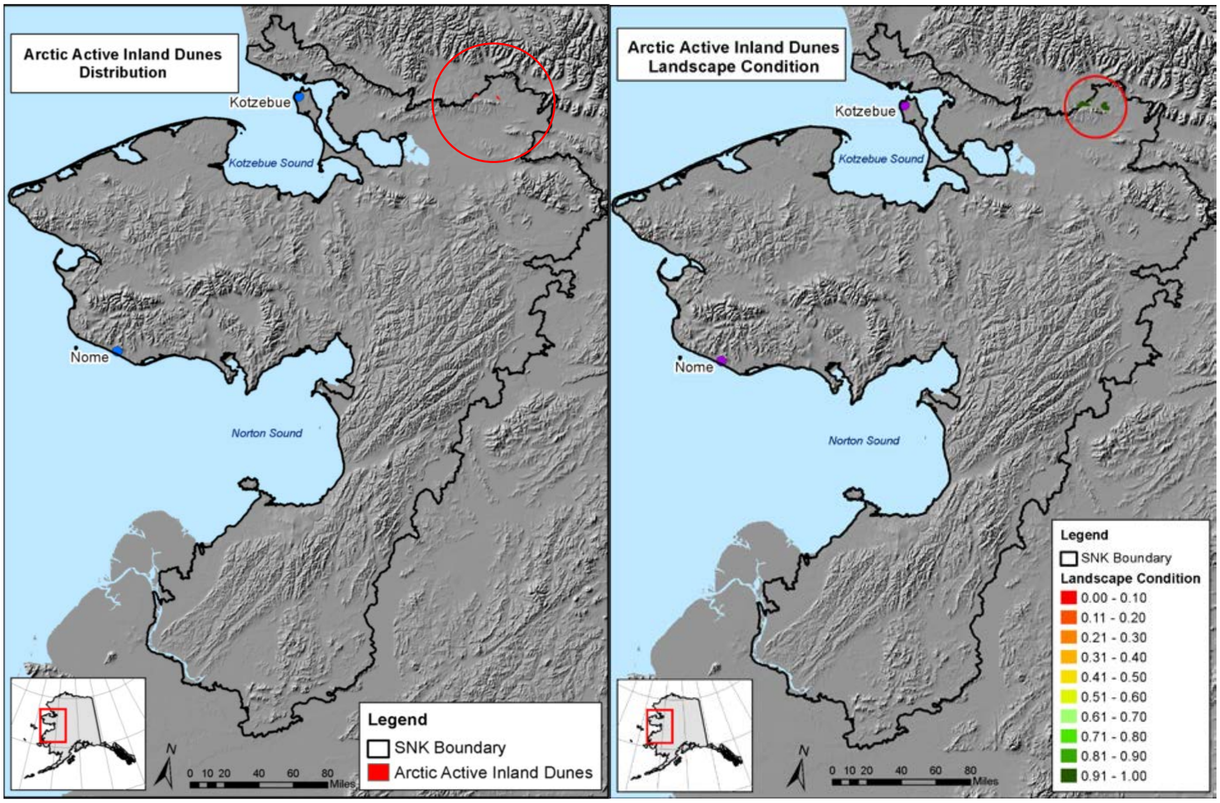



**Figure B-21. Arctic Dwarf Shrubland current distribution and Landscape Condition Index scores.**

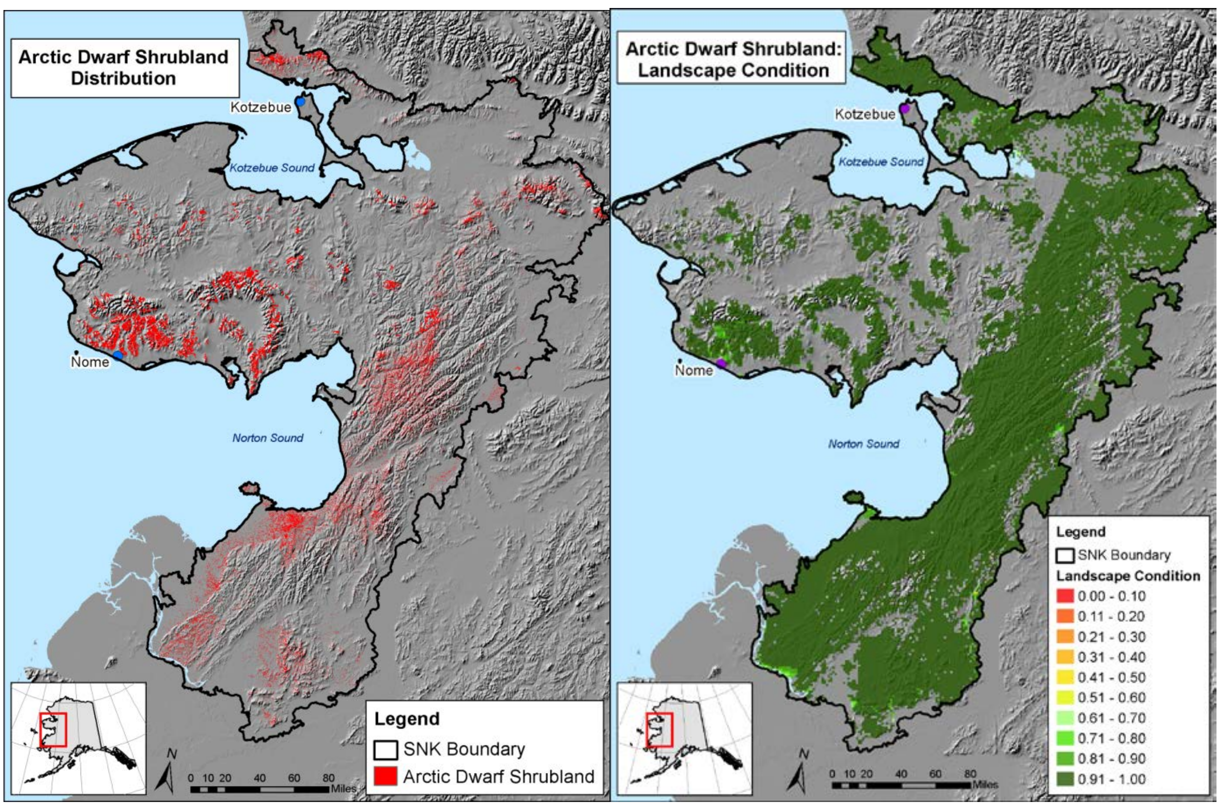


**Figure B-22. Arctic Mesic Alder current distribution and Landscape Condition Index scores.**

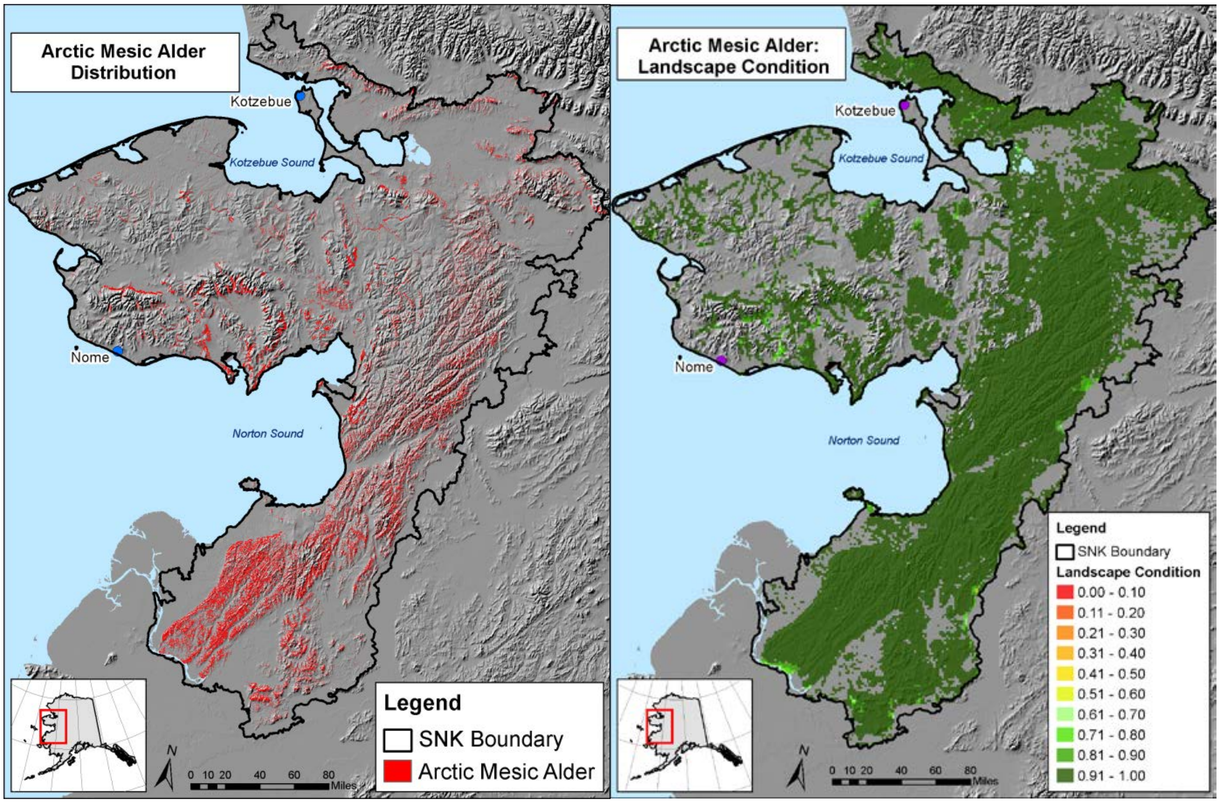



**Figure B-23. Arctic Scrub Birch-Ericaceous Shrubland current distribution and Landscape Condition Index scores.**

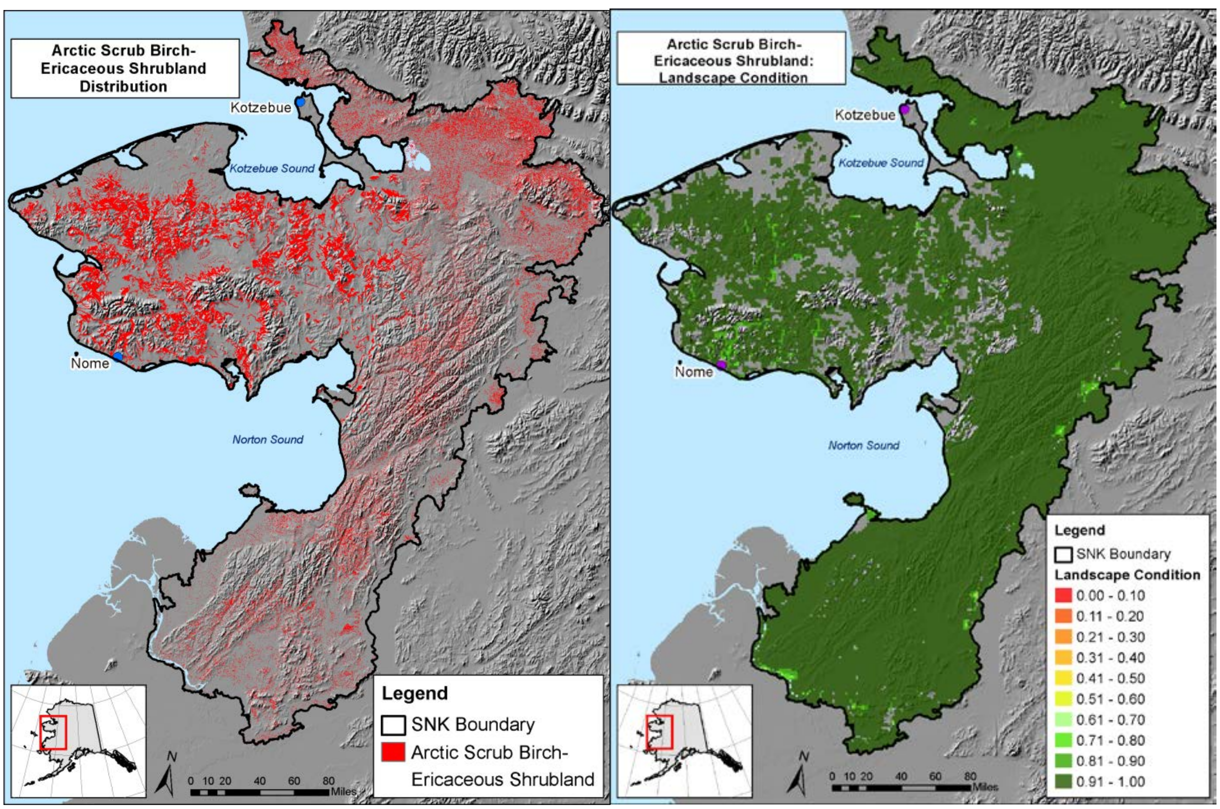


**Figure B-24. Boreal Black or White Spruce Forest and Woodland current distribution and Landscape Condition Index scores.**

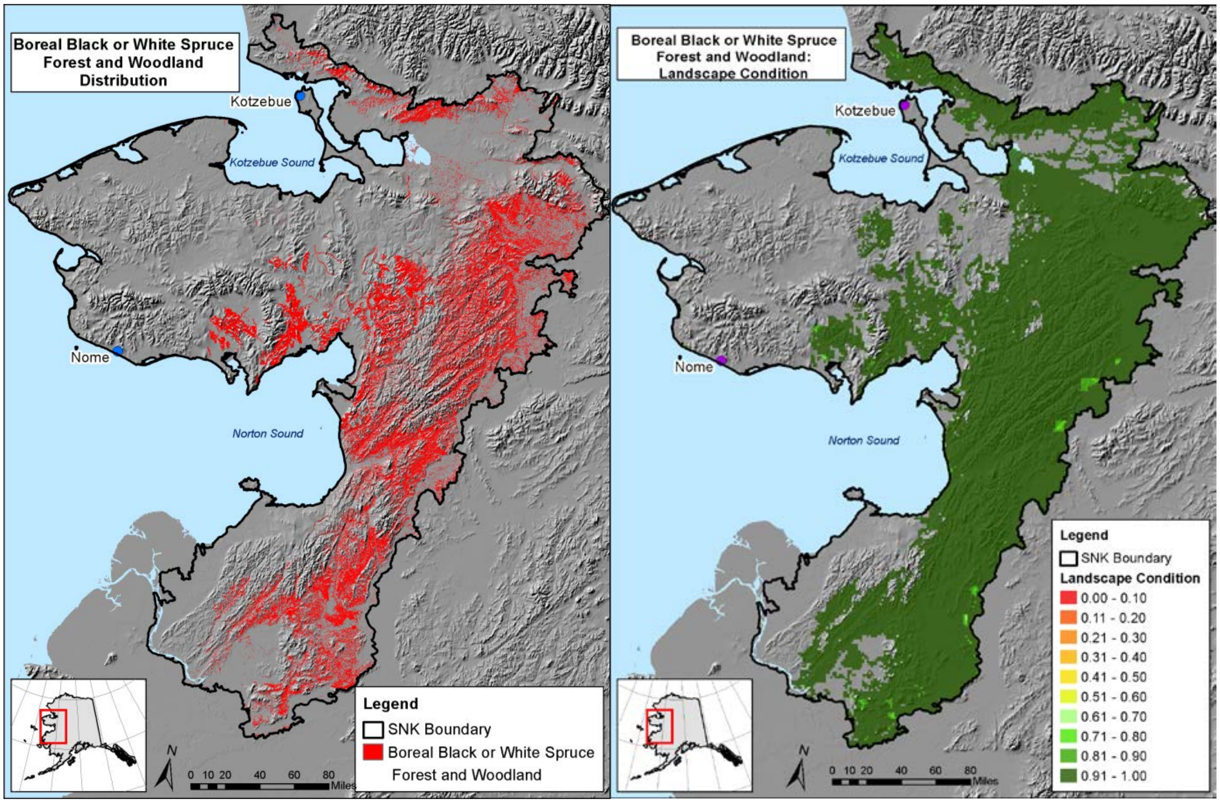



**Figure B-25. Boreal White or Black Spruce - Hardwood Forest current distribution and Landscape Condition Index scores.**

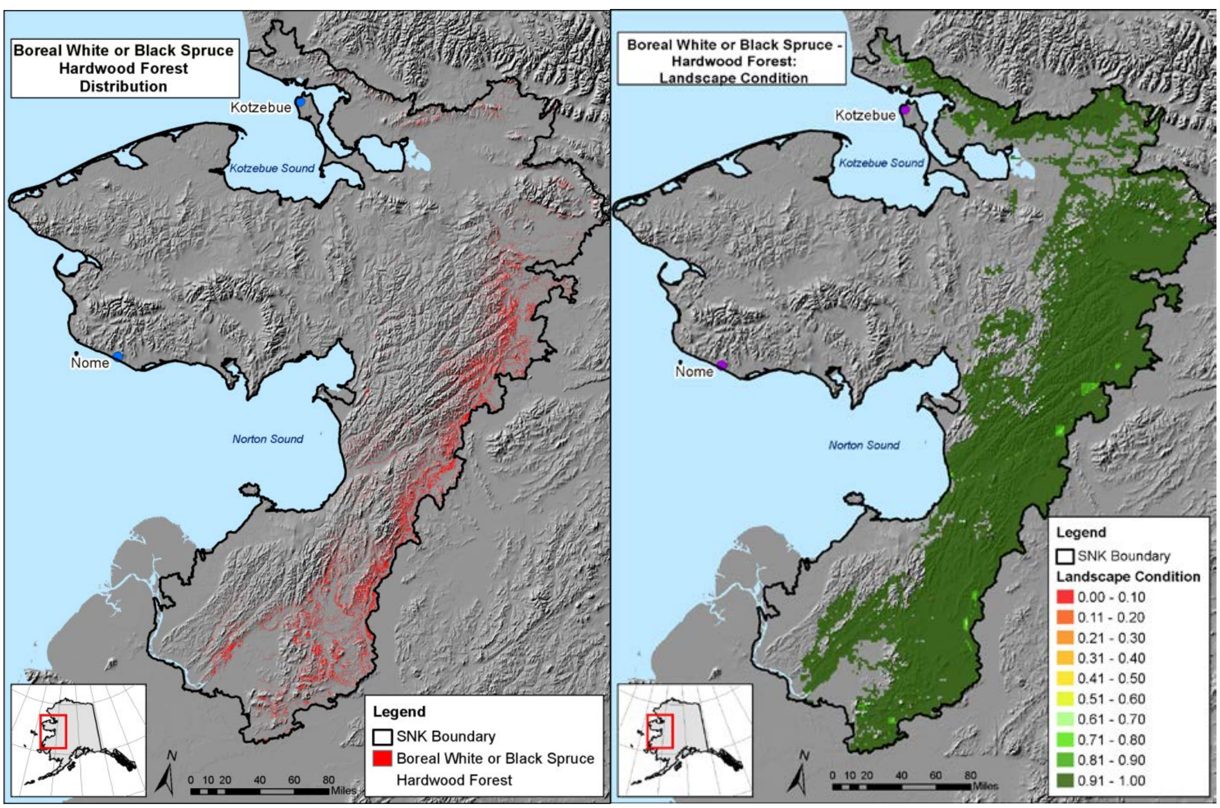
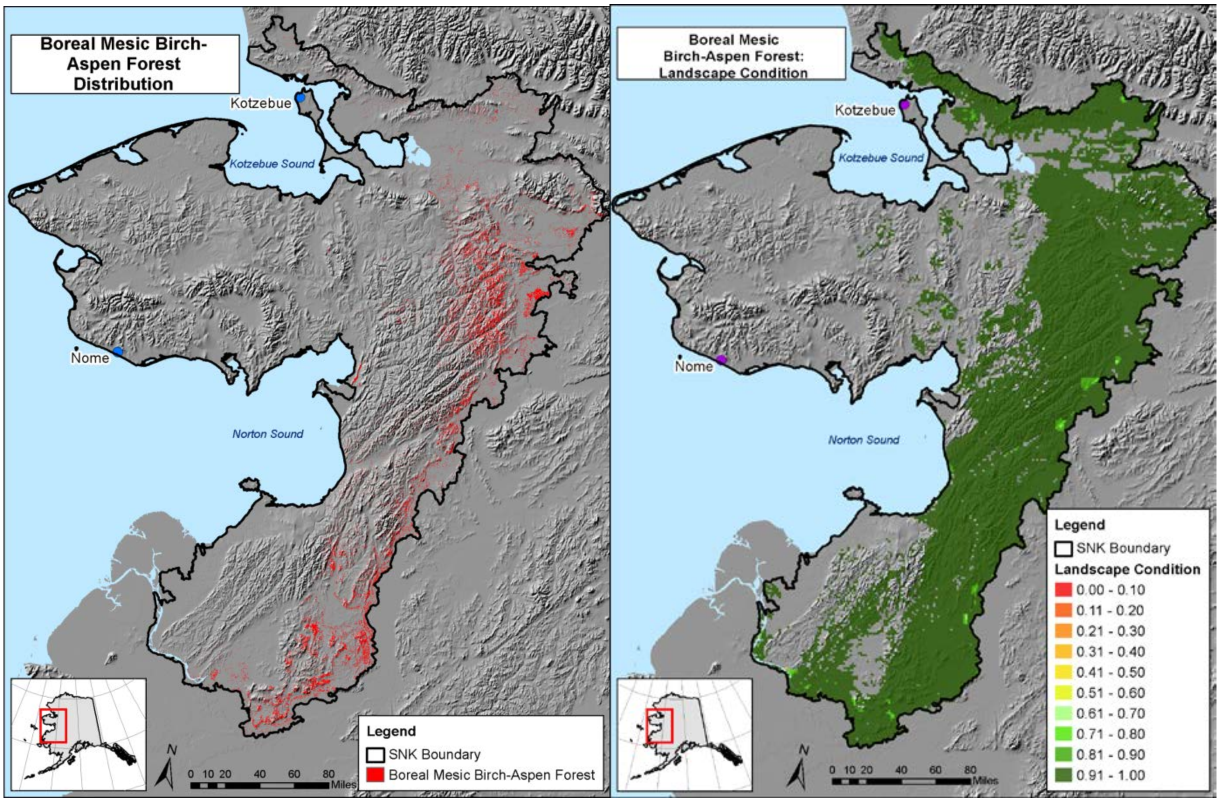


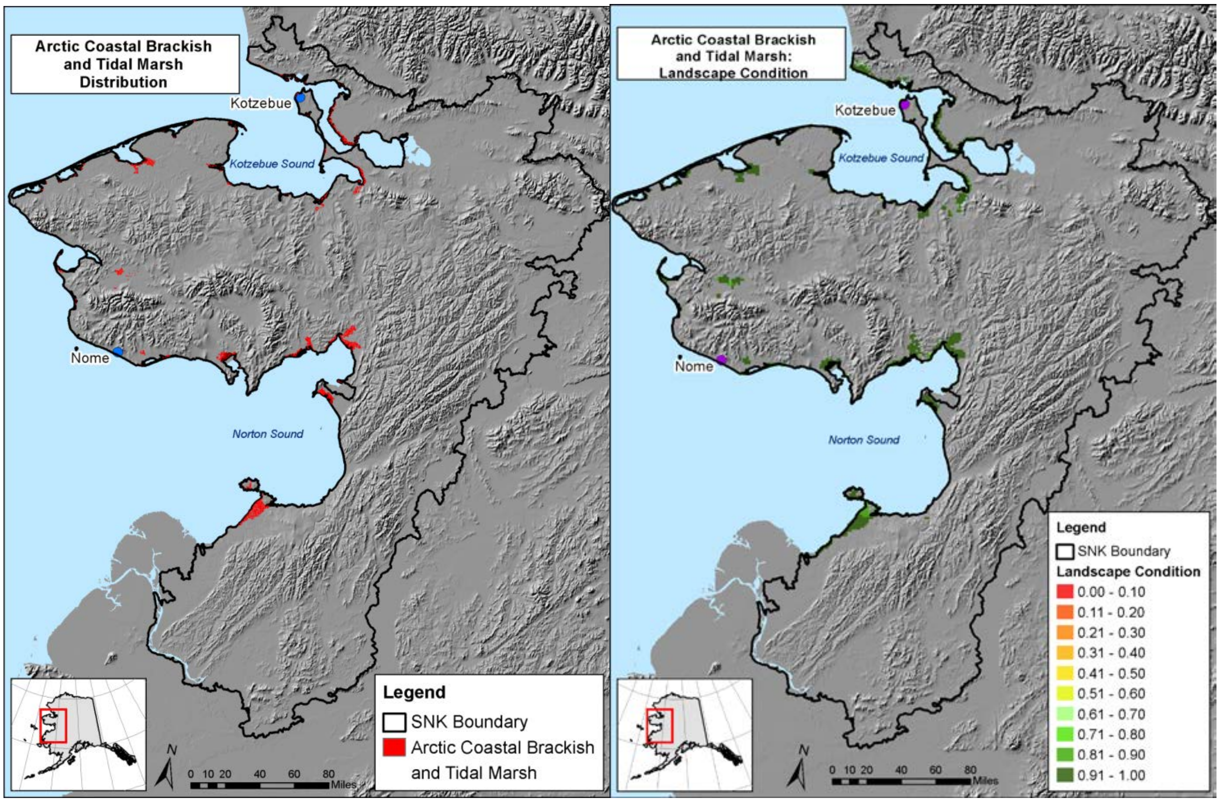
**Figure B-26. Boreal Mesic Birch-Aspen Forest current distribution and Landscape Condition Index scores.**



### *B-2.1.1.3 Coastal*

Current distribution and Landscape Condition Index scores of the coastal terrestrial coarse-filter CE are shown in Figure B-27.

**Figure B-27. Arctic Coastal Brackish and Tidal Marsh current distribution and Landscape Condition Index scores.**



## B-2.1.2 Terrestrial Fine Filter CEs: Additional Distribution and Ecological Status Maps

### *B-2.1.2.1 Mammals*

Current distribution and Landscape Condition Index scores of birds are shown in Figure B-28 through Figure B-34. Subsistence mammals (all except Alaskan Hare, Figure B-34) are shown first.

**Figure B-28. Caribou current predicted habitat distribution and Landscape Condition Index scores. Note: Although the Western Arctic Caribou Herd is the CE of interest in this REA, the Alaska GAP program modeled predicted habitat for caribou as a species, not by individual herds.**

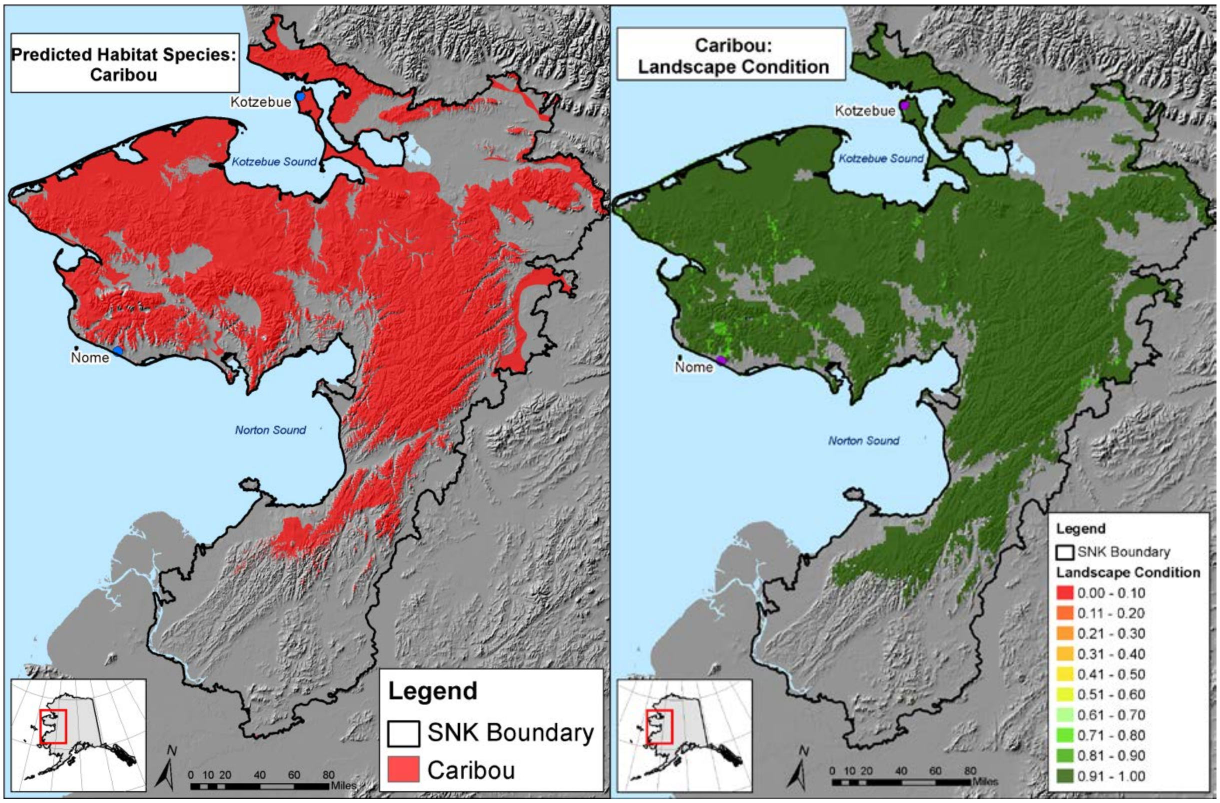


**Figure B-29. Moose current predicted habitat distribution and Landscape Condition Index scores.**

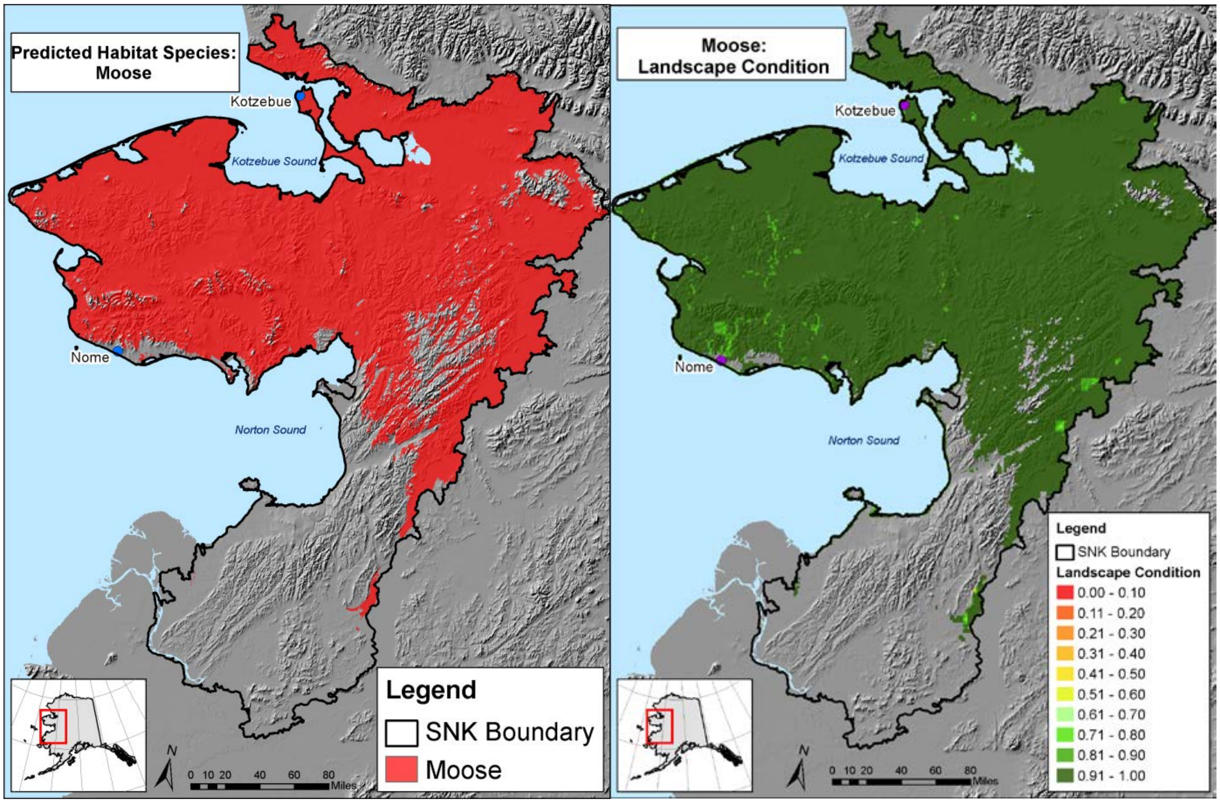



**Figure B-30. Beaver current predicted habitat distribution and Landscape Condition Index scores.**

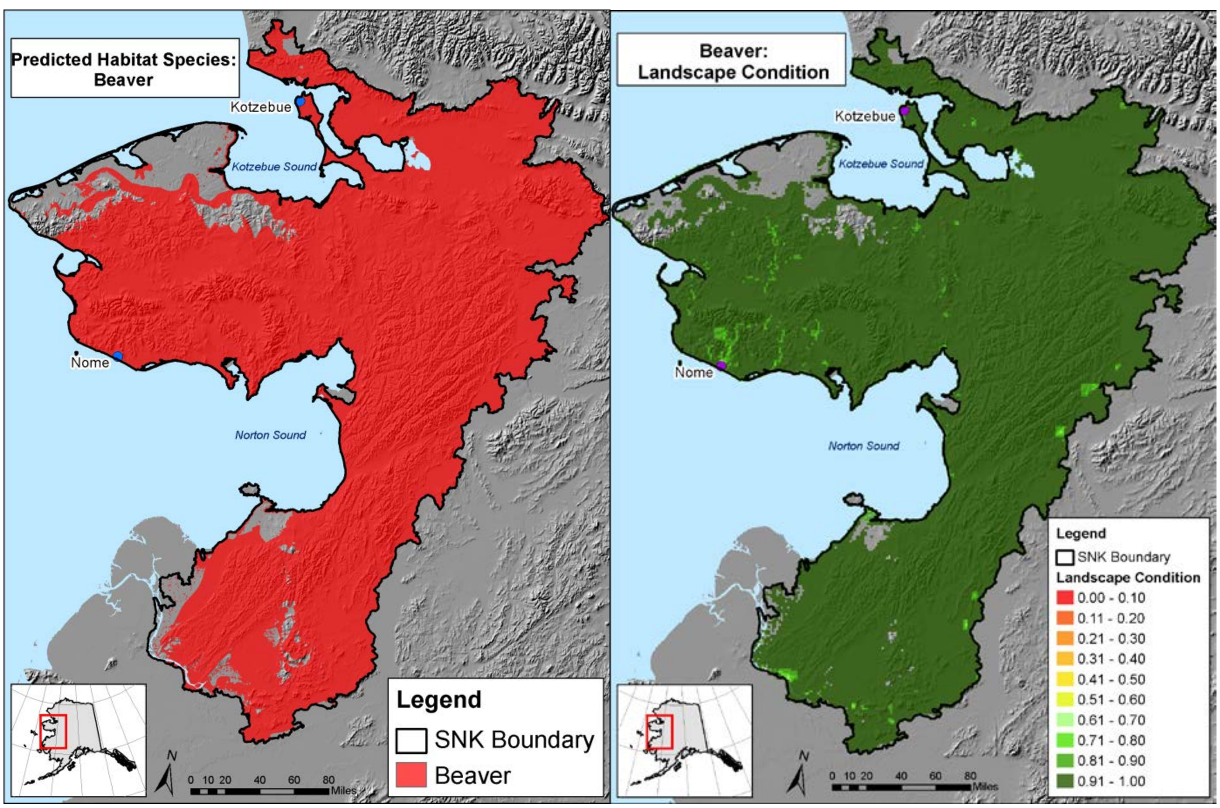


**Figure B-31. Black Bear current predicted habitat distribution and Landscape Condition Index scores.**

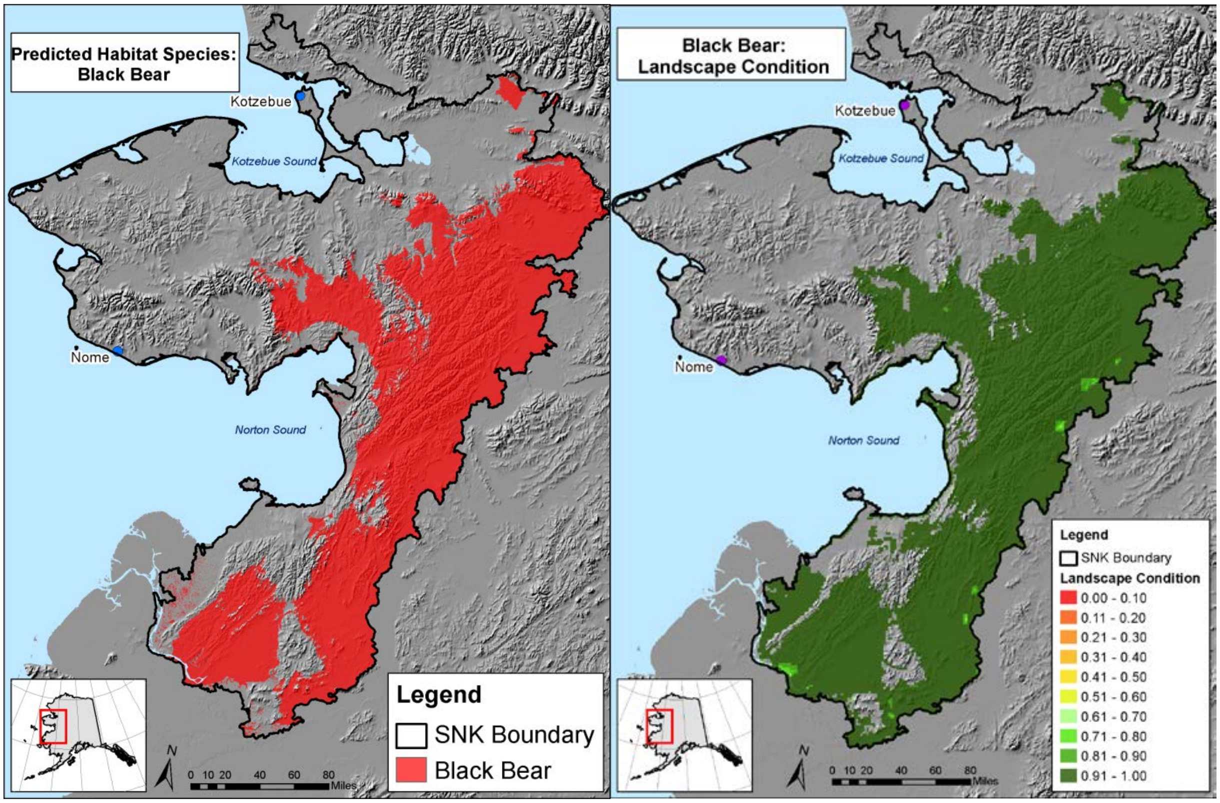



**Figure B-32. Brown Bear current predicted habitat distribution and Landscape Condition Index scores.**

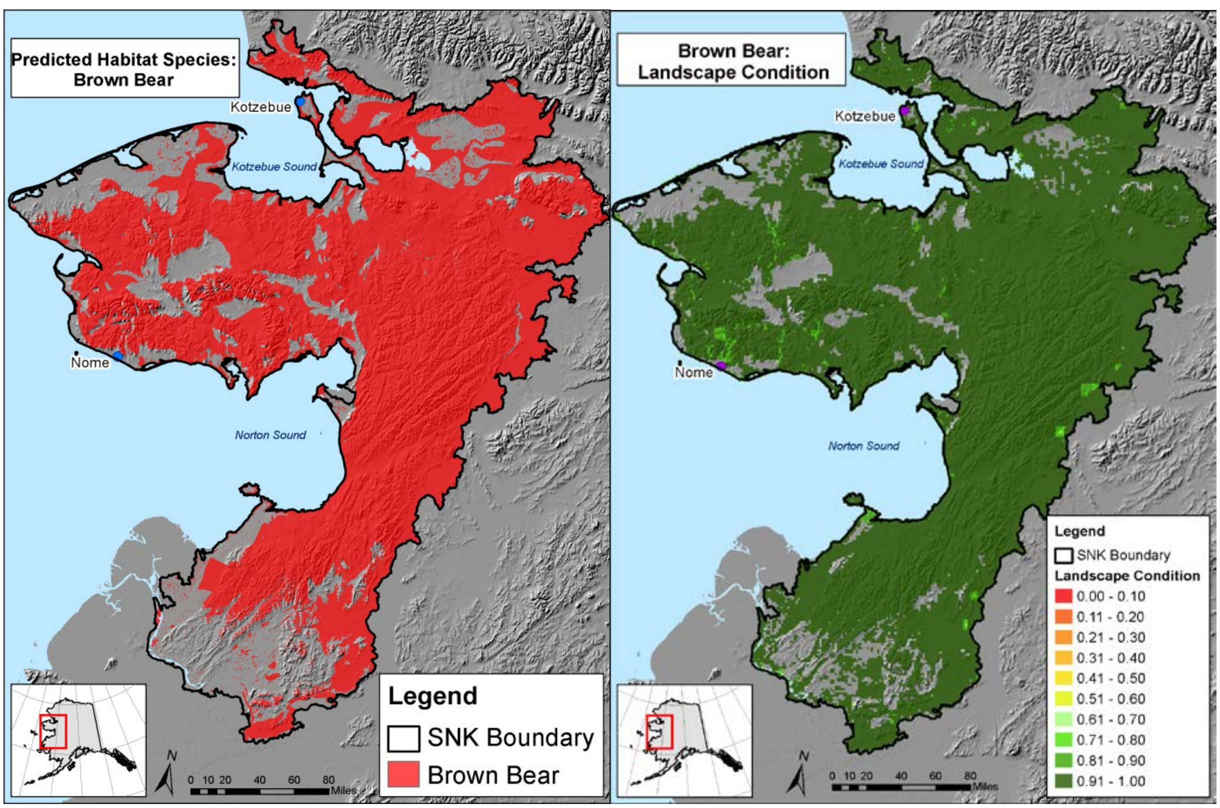


Figure B-33. Muskox current predicted habitat distribution and Landscape Condition Index scores.

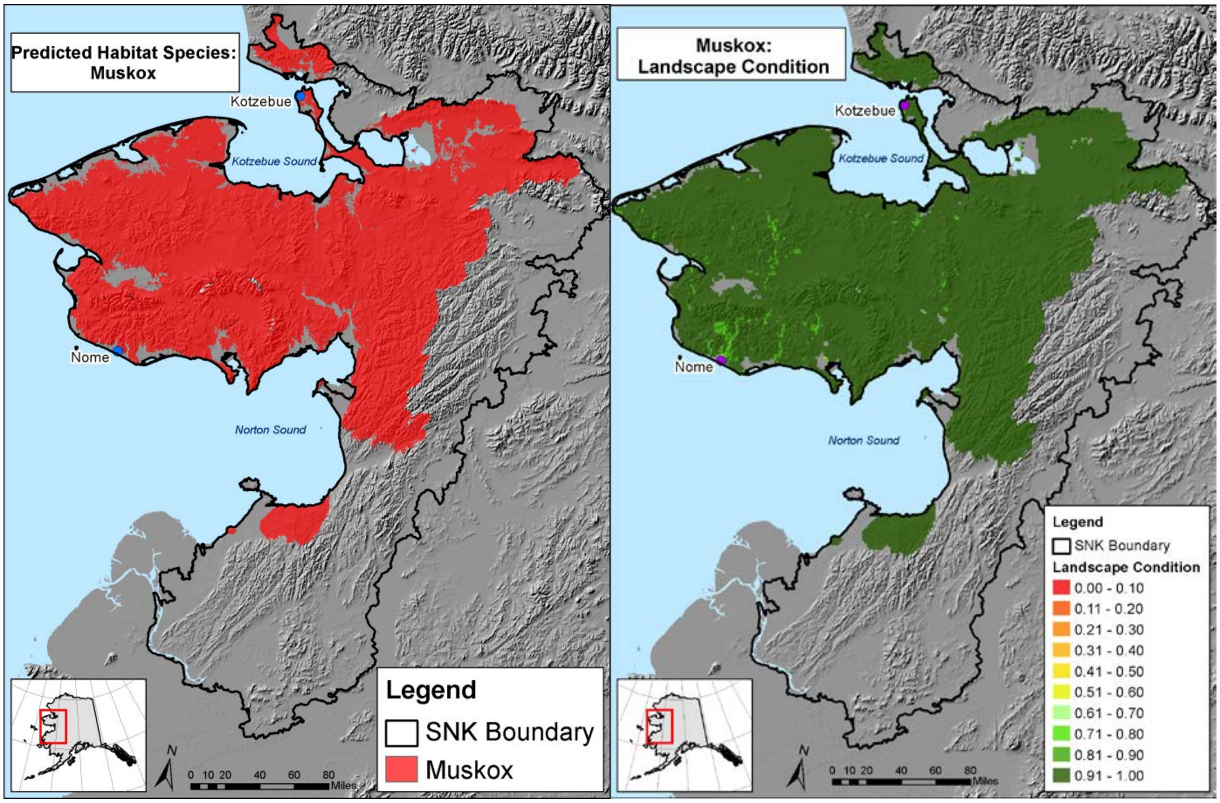
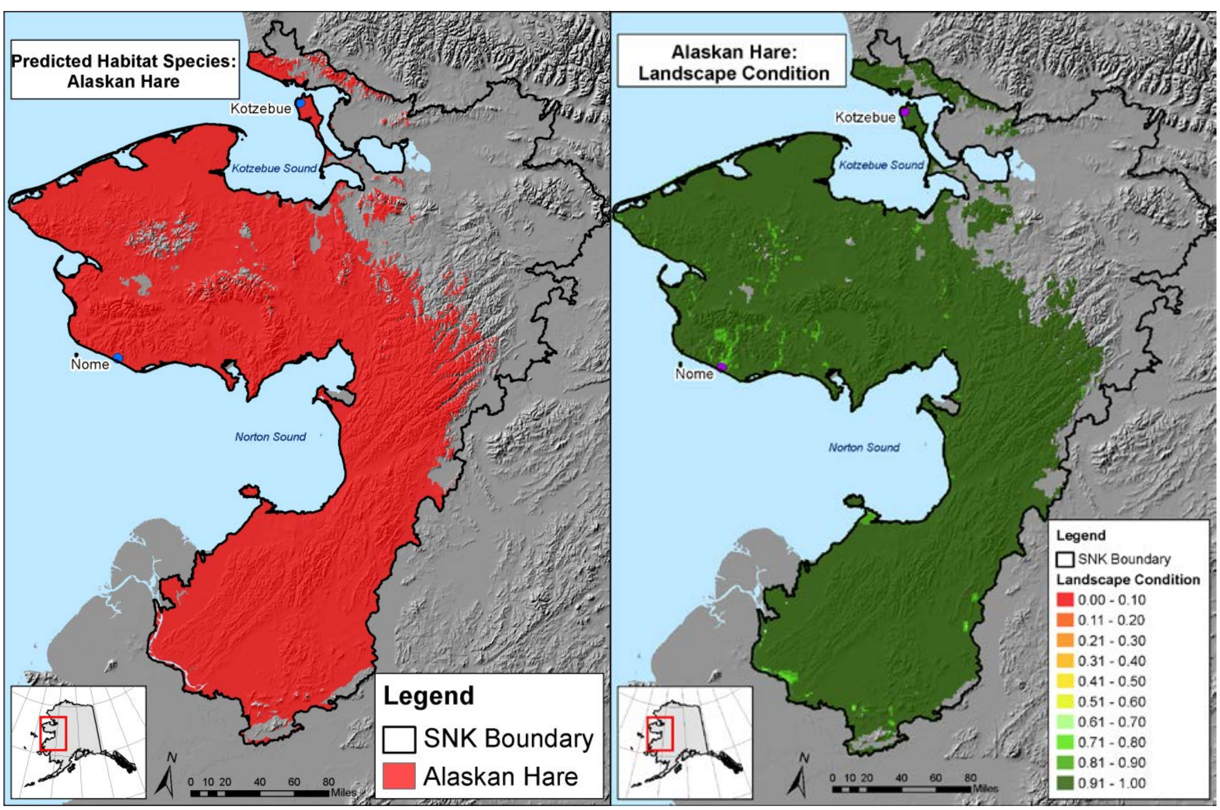



Figure B-34. Alaskan Hare current predicted habitat distribution and Landscape Condition Index scores.



### B-2.1.2.2 Birds

Current distribution and Landscape Condition Index scores of birds are shown in Figure B-35 through Figure B-43. Subsistence birds (Cackling Goose, Figure B-35) are shown first.

**Figure B-35. Cackling Goose current predicted habitat and Landscape Condition Index scores.**

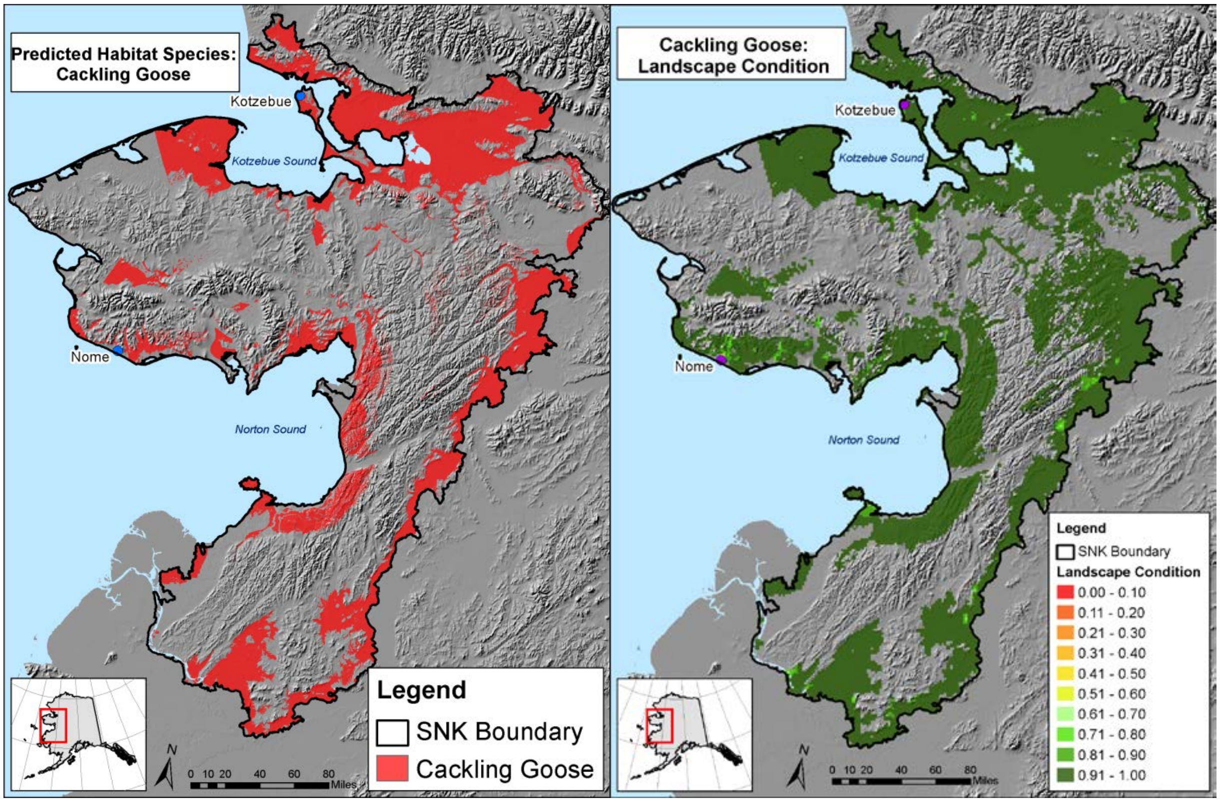


Figure B-36. Arctic Peregrine Falcon current predicted habitat and Landscape Condition Index scores.

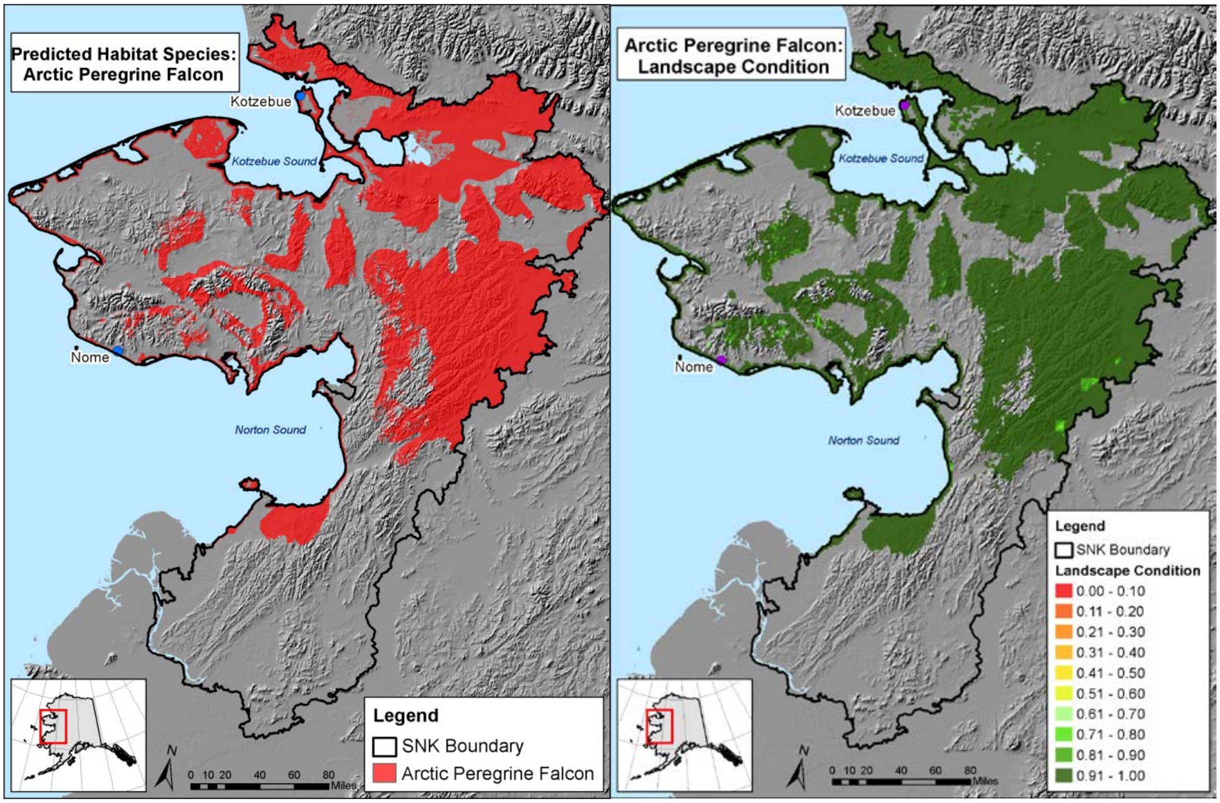



Figure B-37. Bar-tailed Godwit current predicted habitat and Landscape Condition Index scores.

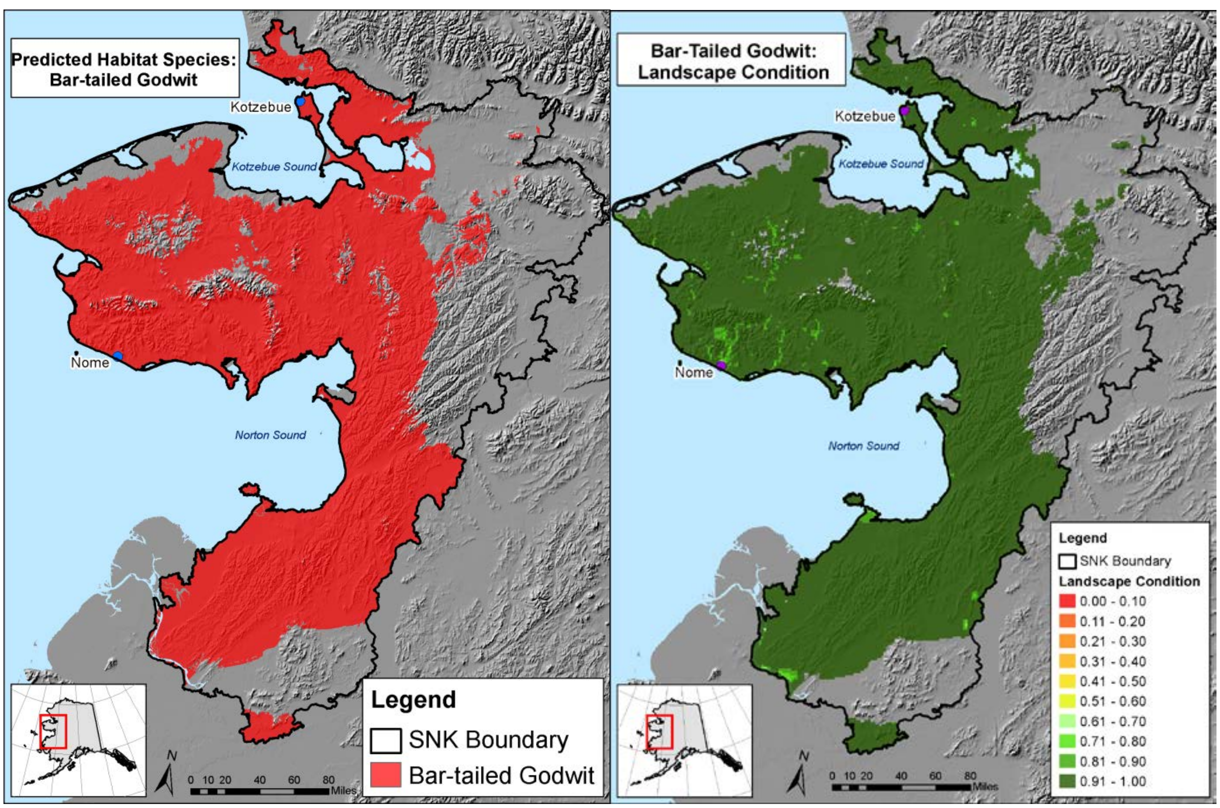


Figure B-38. Black Scoter current predicted habitat and Landscape Condition Index scores.

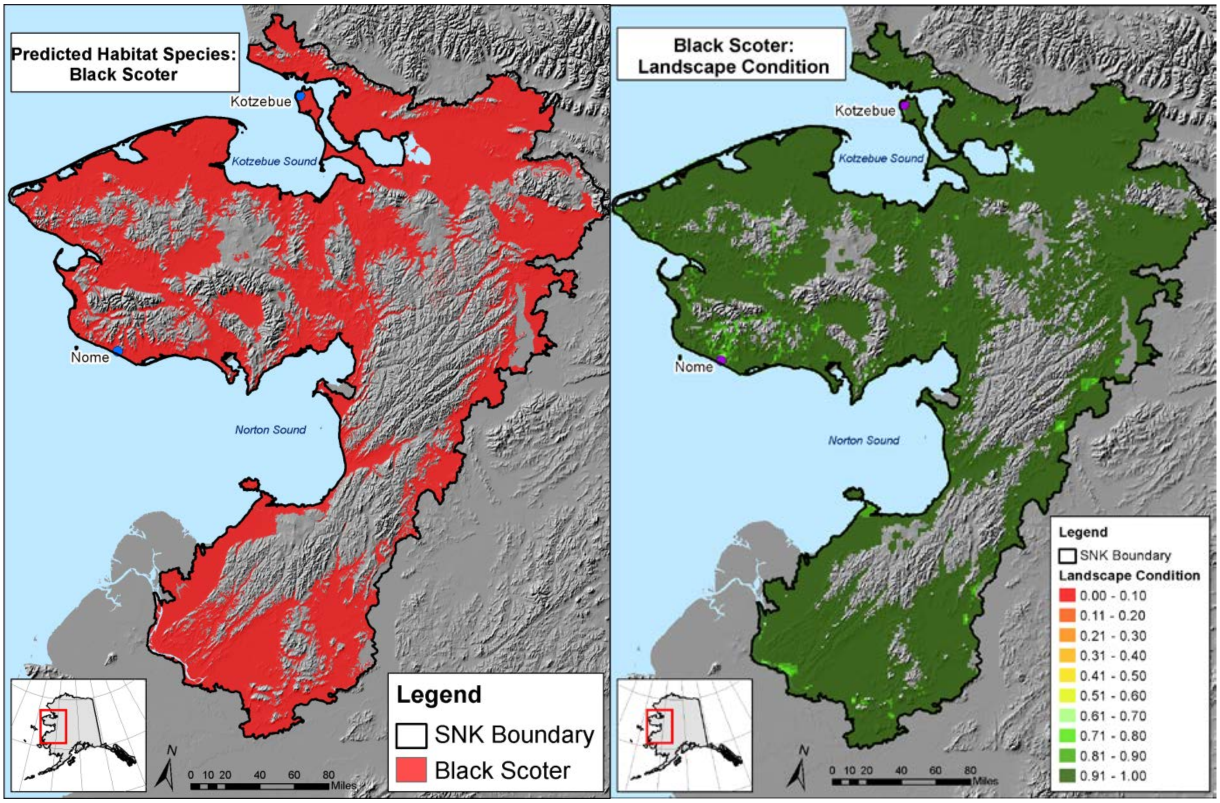



Figure B-39. Bristle-thighed Curlew current predicted habitat and Landscape Condition Index scores.

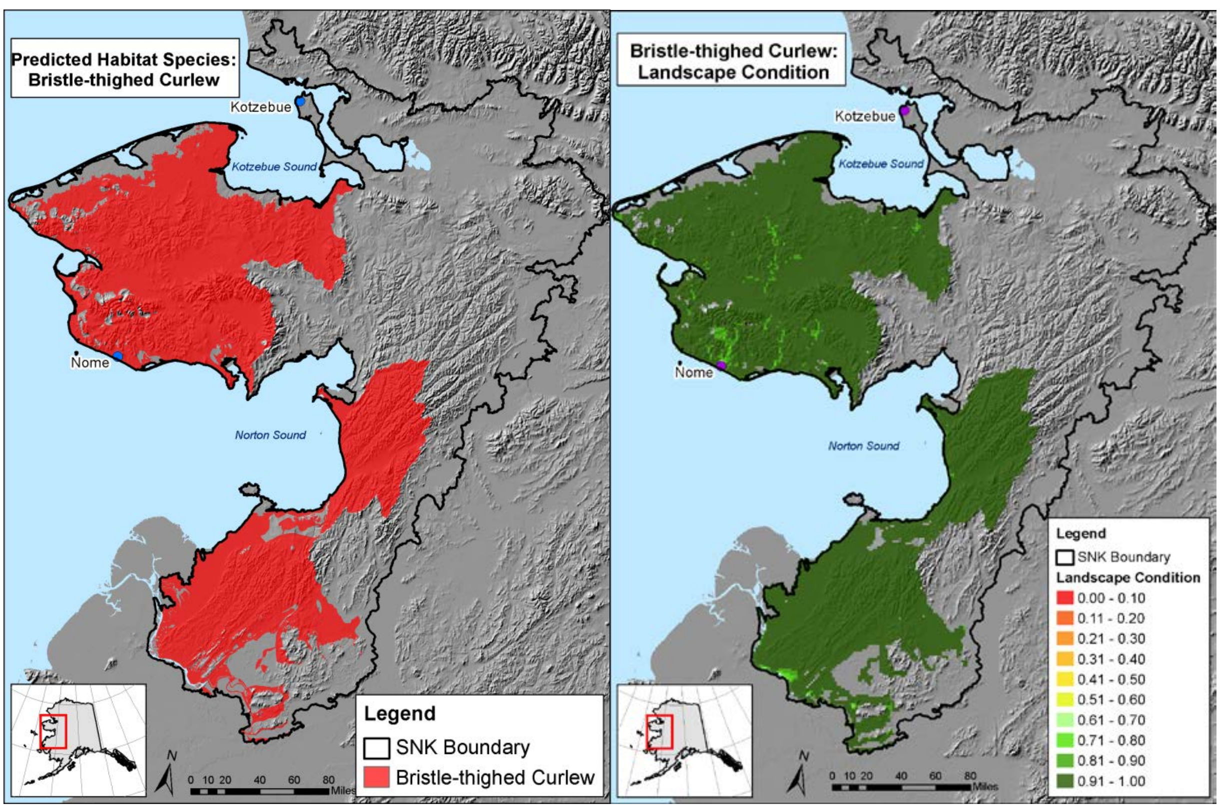


**Figure B-40. Common Eider current predicted habitat and Landscape Condition Index scores.**

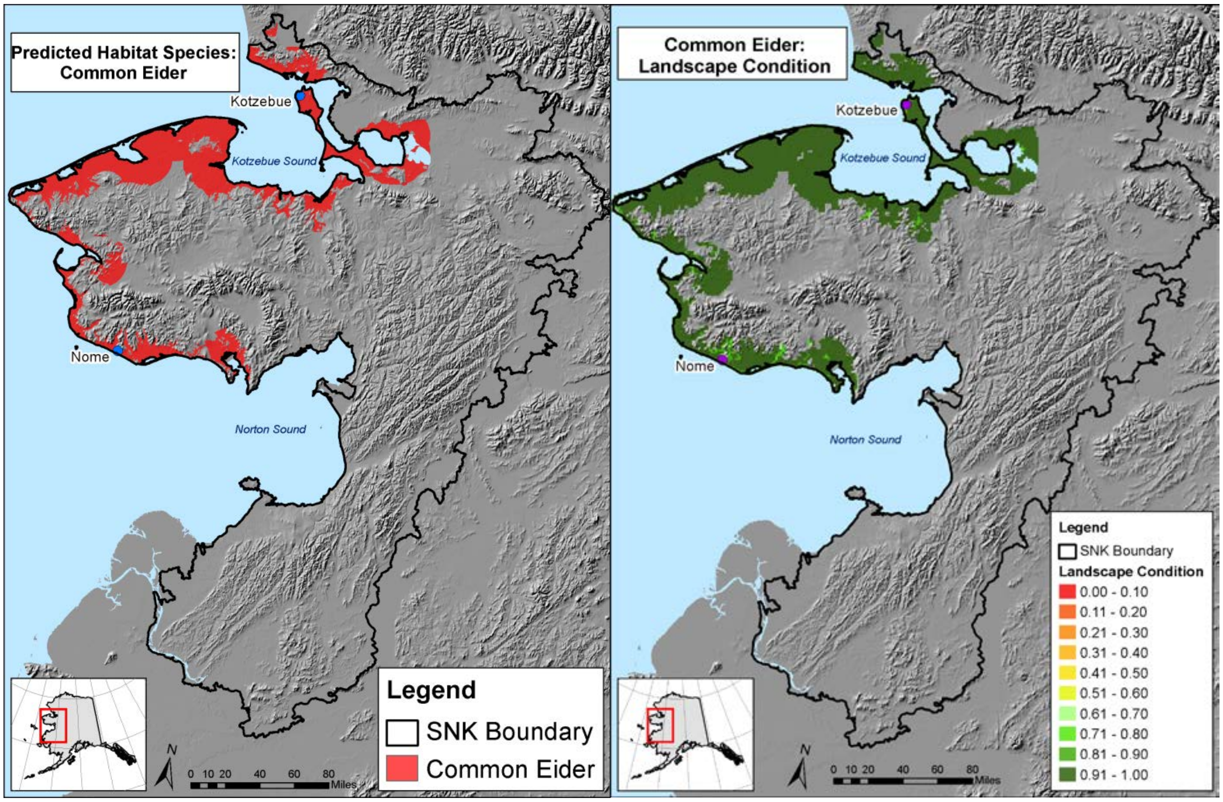



**Figure B-41. King Eider current predicted habitat and Landscape Condition Index scores.**

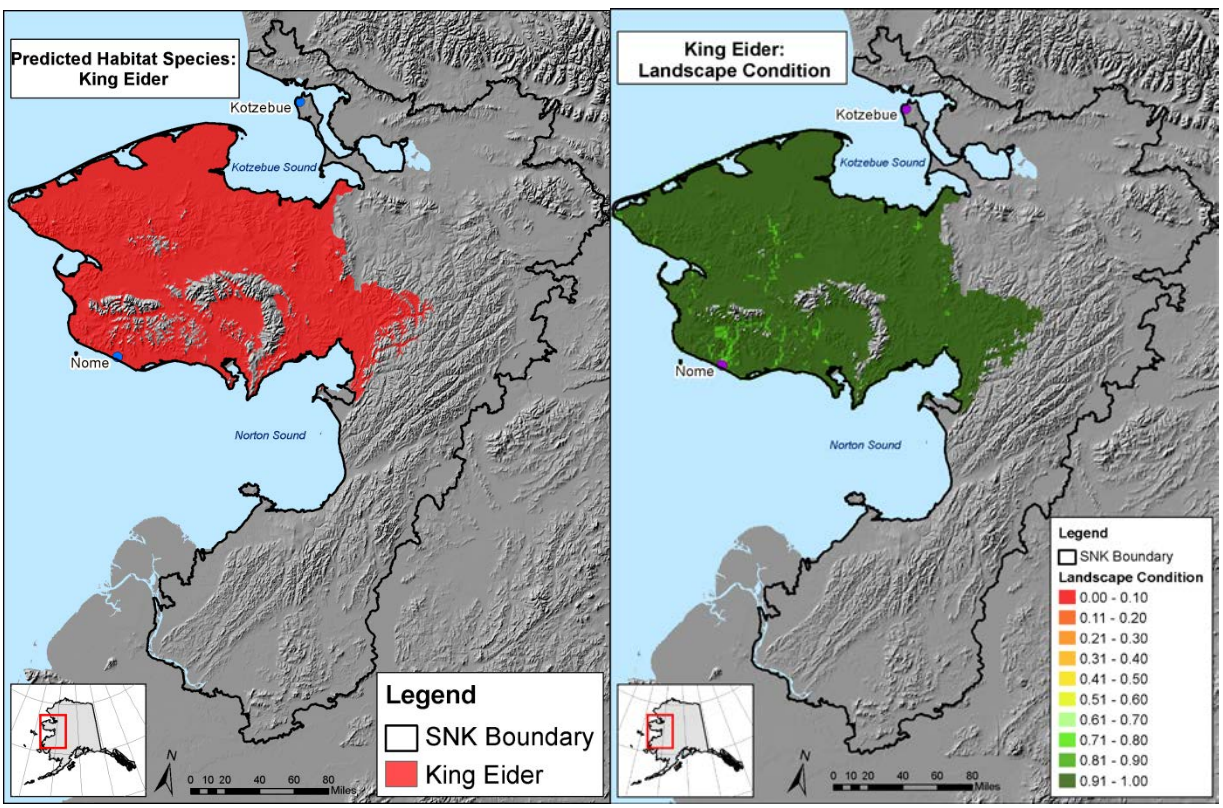


**Figure B-42. Yellow-billed Loon current predicted habitat and Landscape Condition Index scores.**

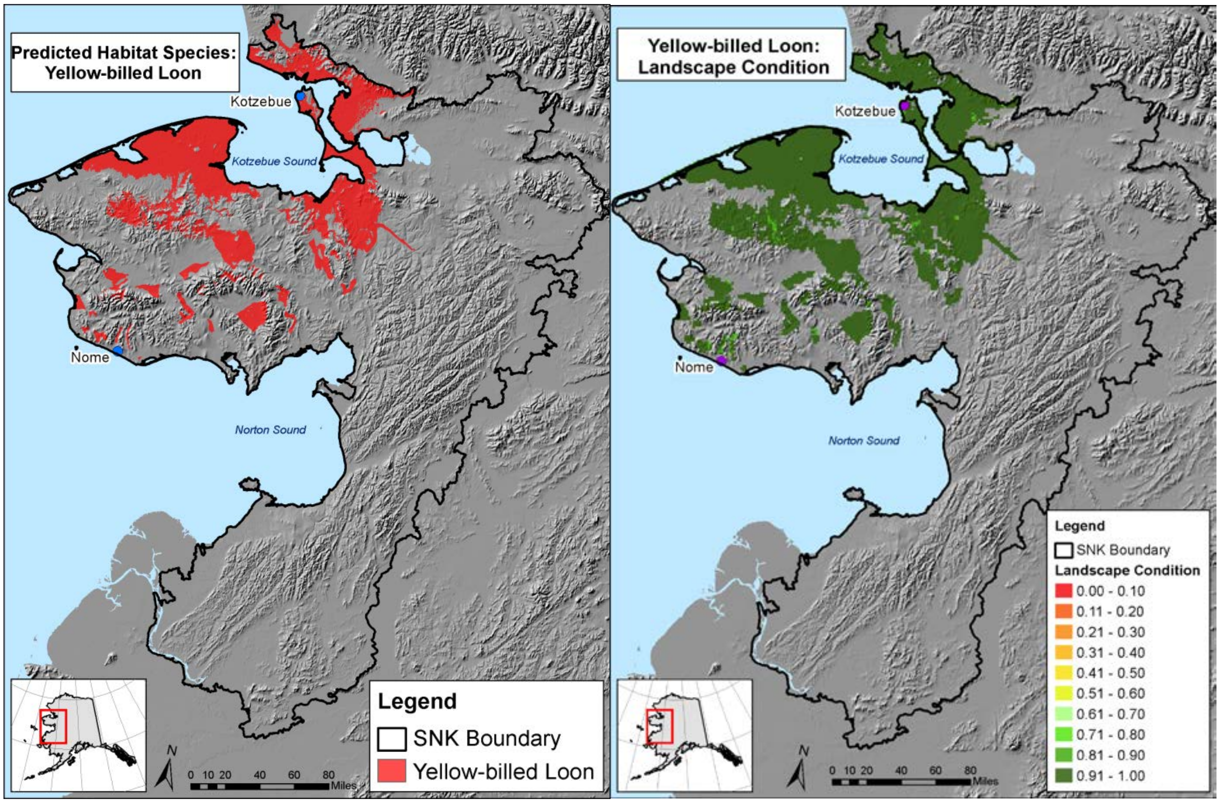
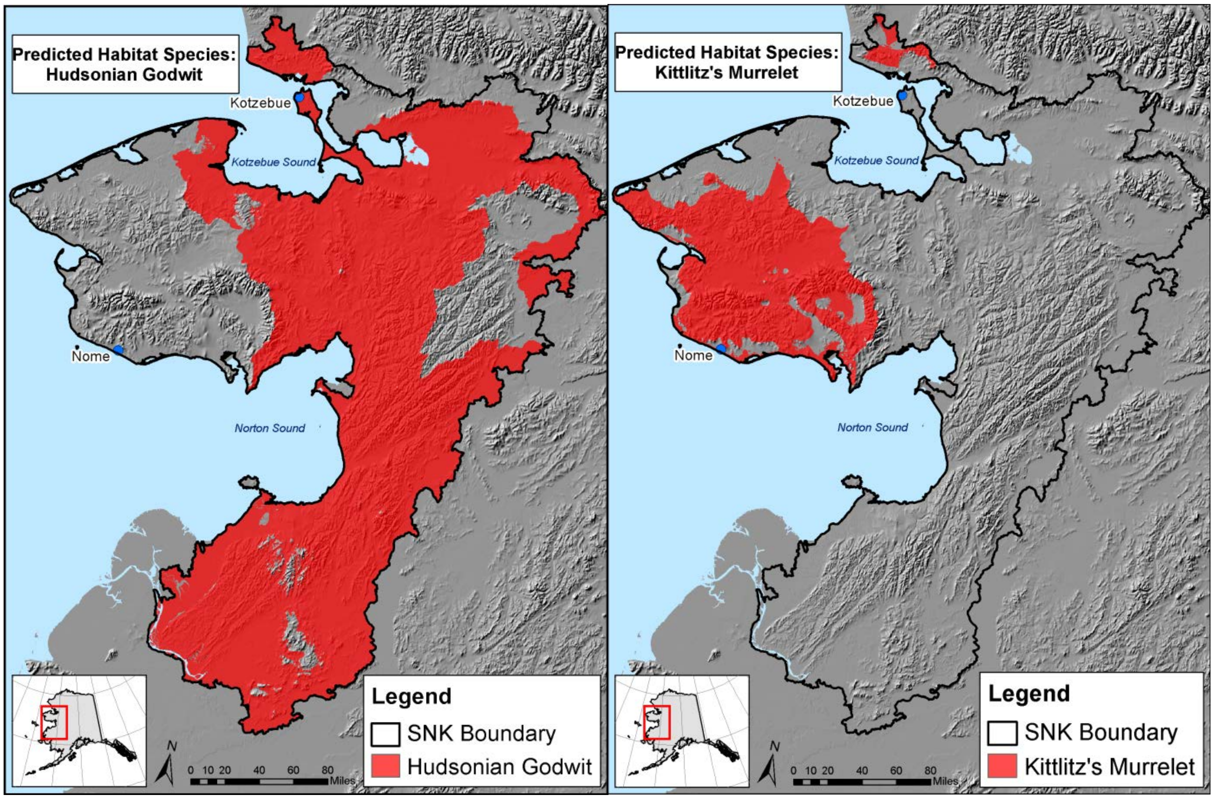


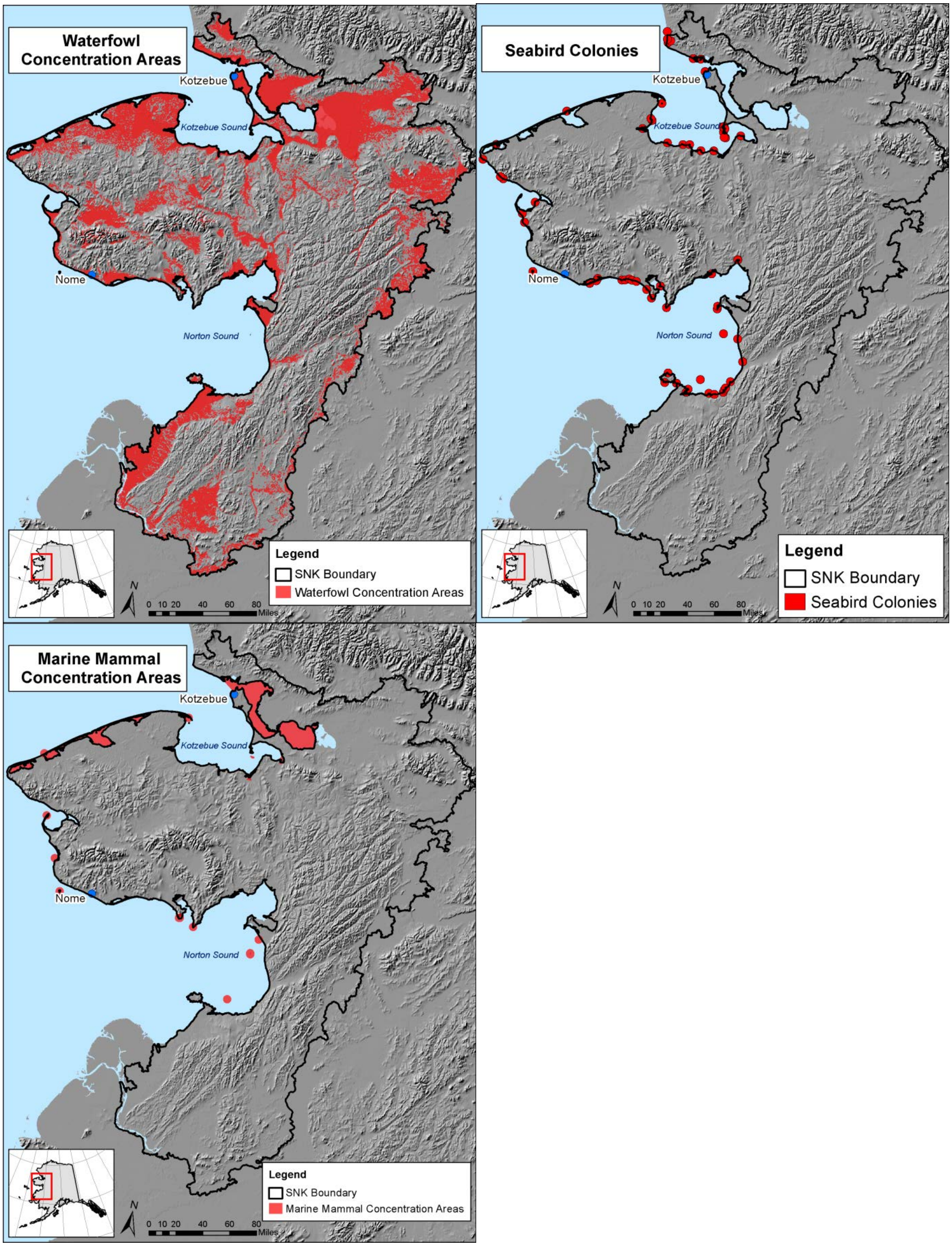
Figure B-43. Hudsonian Godwit and Kittlitz's Murrelet current predicted habitat.



### *B-2.1.2.3 Species Assemblages*

The current distribution of species assemblages is shown in Figure B-44.

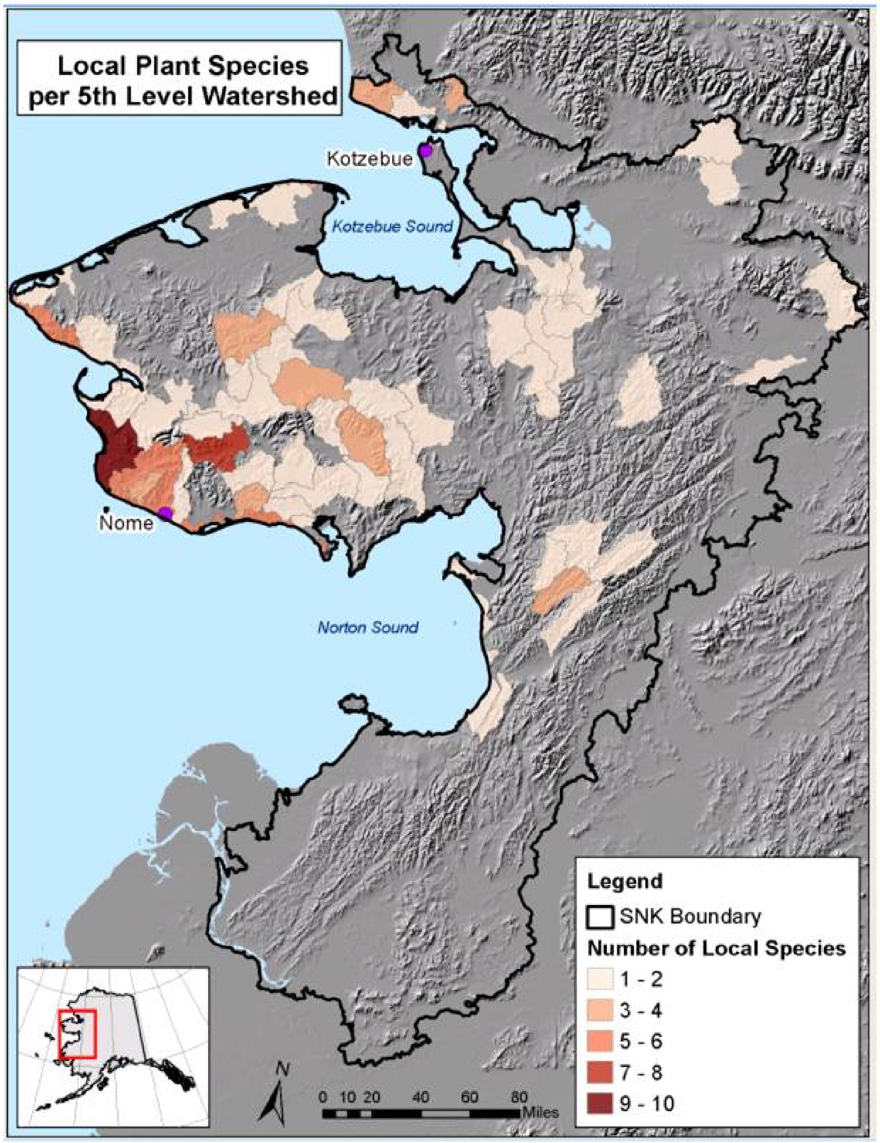
**Figure B-44. Current distribution of species assemblages: Waterfowl Breeding Areas, Seabird Colony Sites, and Marine Mammal Haul-Out Sites.**



### *B-2.1.2.4 Local Species: Plants*

The number of occurrences of rare plant species was summarized by 5$^{th}$-level watershed (Figure B-45).

**Figure B-45. Count of occurrences of rare plants by 5th-level watershed.**




## B-2.2 Species CEs and Habitats

**86**: What habitats support terrestrial species of concern (rare plants, rare animals, and subsistence species?

This question was addressed in two ways: Terrestrial (or non-fish) species CEs for which modeled distributions were available were intersected with the terrestrial coarse-filter CEs to determine the proportion of each species' predicted habitat that is associated with a particular coarse-filter type; these results are summarized in Table B-12. Secondly, the habitats identified in the conceptual models for each of the species CEs were compiled into a tabular summary (Table B-13). The results of the spatial intersection of the landscape species CE modeled distributions with the terrestrial coarse-filter map layer have a moderate degree of confidence at best. The species distributions are models of *predicted habitat* – rather than actual known distribution – developed by the AK GAP program and are undergoing further refinement. While the broad patterns of vegetation as shown in the terrestrial coarse-filter CE map layer are expected to be at least moderately accurate, given the quality of their four source data sets, intersecting these two sets of data creates a greater level of uncertainty. For example, the Alaskan hare results show that the extent of its predicted habitat has the greatest degree of overlap with the following four habitats:

| **Terrestrial Coarse-filter CE** | **Percentage of Alaskan hare predicted habitat overlapping with the coarse-filter CE** |
|---|---:|
| Arctic Scrub Birch-Ericaceous Shrubland | 15 |
| Boreal Black or White Spruce Forest and Woodland | 13 |
| Arctic Shrub-Tussock Tundra | 13 |
| Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra | 11 |

The overlap with tundra and shrubland coarse-filter CEs is not surprising for this species. However, the overlap with the spruce forest/woodland CE is likely incorrect, given that it primarily prefers open tundra but also utilizes shrubby habitats. Therefore, these summary results should be used with caution, in conjunction with expert knowledge of the species under consideration, and updated when new species and/or coarse-filter CE distribution data become available. The second table, compiled from various habitat descriptions, provides a better qualitative summary of the habitats that support various species CEs.

**Table B-12. Percent overlap of landscape and local species' predicted habitat with terrestrial coarse-filter CEs and land cover types.**

| | Mammals | | | | | | | Birds | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Alaskan Hare | Beaver | Black Bear | Brown Bear | Western Arctic Caribou | Moose | Muskox | Arctic Peregrine Falcon | Bar-tailed Godwit | Black Scoter | Bristled-thighed Curlew | Cackling Goose | Common Eider | Emperor Goose | Hudsonian Godwit | King Eider | Kittlitz's Murrelet | McKay's Bunting | Red Knot | Spectacled Eider | Yellow-billed Loon |
| **Upland coarse-filter CEs** | | | | | | | | | | | | | | | | | | | | | |
| Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra | 11 | 9 | 6 | 9 | 9 | 5 | 9 | 6 | 11 | 4 | 14 | 4 | 1 | 3 | 9 | 5 | 12 | 14 | 9 | 3 | 2 |
| Arctic Acidic Sparse Tundra | 2 | 1 | 0 | 2 | 3 | 2 | 3 | 1 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 3 | 8 | 1 | 4 | 1 | 1 |
| Arctic Active Inland Dunes | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Arctic Dwarf-Shrubland | 6 | 5 | 4 | 6 | 7 | 4 | 6 | 5 | 6 | 2 | 7 | 3 | 1 | 1 | 5 | 3 | 10 | 8 | 7 | 2 | 2 |
| Arctic Lichen Tundra | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 2 | 3 | 1 | 2 | 2 | 1 | 2 | 1 | 2 |
| Arctic Mesic Alder | 8 | 7 | 8 | 7 | 6 | 4 | 4 | 5 | 7 | 3 | 8 | 2 | 1 | 2 | 8 | 3 | 3 | 11 | 5 | 2 | 2 |
| Arctic Scrub Birch-Ericaceous Shrubland | 15 | 16 | 11 | 17 | 18 | 19 | 21 | 18 | 17 | 17 | 18 | 15 | 11 | 16 | 14 | 22 | 27 | 13 | 22 | 19 | 17 |
| Boreal Black or White Spruce Forest and Woodland | 13 | 16 | 27 | 17 | 12 | 13 | 9 | 18 | 12 | 13 | 8 | 11 | 1 | 5 | 16 | 7 | 2 | 16 | 9 | 5 | 2 |
| Boreal Mesic Birch-Aspen Forest | 2 | 3 | 6 | 3 | 2 | 2 | 1 | 4 | 1 | 2 | 1 | 3 | 0 | 0 | 3 | 0 | 0 | 2 | 0 | 0 | 0 |
| Boreal Spruce-Lichen Woodland | 2 | 2 | 4 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 0 | 2 | 0 | 0 | 2 | 2 | 0 | 2 | 2 | 1 | 0 |
| Boreal White or Black Spruce - Hardwood Forest | 3 | 3 | 7 | 3 | 2 | 2 | 0 | 3 | 2 | 3 | 1 | 3 | 0 | 0 | 4 | 0 | 0 | 3 | 0 | 0 | 0 |
| **Lowland coarse-filter CEs** | | | | | | | | | | | | | | | | | | | | | |
| Arctic Dwarf-Shrub-Sphagnum Peatland | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 3 | 5 | 4 | 5 | 3 | 1 | 4 | 1 | 0 | 4 | 0 | 4 | 3 |
| Arctic Mesic-Wet Willow Shrubland | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 5 | 4 | 5 | 4 | 7 | 3 | 3 | 3 | 3 | 2 | 4 | 4 |
| Arctic Shrub-Tussock Tundra | 13 | 16 | 9 | 15 | 21 | 22 | 26 | 17 | 18 | 20 | 15 | 15 | 28 | 27 | 16 | 25 | 17 | 8 | 20 | 29 | 31 |
| Arctic Wet Sedge Tundra | 7 | 7 | 3 | 6 | 8 | 9 | 9 | 6 | 7 | 10 | 8 | 10 | 23 | 19 | 5 | 13 | 13 | 5 | 11 | 15 | 16 |

| | Mammals | | | | | | | Birds | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Alaskan Hare | Beaver | Black Bear | Brown Bear | Western Arctic Caribou | Moose | Muskox | Arctic Peregrine Falcon | Bar-tailed Godwit | Black Scoter | Bristled-thighed Curlew | Cackling Goose | Common Eider | Emperor Goose | Hudsonian Godwit | King Eider | Kittlitz's Murrelet | McKay's Bunting | Red Knot | Spectacled Eider | Yellow-billed Loon |
| Arctic Wet Sedge-Sphagnum Peatland | 2 | 0 | 0 | 1 | 2 | 2 | 2 | 1 | 1 | 3 | 2 | 3 | 14 | 8 | 1 | 5 | 0 | 0 | 1 | 5 | 10 |
| Boreal Black Spruce Dwarf-Tree Peatland | 1 | 1 | 2 | 1 | 0 | 1 | 0 | 1 | 1 | 2 | 0 | 2 | 1 | 2 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| Large River Floodplain | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Coastal coarse-filter CEs** | | | | | | | | | | | | | | | | | | | | | |
| Arctic Coastal Brackish and Tidal Marsh | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 1 | 2 | 1 |
| Arctic Marine Beach and Beach Meadow | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Landcover Types** | | | | | | | | | | | | | | | | | | | | | |
| Arctic Freshwater Marsh | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Arctic Mesic Tundra | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| Bedrock Cliff, Talus, and Block Fields | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Freshwater | 3 | 3 | 3 | 3 | 2 | 3 | 1 | 3 | 3 | 5 | 3 | 9 | 7 | 3 | 3 | 3 | 2 | 2 | 1 | 4 | 6 |
| Salt Water | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Snow and Ice | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Urban | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unclassified | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |

**Table B-13. List of each CE's preferred habitat as compiled from habitat summary information in the conceptual models. (The conceptual models are provided in Appendix E.)**

| Species | Habitat | Timing |
|---|---|---|
| ***Landscape Species - Birds*** | | |
| Arctic Peregrine Falcon | bare rock/talus/scree | breeding |
| | bay/sound | |
| | cliff | breeding |
| | herbaceous wetland | |
| | lagoon | |
| | riparian areas | breeding |
| | river mouth/tidal river | breeding |
| | sedge grass marshes | |
| | tidal flat/shore | |
| | tundra | |
| | tussock-heath tundra with lakes | |
| Bar-tailed Godwit | along bays and shorelines | winter/non-breeding |
| | coastal tundra | |
| | estuaries | winter/non-breeding |
| | flats along lower river courses | |
| | gently sloping dwarf shrub and graminoid | breeding |
| | intertidal mudflats | winter/non-breeding |
| | mesic sites along the inner sides of coastal lagoons | breeding |
| | offshore shoals | winter/non-breeding |
| | protected coastal lowlands, especially river estuaries where rivers form deltas in lagoons | winter/non-breeding |
| | sandflats near river mouths | winter/non-breeding |
| | sedge-dwarf shrub tundra | |
| | wet sedge meadows with hummocks | breeding |
| Black Scoter | coastal inshore waters | non-breeding |
| | exposed areas and on open water | winter |
| | pond areas above the estuaries of large rivers | breeding |
| | ponds where coastal lowlands adjoin upland habitats | breeding |
| Bristle-thighed Curlew | low shrub/tussock | breeding |
| | mixed shrub thicket/tundra | breeding |
| | mosaic of subarctic and Arctic tundra | both |
| | sedge and graminoid meadows | non-breeding |
| | sedge and lichen meadows | both |
| | shrub meadow | breeding |
| | upland tundra | both |
| Cackling Goose | bay/sound | |
| | cropland/hedgerow | |
| | grassland/herbaceous | |
| | herbaceous wetland | |
| | herbaceous wetlands | |
| | lagoon | |
| | low gradient large and medium rivers, creeks | |

| Species | Habitat | Timing |
|---|---|---|
| | riparian zones | |
| | river mouth/tidal river | |
| | shallow water lakes and ponds | |
| | tidal flat/shore | |
| | tundra | |
| Common Eider | *Elymus* grass meadow | breeding |
| | rocky headland | breeding |
| | rocky seacoasts | winter |
| | salt grass meadow | breeding |
| | shore of a pond or lagoon | breeding |
| | small islands in freshwater | breeding |
| | wet meadow | breeding |
| King Eider | graminoid meadows within a few miles of the sea | breeding |
| | open tundra | breeding |
| Yellow-billed Loon | open tundra along seacoasts or near ponds or lakes | breeding |
| ***Landscape Species - Mammals*** | | |
| Alaskan Hare | alder thickets | |
| | alluvial plains | |
| | coastal lowlands | |
| | open tundra | |
| | sedge flats | |
| | tundra | |
| | wet meadows | |
| | willow thicket | |
| Beaver | floodplains and backwaters | |
| | lakes and ponds | |
| | marshes | |
| | reservoirs and canals | |
| | rivers and streams | |
| Black Bear | avalanche chutes | |
| | mature or old-growth forest with coarse woody debris | |
| | meadows | |
| | mosaic of types | |
| | riparian habitat | |
| | river bottoms | |
| Brown Bear | alluvial plains | |
| | along rivers | |
| | alpine meadows | |
| | alpine slabrock areas | |
| | avalanche chutes | |
| | coastal areas | |
| | grassland | |
| | high elevation meadows | |
| | low elevation meadows | |
| | mountain meadows muskegs | |

| Species | Habitat | Timing |
|---|---|---|
| | mountainous areas | |
| | open Arctic alpine tundra | |
| | open grassy timbered sites | |
| | open shrub communities | |
| | ridges | |
| | riparian areas | |
| | sedge flats | |
| | seeps | |
| | subalpine forests | |
| | wet meadows | |
| Moose | aquatic habitats | |
| | closed-canopy forests | winter |
| | conifer-hardwood forests | |
| | high forage-producing early-successional forests | |
| | mature closed-canopy conifer forests | |
| | riparian shrublands | |
| | wetlands | |
| Muskox | Arctic tundra | |
| | hilltops slopes and plateaus | winter |
| | hummocky lichen mats | winter |
| | moist habitats and riparian vegetation (sedges, shrubs) | summer |
| | mountain avens-lichen heath | |
| | well-vegetated sedge slopes on low-elevation coast | |
| | well-vegetated sedge slopes, valleys of watercourses | |
| | wet meadows | both |
| | willow and birch thickets | |
| | windswept ridges | winter |
| Western Arctic Caribou | Arctic sedge meadow tundra | |
| | Arctic tussock tundra | |
| | large riparian corridors | |
| | lowland treeless tussock tundra | winter |
| | mature coniferous forest | |
| | riparian zone | |
| | rocky ridges with jack pine | |
| | rolling hills | |
| | semi-open and open bogs | |
| | subarctic taiga | |
| | winter in boreal forest | |

| Species | Habitat | Timing |
|---|---|---|
| ***Local Plant Species*** | | |
| *Artemisia globularia ssp. lutea* (a Boreal Wormwood ssp.) | alpine tundra | |
| | willow-herbaceous fellfields | |
| *Artemisia senjavinensis* (Arctic Sage) | barren to dry dwarf shrub herbaceous barrens | |
| | moister dwarf shrub herbaceous meadows | |
| *Cardamine microphylla ssp. blaisdellii* (Littleleaf Bittercress) | alpine ridges | |
| | creek and lake edges | |
| | herbaceous meadows | |
| | hillslopes | |
| | mossy areas | |
| | scree habitats | |
| | wet graminoid-forb or graminoid-*Dryas* slopes | |
| *Carex heleonastes* (Hudson Bay Sedge) | low tussocks | |
| | sedge bogs | |
| | well-developed oligotrophic bogs | |
| | wet meadows | |
| | wet-sandy roadsides | |
| *Claytonia arctica* (Arctic Springbeauty) | alpine tundra | |
| | riverbeds | |
| | scree and talus slopes | |
| | sparsely vegetated fellfields | |
| *Douglasia alaskana* (Alaska Rockjasmine) | alpine dwarf scrub | |
| | alpine sedge - scrub | |
| | *Dryas*-lichen mat | |
| | dwarf shrub tundra | |
| | floodplains | |
| | heath | |
| | rock outcrops | |
| | scree and talus slopes | |
| | sparsely vegetated | |
| *Douglasia beringensis* (Arctic Dwarf-primrose) | alpine slopes and ridges | |
| | *Dryas* heath | |
| | moss | |
| | rock outcrops | |
| | scattered forbs | |
| | sparsely vegetated | |
| *Gentianopsis richardsonii* (Sheared Gentian) | coastal meadow | |
| | heath | |
| *Lupinus kuschei* (Yukon Lupine) | sparsely vegetated poplar floodplain, scattered willows | |
| | sparsely vegetated sand dunes and sand sheet | |
| | sparsely vegetated sandy river terraces | |

| Species | Habitat | Timing |
|---|---|---|
| *Oxytropis arctica var. barnebyana* (Barneby's Locoweed) | barrens | |
| | dry to mesic *Dryas*-herb tundra | |
| | *Dryas* fellfields | |
| | herbaceous shrub tundra | |
| | mixed herbaceous meadows | |
| | open floodplains | |
| | tundra vegetation | |
| | willow heath | |
| *Oxytropis kokrinensis* (Kokrines Oxytrope) | *Dryas* meadows | |
| | fellfields | |
| | scree slopes | |
| *Papaver walpolei* (Walpole's Poppy) | barren scree slopes | |
| | fellfields | |
| | mesic tundra | |
| | willow-heath | |
| *Parrya nauruaq* (Naked-stemmed Wallflower) | barrens | |
| | *Dryas* fellfields | |
| | open *Dryas* mats | |
| | shrub tundra | |
| *Potentilla stipularis* (Circumpolar Cinquefoil) | *Dryas*-heath hummock tundra | |
| | graminoid-*Salix*-*Dryas* tundra | |
| | grassy meadow enclosed by tall willow and alder | |
| | river and stream banks, terraces and floodplains | |
| | sedge tussock | |
| *Primula tschuktshorum* (Chukchi Primrose) | forb-graminoid tundra | |
| | mixed herbaceous-dwarf willow tundra | |
| | moist barren tundra | |
| | open mesic *Dryas* tundra | |
| | stream edges and lake margins | |
| *Puccinellia wrightii ssp. wrightii* (a Wright's Arctic Grass ssp.) | alpine wet meadow | |
| | dwarf shrub meadows | |
| | herbaceous graminoid meadows | |
| *Ranunculus auricomus* (Goldilocks Buttercup) | *Dryas*-heath meadows | |
| | lush meadows | |
| | mixed herbaceous-shrub tundra | |
| | shrub tundra | |
| | streambanks | |
| | willow thickets | |
| *Ranunculus camissonis* (Glacier Buttercup) | *Dryas* mats | |
| | fellfields | |
| | graminoid meadows | |
| | mesic seep/tundra | |
| | wet marshy areas | |
| | wet sedge-grass meadows | |

| Species | Habitat | Timing |
|---|---|---|
| *Ranunculus glacialis ssp. alaskensis* (a Glacier Buttercup ssp.) | barren scree | |
| *Rumex krausei* (Krause's Sorrel) | barrens | |
| | dryas fellfields | |
| | grassy hummocks | |
| | moist-marshy disturbed areas | |
| | open-graminoid meadows | |
| | river terraces | |
| | wet-sedge rock stripes | |
| *Taraxacum carneocoloratum* (Pink Dandelion) | sparsely vegetated alpine slopes | |
| | sparsely vegetated ridges | |
| | sparsely vegetated river terraces and floodplains | |
| | sparsely vegetated rock outcrops | |

## B-2.3 Influences on Future Distribution of CEs: Bioclimate Envelope Modeling Findings

**63**: Where will the distribution of CEs and wildlife ranges likely experience significant change in climate?

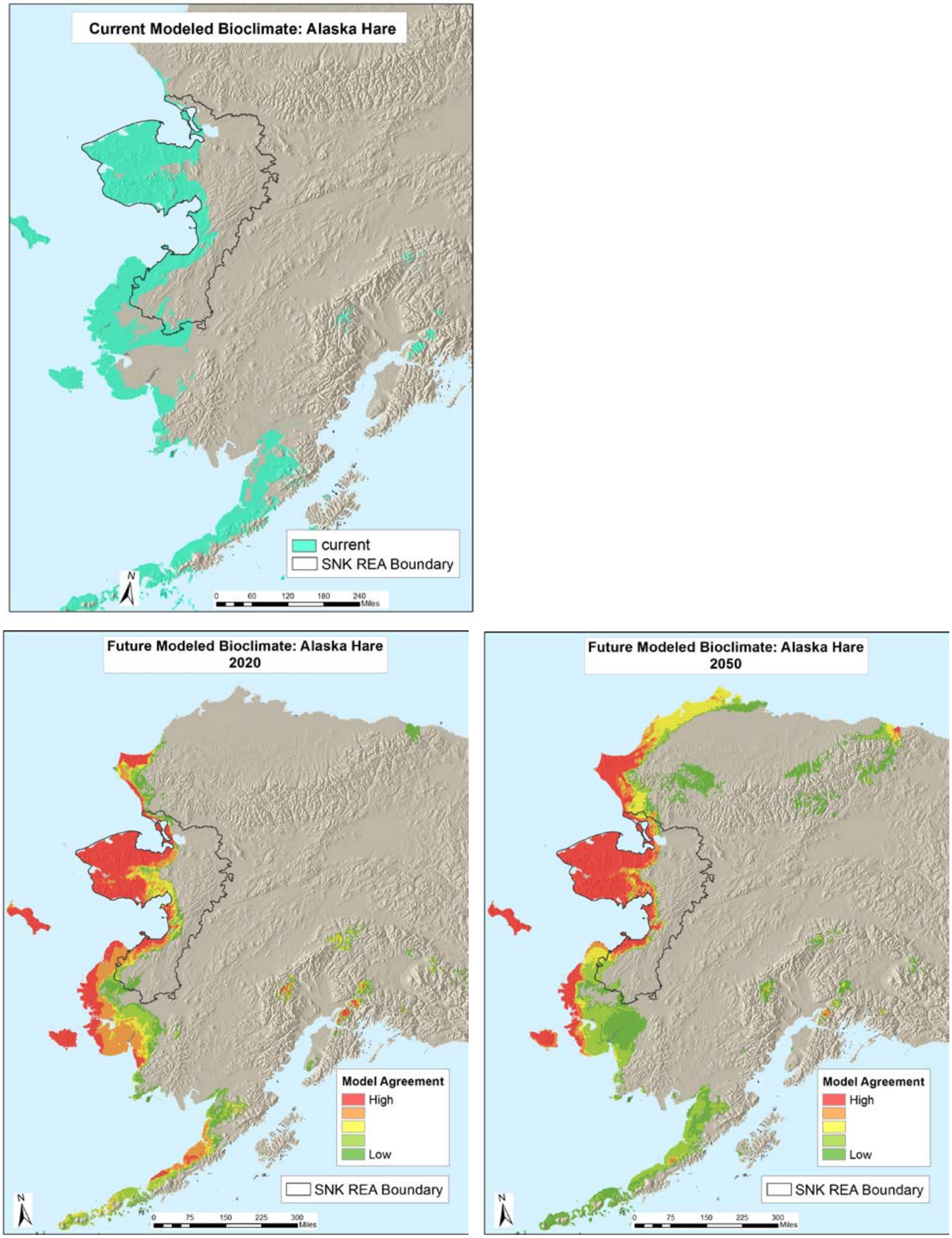
**139**: Given current patterns of occurrence, what is the potential future distribution of invasive species included as CAs?

### B-2.3.1 Landscape Species

#### *B-2.3.1.1 Mammals*

Management questions for conservation elements were addressed by assessing the difference in modeled bioclimatic distributions between the present and the 2050s. Figure B-46 shows an example of current modeled bioclimate as well as the bioclimatic shift for the 2020s and 2050s for the Alaskan hare. Green areas are areas where current and future projections of its climate envelope overlap, indicating where the current distribution of suitable bioclimate may be maintained in the future. The Alaskan hare is predicted to maintain most of its bioclimate within the SNK REA. Blue areas in the southern part of its range indicate areas of envelope contraction from its current extent, suggesting a climate regime shift and potential impact on the Alaskan hare. Pink areas show where current climate conditions are projected by midcentury to occur outside the current bioclimate extent. The Alaskan hare shows a potential for expansion of suitable bioclimate north of the REA.

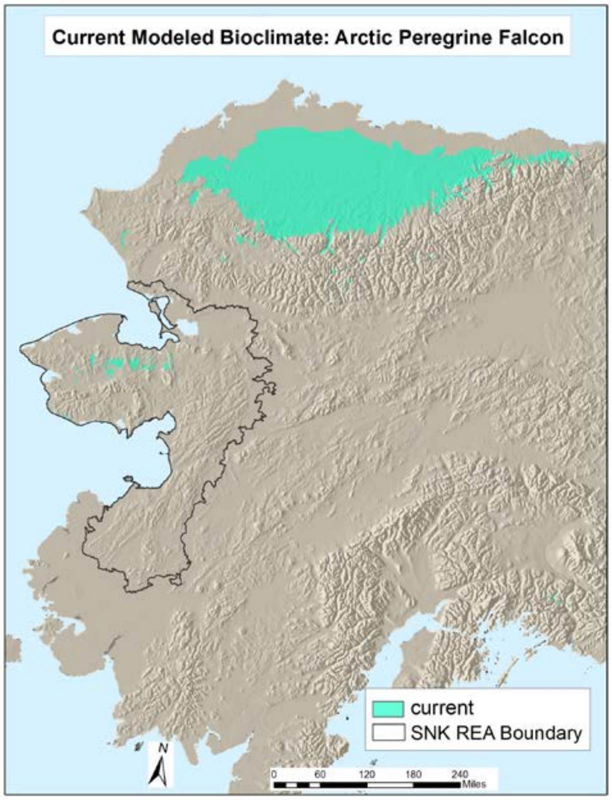
**Figure B-46. Current modeled bioclimate and forecasted suitable bioclimate for Alaskan Hare by 2020s and 2050s.**

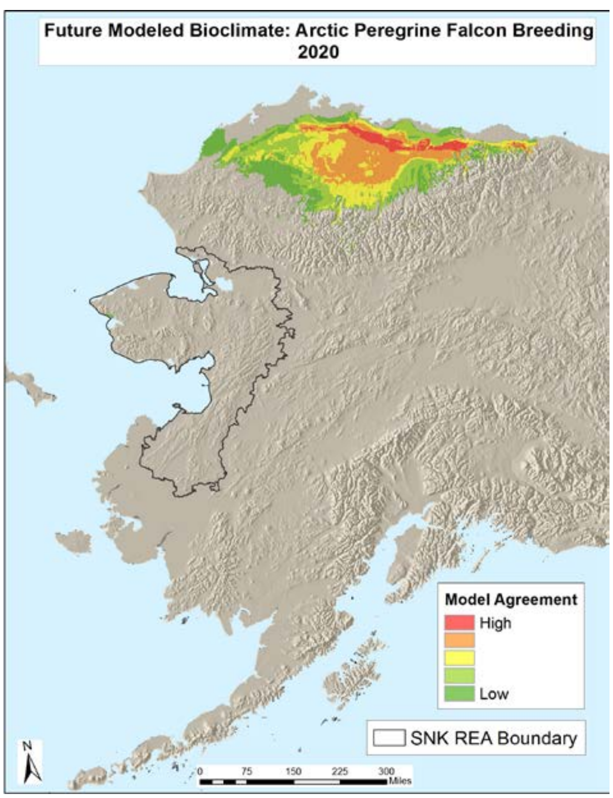


#### *B-2.3.1.2 Birds*

The breeding birds (with the exception of the Arctic peregrine falcon) show a high percentage of their bioclimate envelopes maintained within the REA boundary. Hudsonian godwit (Figure B-50) maintains 55% of its bioclimate within the REA boundary, while bar-tailed godwit (Figure B-51) and bristle-thighed curlew (Figure B-49) maintain about 74% of their bioclimate within the REA. As shown in Figure B-47, Arctic peregrine falcon breeding bioclimate shows 100% contraction within the REA, but is maintained in the northern part of its range. The change summary in the northern extent of the breeding range also shows a potential contraction of bioclimate in the foothills and mid-elevations. Based on the relatively limited distribution data available for summer breeding observations, again the interpretation should focus on the areas of overlap between current and future climate envelopes, and the relative loss of suitable bioclimate across these different summer bird residents. Across all four species, the largest contractions in suitable bioclimate are at the southern end of the modeled envelope of the bar-tailed godwit. This area may be a good candidate for population monitoring. Large areas of suitable bioclimate are projected to remain in the future in the northern parts of the Seward Peninsula, and if climate change does eliminate southern populations, this potential climate refuge may increase in importance as summer breeding habitat for the bar-tailed godwit. The bristle-thighed curlew is projected to experience relatively little loss of bioclimate across its current summer breeding range. Overall, these results suggest that, across all four species, the climatic conditions they currently experience at summer breeding sites will not vanish by midcentury. But these birds face many threats at different life history stages, and continued monitoring is essential to informed management of these conservation elements.

**Figure B-47. Current modeled bioclimate and ensemble model forecast of suitable bioclimate in 2020s and 2050s for Arctic peregrine falcon breeding.**



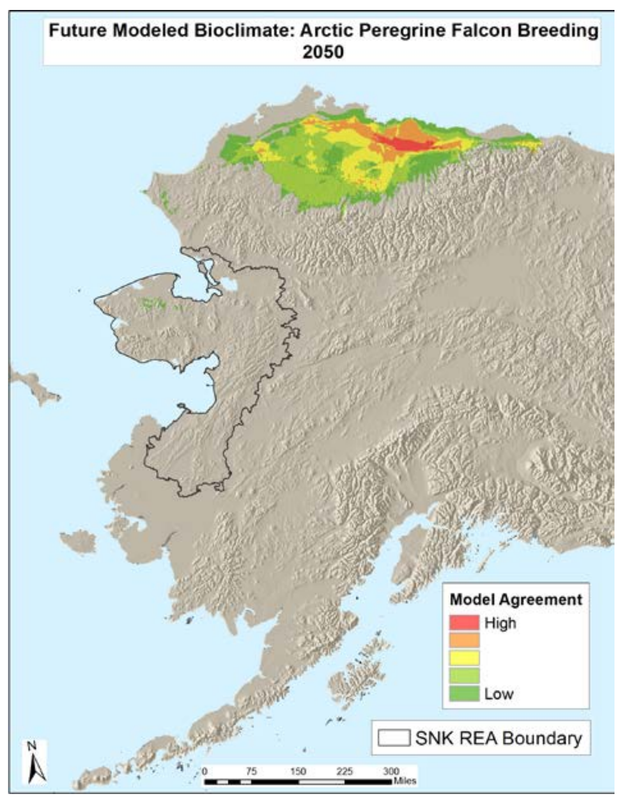



**Figure B-48. Current modeled bioclimate and ensemble model forecast of suitable bioclimate in 2020s and 2050s for bar-tailed godwit breeding.**

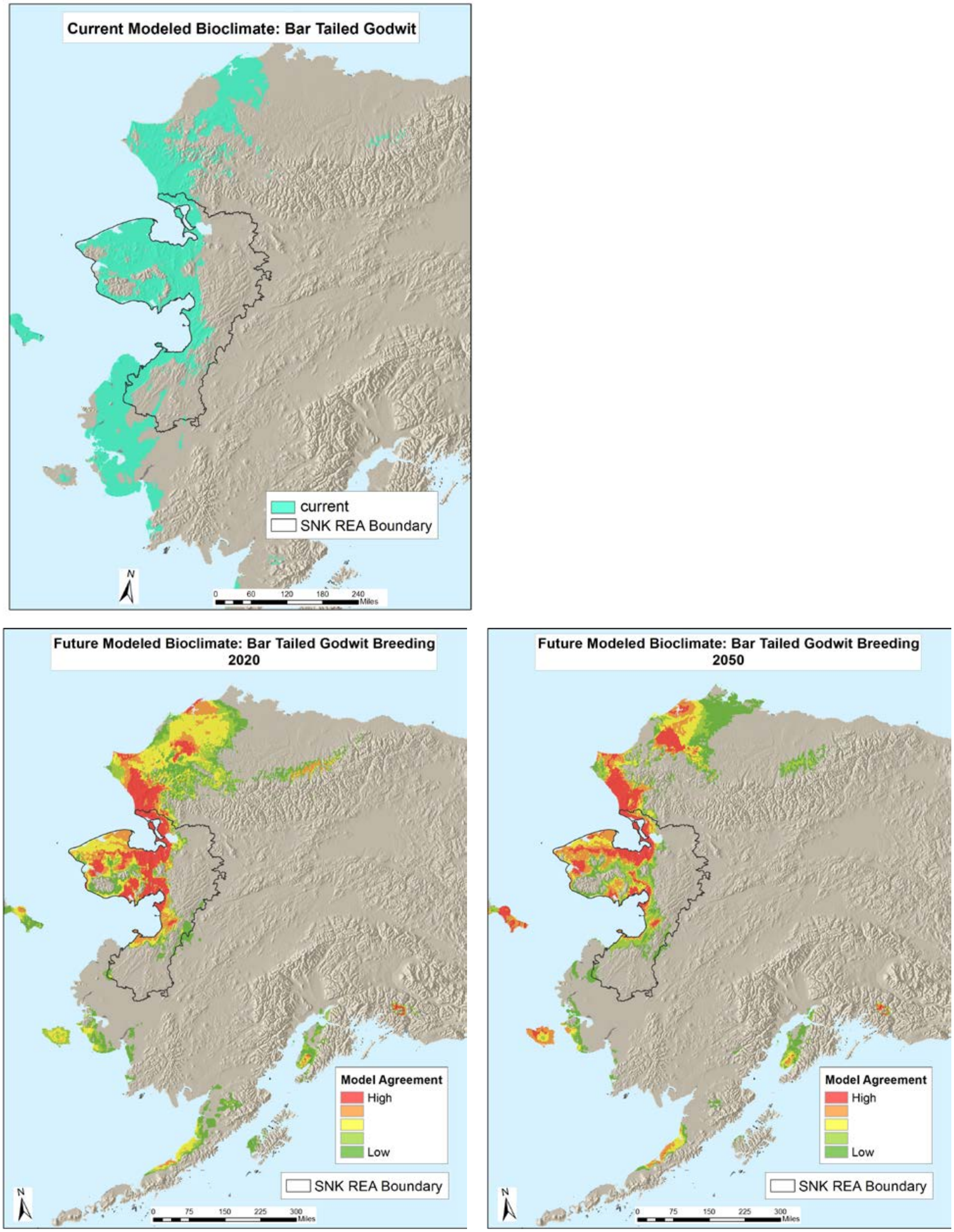


**Figure B-49. Current modeled bioclimate and ensemble model forecast of suitable bioclimate in 2020s and 2050s for bristle-thighed curlew breeding.**

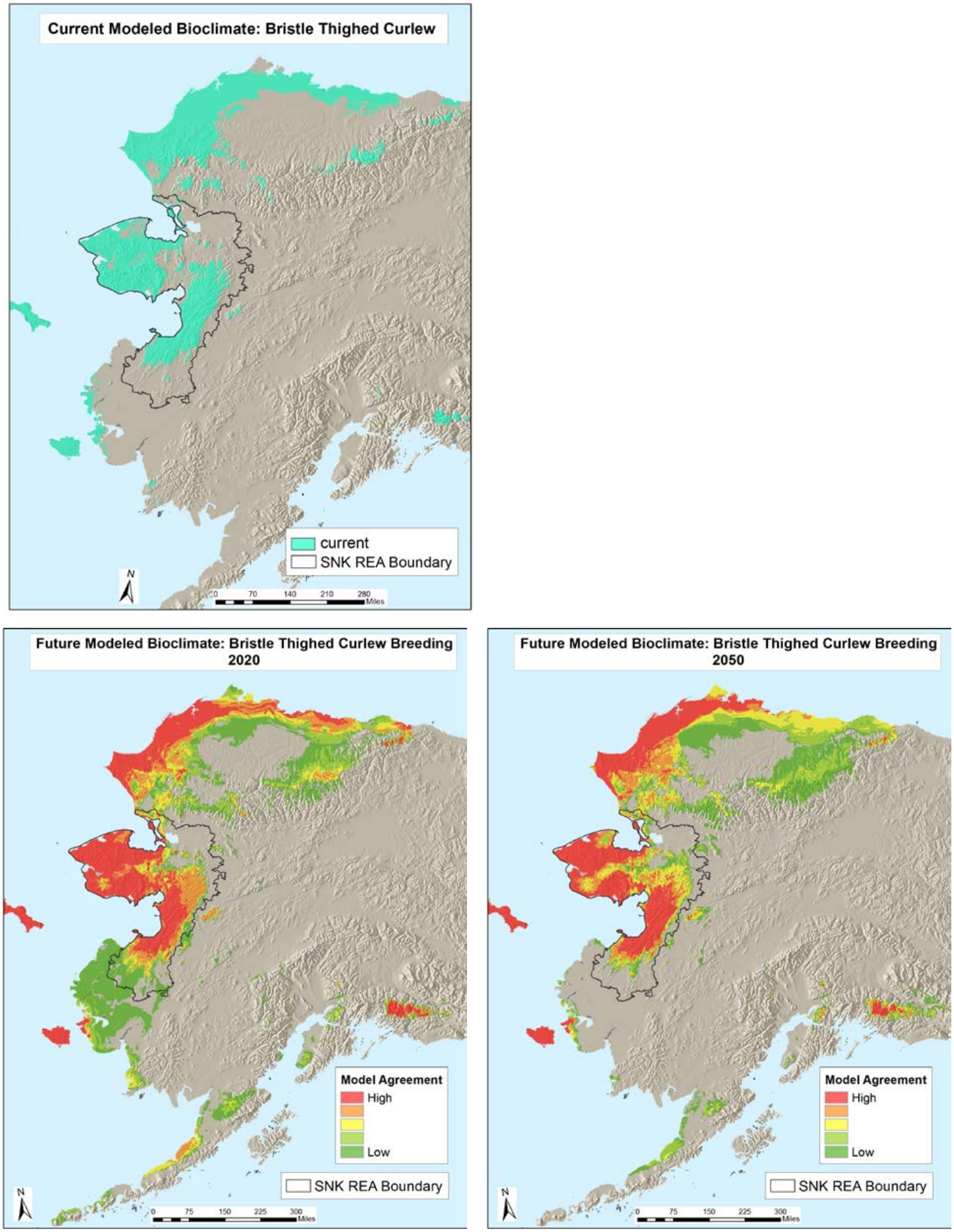
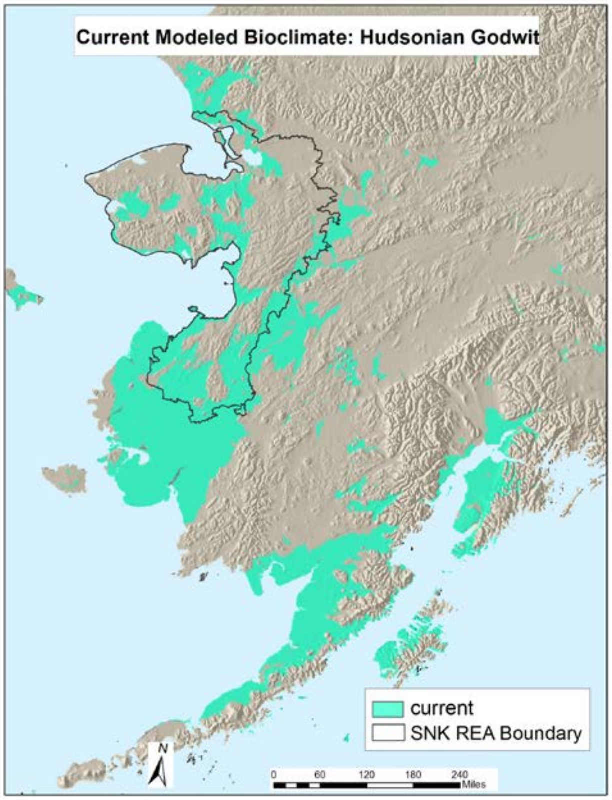
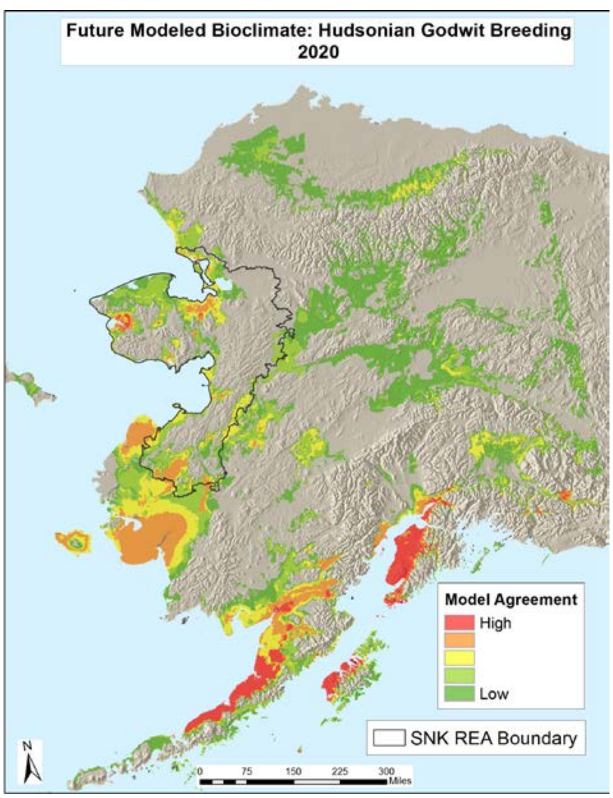
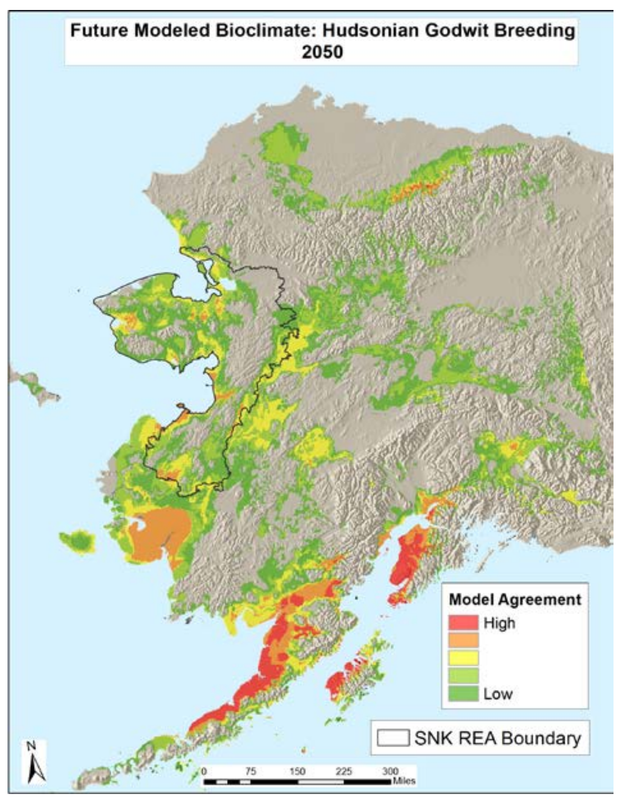


**Figure B-50. Current modeled bioclimate and ensemble model forecast of suitable bioclimate in 2020s and 2050s for Hudsonian godwit breeding.**



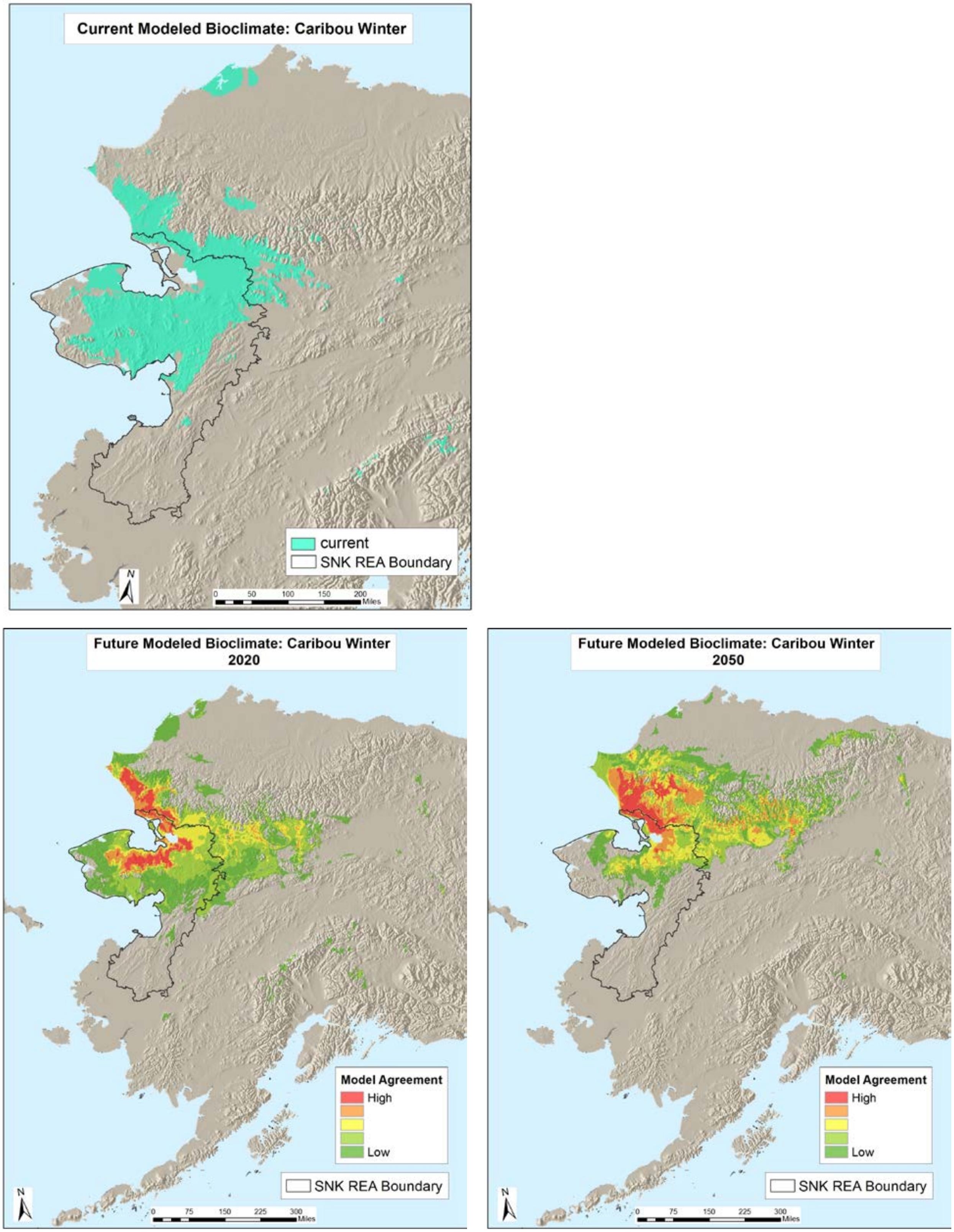
### B-2.3.2 Subsistence Species

As shown in Figure B-51, the change summary for Western Arctic Caribou Herd winter bioclimate illustrates a clear shift of suitable conditions to the north, with contraction in the southern part of the range within the SNK REA. There is a portion of the current range, in the northeastern part of the ecoregion, which is projected to retain suitable winter bioclimate for the modeled caribou population. In considering these results, it is essential to keep in mind the management question as it applies to caribou, and the limited winter season distribution dataset that was used in the modeling effort. The question for caribou could be framed as: *What is the potential impact of climate change on the suitable climatic conditions for the winter range of the Western Arctic caribou herd that frequents the Seward Peninsula?* The model results cannot be generalized for Alaska caribou.

The input data for this model was based on winter distribution (October – April) of caribou locations acquired by satellite telemetry from 1999-2005 (Joly 2011). The baseline climate data used to define the climate envelope used the same baseline years and winter months as defined by the input locality data. The most appropriate way to interpret these results is to focus primarily on the regions of overlap, where suitable bioclimate today is projected to be retained into midcentury. The modeled contraction and expansion of climate envelopes are less reliable, because the full range of conditions to which Alaska caribou are adapted are not included in the locality data used as model input.

Globally, caribou are broadly distributed in both tundra and taiga habitats of holarctic boreal ecosystems. Their wide distribution suggests a broad climate tolerance. They can be relatively nomadic, are flexible in their summer forage habits, and their distributions are not likely to be strongly controlled by a limited set of climate variables. Modeling current and potential future bioclimate distribution for a single herd, as requested by the AMT for this REA, may produce erroneous conclusions by defining a bioclimatic envelope with values more restricted than those in which the species can actually occur. Models of the future bioclimate distribution of the winter range of the Western Arctic Caribou Herd have low model validation scores (low AUC; see section B-2.1.3.2), indicating low model performance.

**Figure B-51. Current modeled bioclimate and ensemble model forecast of suitable bioclimate in 2020s and 2050s for winter range of the Western Arctic Caribou Herd.**



### B-2.3.3 Invasive Species

As shown in Figure B-53, the areas of suitable climate for the invasive species white sweetclover (*Melilotus alba*) and orange hawkweed (*Hieracium aurantiacum*) are not projected to have much overlap with the REA under mid-century climate change scenarios, with the criterion of having high agreement among models. However, under mid-century climate projections, one or two of the five models predicts suitable climatic conditions for white sweetclover in the SNK ecoregion. White sweetclover was run with a spatial extent that included Canada because the distribution of the locality data extended into Canada. This was the only species that required climate surfaces to extend into Canada. Results for invasive species (white sweetclover in particular) should be interpreted with caution due to sample selection bias (locality data mainly sampled along roads) potentially influencing model outputs.

**Figure B-52. Current modeled bioclimate and ensemble model forecast of suitable bioclimate in 2020s and 2050s for orange hawkweed.**

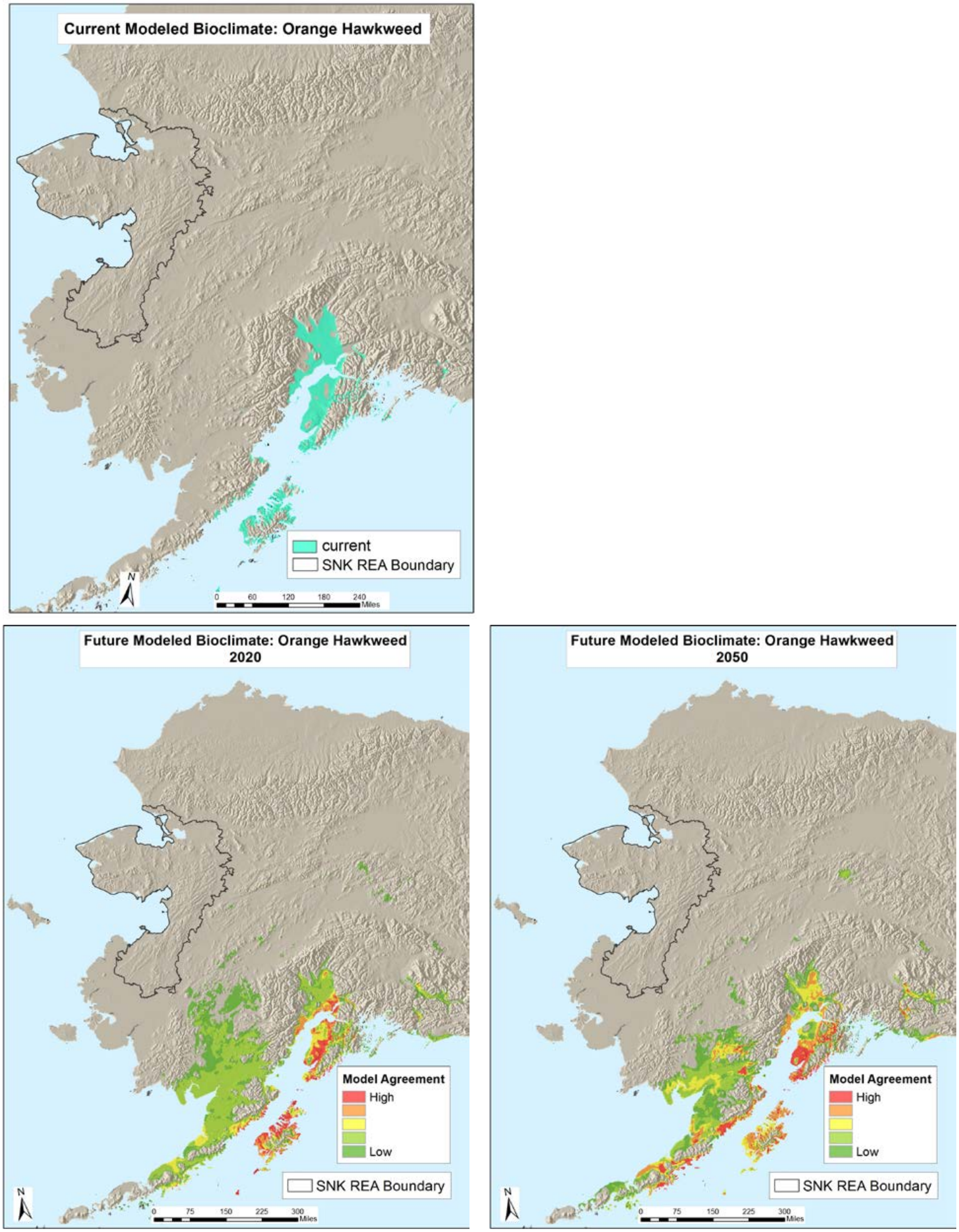
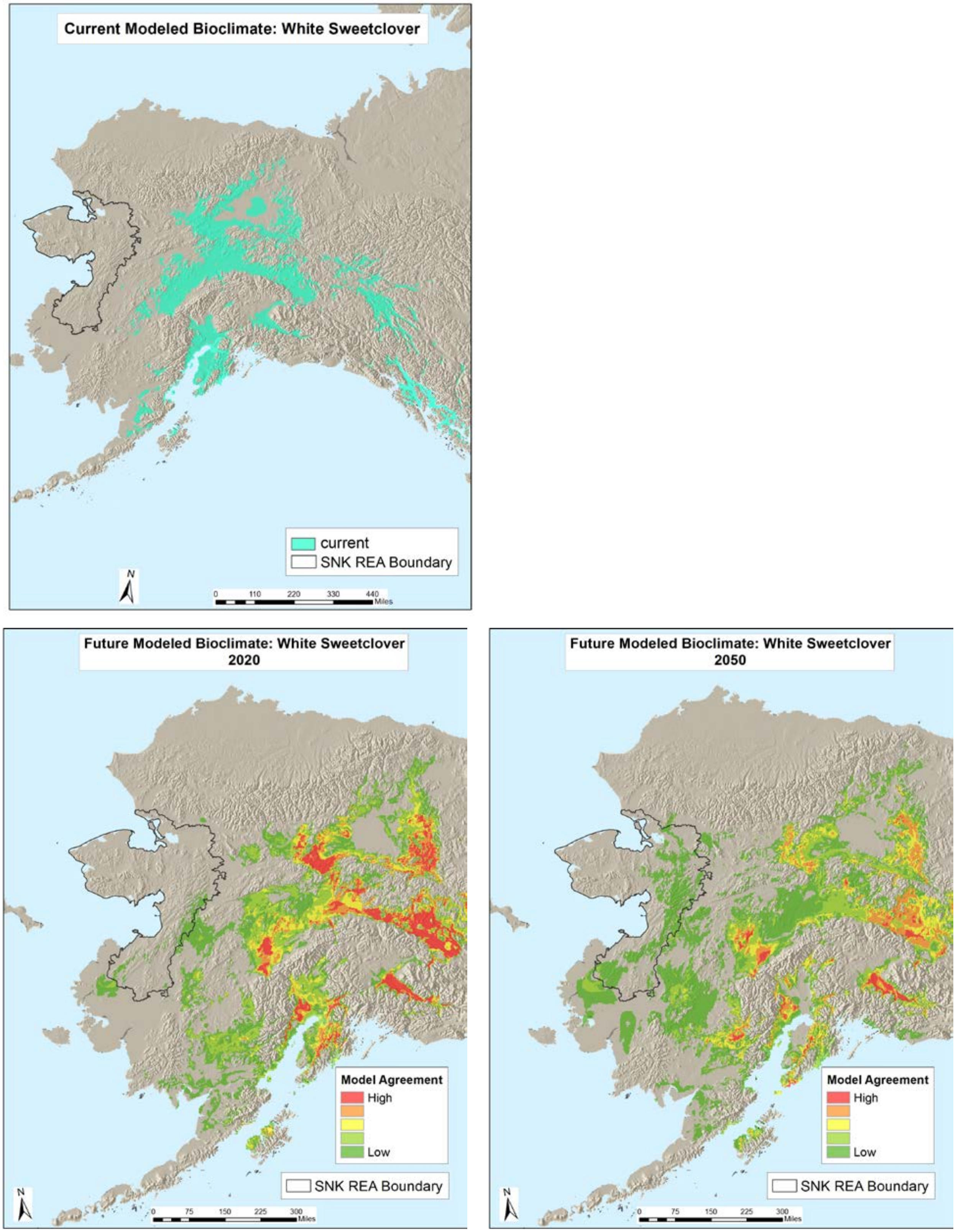


**Figure B-53. Current modeled bioclimate and ensemble model forecast of suitable bioclimate in 2020s and 2050s for white sweetclover.**



Tabular summary tables are also useful for answering management questions by summarizing all model results and looking at patterns of change in the distribution of suitable bioclimate under future climate scenarios within the SNK boundary. These summaries use the change summary layer, which is a raster of the difference between 2050 and current for each species. From this layer the percent of pixels (area) projected to contract, overlap, or expand from the current bioclimate can be determined for each species. Each species change summary layer was clipped to the SNK boundary, so it is important to note that these tabular results do not represent the entire modeled bioclimate of the species. For example, Arctic peregrine falcon shows 100% contraction in 2050 within the SNK boundary (Table B-14), but most of their suitable bioclimate is outside the SNK in northern Alaska. Although Arctic peregrine falcon breeding habitat might be vulnerable to changing climate conditions within the SNK, there is maintained suitable bioclimate in northern Alaska (as shown in Figure B-47).

**Table B-14. Tabular summary of suitable bioclimate change in 2050s within the SNK REA. AUC is listed to show confidence in model results; see B-1.2.1.2 for information about AUC and model evaluation.**

| CE/CA | Species | % Contraction | % Overlap | % Expansion | AUC |
|---|---|---|---|---|---|
| Mammal | Alaskan Hare | 8 | 82 | 11 | .961 |
| Birds | Arctic Peregrine Falcon | 100 | 0 | 0 | .966 |
| | Bar-Tailed Godwit | 20 | 74 | 7 | .918 |
| | Bristle-Thighed Curlew | 0 | 73 | 27 | .920 |
| | Hudsonian Godwit | 21 | 55 | 24 | .965 |
| Subsistence | Western Arctic Caribou Herd: Winter Range | 55 | 38 | 7 | .638 |
| Invasive CAs | Orange Hawkweed | 0 | 0 | 0 | .953 |
| | White Sweetclover | 0 | 0 | 0.4 | .972 |

Table B-15 shows the percent of model agreement (out of 5 GCMs) for presence of suitable bioclimate for a species within the SNK boundary in 2050. Low model agreement = 1-2 GCMs, Medium model agreement = 3-4 GCMs, High model agreement = 5 GCMs. Model agreement adds a degree of confidence when analyzing “overlap” and “expansion” of bioclimate, but not useful for “contraction”. For, example Alaskan hare has 84% high model agreement and 82% overlap, so we can assume with some confidence that Alaskan hare will maintain its bioclimate in the SNK region into mid-century. The Hudsonian godwit has 55% projected overlap, but 75% low model agreement. We are, therefore, less certain about these results because although the change summary shows overlap, only a small number of the five climate models project this future. The species with 100% low model agreement are species that mostly exist outside the SNK boundary, and only a couple GCMs agree that these species’ climate envelopes will either shift or remain in the SNK. High percentage of low model agreement can also be a cause of species with high contraction of their climate envelope. Because model agreement is essentially looking at stacked presence of suitable bioclimate, if there is no suitable bioclimate projected in 2050s then naturally there will be low model agreement. This is why model agreement is not useful for analyzing contraction or loss of suitable bioclimate.

**Table B-15. Percent model agreement of suitable bioclimate for a species within the SNK boundary in 2050s.**

| CE/CA | Species | % low model agreement | % medium model agreement | % high model agreement |
|---|---|---|---|---|
| Mammal | Alaskan Hare | 11 | 5 | 84 |
| Birds | Arctic Peregrine Falcon breeding | 100 | 0 | 0 |
| | Bar Tailed Godwit breeding | 37 | 14 | 48 |
| | Bristle Thighed Curlew breeding | 16 | 15 | 69 |
| | Hudsonian Godwit breeding | 75 | 19 | 6 |
| Subsistence | Caribou Winter | 61 | 23 | 16 |
| Invasive CAs | Orange Hawkweed | 100 | 0 | 0 |
| | White Sweetclover | 100 | 0 | 0 |

Table B-16 aims to answer the question: which variables matter most for the species in question? The table shows the top three variables that contributed to training the Maxent model for each species. "Temp" is average temperature and "precip" is total precipitation. The number next to the variable stands for the corresponding month. For example, March average temperature (temp3) contributed to 55% of model fitting for caribou winter range. Knowing variable contributions for species might help to understand how a species might be vulnerable to climate change and where to focus attention for future research.

**Table B-16. Variable contribution in Maxent model training for modeled current bioclimatic envelopes.**

| CE/CA | Species | Top 3 variable contribution |
|---|---|---|
| Mammal | Alaskan Hare | temp11 31%, precip6 15%, temp4 13% |
| Birds | Arctic Peregrine Falcon | precip7 33%, precip6 32%, temp6 14% |
| | Bar-Tailed Godwit | precip6 74%, precip7 11%, precip8 8% |
| | Bristle-Thighed Curlew | precip6 62%, temp6 29%, precip7 8% |
| | Hudsonian Godwit | temp8 40%, precip8 27%, precip6 16% |
| Subsistence | Western Arctic Caribou Herd: Winter Range | temp3 55%, temp4 16%, temp1 6% |
| Invasive CAs | Orange Hawkweed | temp4 40%, temp3 14%, temp5 8% |
| | White Sweetclover | precip4 27%, temp5 20%, temp8 19% |

### B-2.3.4 Use in Assessment: Overall Uncertainty, Limitations and Data Gaps

Results from bioclimatic envelope analyses should be carefully considered in light of the limitations and uncertainties that constrain virtually all scientific efforts to understand the potential impacts of changes in climate. This is particularly true when the analysis objective requires an understanding of current and future climate conditions at fine spatial and temporal scales relevant to plant and animal populations of management concern. Each of the data inputs and modeling tools has associated limitations and uncertainties that contribute to interpretation in modeling results.

1. Species Occurrence data: A rapid ecological assessment must utilize already existing datasets, which creates some limitations. Our knowledge of biodiversity distributions is based on observation records, which are often biased. The locality data may not have been intended for this kind of analysis, or are incomplete. For example some of the breeding bird localities are

sparse and may not represent the complete distribution of each species summer breeding range. Also, the invasive species data showed significant sample selection bias in that localities were mainly along roads. This creates issues of accuracy in a model that defines a species climatic niche based on the input data for species distributions. Thus, locality data quality should be considered before interpreting results.

2. Climate data: Assessing climate change impacts to biodiversity requires gridded spatial climate data for both the current and the future. For the current, interpolated weather station observations establish baseline climate conditions that are used as input into species distributions modeling algorithms, providing baseline modeled distributions from which to measure potential climate-induced changes. Interpolating point observations from weather stations introduces some uncertainty, particularly for precipitation in regions of complex topography.

   Understanding the impacts of future climate change on biodiversity requires outputs from global or regional climate models. No single climate model outperforms all others in reproducing patterns of observed climate across the globe, which is the primary way climate model performance is evaluated. The climate modeling community supports the concept that multimodel ensembles generally outperform any single climate model in reproducing observed patterns of global climate (Tebaldi & Knutti 2007). Comparing results across a range of models also supports an evaluation of model agreement, which is one approach to decreasing uncertainty in future climate impacts assessments (Tebaldi et al. 2011). Also, the coarse spatial resolution of global climate model outputs must be *downscaled* to finer spatial resolution when analyzing climate change impacts to biodiversity. Downscaling assumes that the relationships observed between climate and topography today, such as cold air drainage into valleys, will be maintained into the future.

3. Niche modeling: Niche models make several simplifying assumptions. They do not account for the varying dispersal ability of different taxa, they do not consider genetic or evolutionary adaptive potential across individuals or populations, and they do not account for the influence of biotic interactions. For this REA, we worked with the AMT to choose species whose distribution is strongly influenced by climate, but there is still a recognized element of oversimplification inherent in ecological niche modeling.

Due to these limitation and uncertainties, these REA results are most useful to understand the relative threat of climate change to the modeled current distribution of the studies species – that is, which species may be more at risk of losing the climate envelope that occurs in their current range? This can help BLM prioritize which species might warrant further study, or at least the need to exercise the precautionary principle in considering the impacts of management decisions. In addition, the range shift results are better suited to focus on where the current range is projected to remain stable, rather than trying to understand where a species might live in the future.

SEWARD PENINSULA – NULATO HILLS – KOTZEBUE LOWLANDS
RAPID ECOREGIONAL ASSESSMENT
FINAL REPORT II-3-c

# Appendix C: Places in the Seward Peninsula – Nulato Hills – Kotzebue Lowlands Ecoregion

**REA Final Report for:**
Department of the Interior
Bureau of Land Management
Rapid Ecoregional Assessments

Version Date: 22 October 2012

**Submitted to:**
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# Tables



# Figures

# C Places

This appendix addresses the management question relating to managed areas and CEs. Data sets on areas identified as important for biodiversity conservation were also requested for this REA; therefore, they are summarized here as well.

**88.** What are the proportions of CEs that coincide with different management areas?

## *C-1 Model Approach*

### C-1.1 Spatial Modeling

"Places" data references data that delineate the location of places as important for conservation, as well as managed areas. Datasets representing places of conservation and management interest were acquired and summarized as three datasets: Sites of High Biodiversity (Places I), Specially Designated Areas of Ecological and Cultural value (Places II), and Other Managed Lands (Places III).

Places Class I: Areas of High Biodiversity were compiled from source data characterizing locations with concentrated at-risk biodiversity or existing source data of a prioritization exercise that identified areas of high conservation significance (e.g., TNC Portfolio Sites, see Table C-1).

Places Class II: Specially Designated Areas of Ecological and Cultural Value were derived from source data delineating legally protected lands/waters (e.g., ACECs, see Table C-2).

Places Class III: Other Managed Lands describe the majority of federal or state managed lands characterized by management for multiple uses (e.g., BLM lands, see Table C-3).

The *Places I class often overlaps spatially with the Places II and III classes*, but differ in that the latter categories include established legal boundaries for land and water units (e.g., ACECs). Areas of high biodiversity significance most frequently imply a more flexible boundary definition and suggest the need for future field verification prior to settling upon new legal or management designations.

**Table C-1. Places class I – Source data for sites of high biodiversity.**

| Source Dataset |
|---|
| TNC Portfolio Sites (2000) |
| Audubon Important Bird Areas (2009) |

**Table C-2. Places class II – Source data for designated sites of ecological and cultural value.**

| Source Dataset |
|---|
| USGS Protected Areas of the United States (PADUS) v1.2 (records attributed as Places II) |

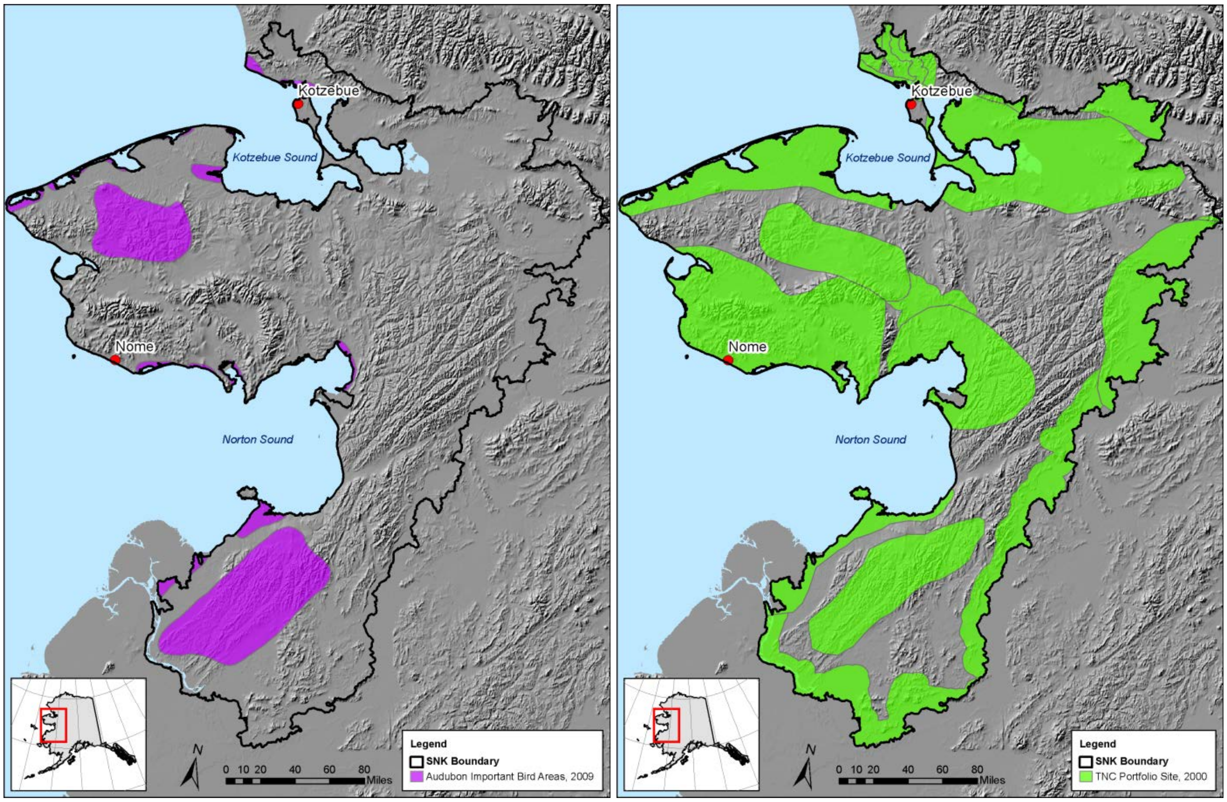
**Table C-3. Places class III – Source data for other managed lands.**

| Source Dataset |
|---|
| USGS Protected Areas of the United States (PADUS) v1.2 (records attributed as Places III) |

### C-1.1.1 Source Data

Three datasets were used as source data to produce the SNK REA Places dataset: Audubon Important Bird Areas (IBA), TNC portfolio sites, and the USGS Protected Areas Database (PADUS) v1.2 (Figure C-1 and Figure C-2 ). Each source dataset was clipped to the SNK REA boundary.

**Figure C-1. Audubon Important Bird Areas (IBA), 2009, map (left) and The Nature Conservancy portfolio sites, 2000 (right).**




### C-1.1.2 Non-Overlapping Raster Places Datasets

Non-overlapping Places I, Places II, and Places III raster datasets were provided to BLM for use in future step-down assessment work (e.g., gap analysis).

#### *C-1.1.2.1 Places Class I: Sites of High Biodiversity*

All Places I source datasets listed above were clipped to the REA boundary, merged, and converted to a raster dataset. *All Places Class II sites were then subtracted from the Places Class I raster dataset.*

Each record in the USGS PADUS 1.2 data was first attributed to one of the three Places categories, and then Places I records were subset.

#### *C-1.1.2.2 Places Class II: Specially Designated Areas of Ecological or Cultural Value*

The USGS PADUS 1.2 was clipped to the REA boundary, merged and converted to a raster dataset.

Each record in the USGS PADUS 1.2 dataset was first attributed to one of the three Places categories, and then Places II records were subset. All Gap Status 1 and 2 were classified as Places II. PADUS 1.2 Places II include: Area of Critical Environmental Concern, National Monument, National Park, National Preserve, National Wildlife Refuge, Research Natural Area, Wild and Scenic Rivers, and Wilderness Area.

#### *C-1.1.2.3 Places Class III: Other Managed Lands*

The Places III source dataset listed above was clipped to the REA boundary and converted to a raster. *All Places I sites were then subtracted from the Places Class III raster dataset.*

Each record in the USGS PADUS 1.2 dataset was first attributed to one of the three Places categories, and then Places III records were subset. All Gap Status 3 and 4 were classified to Places III. PADUS 1.2 Places III include: Bureau of Land Management lands, Stewart River Training Area, and private land inclusions within National Monuments, National Parks, National Preserves, Native Corporation, or Other State.

## C-1.2 Overlapping Polygon Region Places Dataset

An overlapping polygon region places dataset was also produced to enable users to identify the individual source data for each Places site (keeping in mind that in this version of the Places data, Places II and III sites overlap with Places I sites). All attribute fields from each of the three source datasets were included in the Places dataset (see metadata from original source datasets for information about these attributes).

The Places I, II and III polygon source datasets listed above were clipped to the REA boundary. All source datasets were then merged into an overlapping region polygon dataset. Two new attribute fields were added: SourceData (text) and PlacesCd (numeric, short integer). The SourceData attribute was coded as either USGS PADUS1.2, TNC Portfolio Site or Audubon IBA. The PlacesCd attribute was coded as 1, 2, or 3 (representing Places I, II, or III, respectively). All TNC Portfolio site and Audubon IBA records were selected and the PlacesCd was coded as 1 (Places I - Sites of High Biodiversity). All GapStatus 1 and 2 records from the PADUS1.2 were selected and the Places CD was coded as 2 (Places II – Specially Designated Sites of Ecological and Cultural Value). All GapStatus 3 and 4 records from the PADUS1.2 were selected and the PlacesCd was coded as 3 (Places III – Other Managed Lands).

Places II and Places III do not overlap and cover the entire extent of the SNK study area. Places I overlap with both Places II and Places III.

# *C-2 Findings in Terms of Management Questions*

To answer the primary management question, each CE distribution was intersected with the USGS Protected Areas Database (PADUS) v1.2 primary land management description/designation class (Figure C-2). The percentage of the total area of each CE across the ecoregion that occurs within each PADUS primary land management description/designation type was calculated (Table C-4). The statistics in Table C-4 show the proportion of overlap of each CE with various categories of managed lands (e.g., BLM lands).

The Bureau of Land Management manages the largest proportion of land (~43%) within the ecoregion compared to any other land owner or managing agency. Consequently, for most CEs the majority of their distribution occurs on BLM lands (column three in Table C-4), with some notable exceptions (see bold values in Table C-4). For example, 61% of estuaries occur on Native Corporation lands; the majority of lakes, over 40% for all four lake classes, occur in national wildlife refuges; 43% of pink salmon, 51% of sheefish, and 50% of sockeye salmon habitat occur on Native Corporation lands; 98% of Arctic active inland dunes occur in wilderness areas; 61% of Arctic dwarf shrub-sphagnum peatland occurs in national wildlife refuges; 68% of Arctic coastal brackish and tidal marsh occurs on Native Corporation lands; 48% of large river floodplains occur in national wildlife refuges; and 50% of marine mammal haul-out sites and concentration areas and 48% of seabird colonies occur on Native Corporation lands.

High percentages within a single land management class may reflect that a CE has a very small, and geographically limited, distribution (e.g., Arctic active inland dunes or hot springs). The statistics in Table C-4 reflect that native communities/Native Corporation lands are predominantly located in lowlands and along the coast (i.e., estuaries and tidal marshes); and that current National Wildlife Refuges within the ecoregion are also predominantly located in lowlands.

**Figure C-2. USGS Protected Areas Database (PADUS) v1.2 primary land management description/designation map (left) and example map of Arctic Shrub-Tussock Tundra CE distribution (black) overlaid with USGS PADUS primary land management description/designation map (right).**

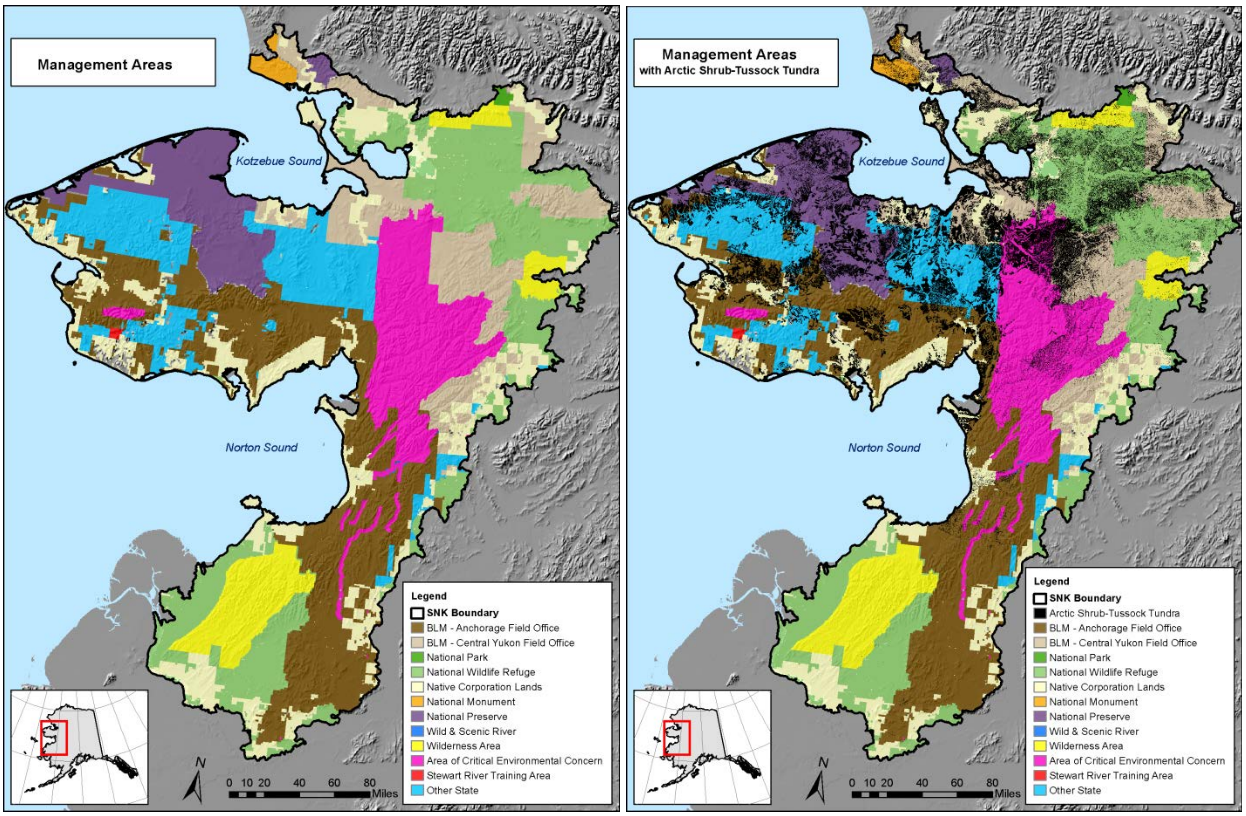


**Table C-4. Percent of CE distribution within each USGS Protected Areas Database (PADUS) v1.2 primary land management description/designation class. Primary land management description/designations (columns) are ordered in the table from classes with the most extensive distributions in the ecoregion (i.e., Bureau of Land Management) to classes with the least extensive distributions (i.e. Wild & Scenic River). For each CE, the cell with the largest percentage (i.e., distribution) is in bold. The mapped or modeled spatial distribution of all CEs was treated in a raster format, resulting in *acreage* totals for all CEs in the "Total Area" column (rather than, for example, stream and fish CEs being reported in miles). The key is understanding the approximate proportion of overlap between CEs and different categories of ownership/management.**

| Element Name | Total Area of CE (acres) | Bureau of Land Management - Anchorage | Bureau of Land Management - Central Yukon | Area of Critical Environmental Concern | National Wildlife Refuge | Native Corporation Lands | Other State | National Preserve | Wilderness Area | National Monument | National Park | Stewart River Training Area | Wild & Scenic River |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aquatic Coarse Filter** | | | | | | | | | | | | | |
| Headwater Streams | 1,276,132 | **22** | 11 | 10 | 19 | 15 | 10 | 7 | 6 | 1 | 0 | 0 | 0 |
| Low-gradient Streams | 367,340 | 19 | 7 | 8 | **24** | 19 | 9 | 8 | 5 | 1 | 0 | 0 | 0 |
| Rivers | 91,127 | **22** | 14 | 19 | 9 | 10 | 11 | 6 | 8 | 0 | 0 | 0 | 0 |
| Estuaries | 15,915 | 5 | 6 | 0 | 6 | **61** | 4 | 15 | 0 | 3 | 0 | 0 | 0 |
| Lakes – Large, Connected | 611,179 | 12 | 3 | 0 | **43** | 21 | 1 | 15 | 2 | 3 | 0 | 0 | 0 |
| Lakes – Large, Disconnected | 118,861 | 6 | 4 | 0 | **48** | 30 | 1 | 8 | 1 | 1 | 0 | 0 | 0 |
| Lakes – Small, Connected | 77,755 | 10 | 7 | 2 | **42** | 20 | 4 | 13 | 2 | 1 | 0 | 0 | 0 |
| Lakes – Small, Disconnected | 270,525 | 9 | 5 | 1 | **42** | 29 | 3 | 9 | 2 | 1 | 0 | 0 | 0 |
| Hot Springs | 2 | 22 | **33** | 0 | 11 | 11 | 11 | 11 | 0 | 0 | 0 | 0 | 0 |
| **Aquatic Fine Filter** | | | | | | | | | | | | | |
| Alaska Blackfish | 405,332 | 10 | 5 | 1 | **38** | 28 | 3 | 13 | 1 | 1 | 1 | 0 | 0 |
| Chinook Salmon | 88,155 | 24 | 5 | 15 | 16 | **28** | 2 | 0 | 9 | 0 | 0 | 0 | 0 |
| Chum Salmon | 86,864 | 25 | 4 | 10 | 17 | **32** | 6 | 1 | 4 | 0 | 0 | 0 | 0 |
| Coho Salmon | 72,637 | 26 | 11 | **29** | 7 | 11 | 7 | 1 | 8 | 0 | 0 | 0 | 0 |
| Dolly Varden | 607,419 | **27** | 14 | 22 | 7 | 8 | 9 | 5 | 8 | 0 | 0 | 0 | 0 |
| Pink Salmon | 55,783 | 24 | 1 | 7 | 12 | **43** | 7 | 2 | 5 | 0 | 0 | 0 | 0 |
| Sheefish | 26,056 | 2 | 2 | 1 | 40 | **51** | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| Sockeye Salmon | 17,431 | 9 | 3 | 8 | 22 | **48** | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Terrestrial Coarse Filter - Ecological Systems** | | | | | | | | | | | | | |
| Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra | 3,183,136 | **32** | 4 | 12 | 13 | 7 | 11 | 4 | 17 | 0 | 0 | 0 | 0 |
| Arctic Acidic Sparse Tundra | 568,923 | 24 | 0 | 7 | 0 | 22 | **42** | 4 | 0 | 0 | 0 | 0 | 0 |
| Arctic Active Inland Dunes | 4,044 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **98** | 0 | 2 | 0 | 0 |
| Arctic Coastal Brackish and Tidal Marsh | 216,766 | 9 | 4 | 0 | 9 | **68** | 2 | 6 | 0 | 1 | 0 | 0 | 0 |
| Arctic Dwarf-Shrubland | 1,873,633 | **29** | 7 | 18 | 10 | 12 | 12 | 4 | 6 | 2 | 0 | 0 | 0 |
| Arctic Dwarf-Shrub-Sphagnum Peatland | 1,121,717 | 7 | 5 | 0 | **61** | 19 | 1 | 3 | 3 | 1 | 0 | 0 | 0 |

| Element Name | Total Area of CE (acres) | Bureau of Land Management - Anchorage | Bureau of Land Management - Central Yukon | Area of Critical Environmental Concern | National Wildlife Refuge | Native Corporation Lands | Other State | National Preserve | Wilderness Area | National Monument | National Park | Stewart River Training Area | Wild & Scenic River |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arctic Mesic Alder | 2,455,966 | **31** | 10 | 10 | 10 | 11 | 5 | 2 | 21 | 0 | 0 | 0 | 0 |
| Arctic Mesic-Wet Willow Shrubland | 1,261,850 | 16 | 6 | 3 | **28** | 21 | 9 | 7 | 9 | 0 | 1 | 0 | 0 |
| Arctic Scrub Birch-Ericaceous Shrubland | 6,041,350 | 18 | 11 | 9 | 16 | 12 | **21** | 7 | 4 | 1 | 0 | 0 | 0 |
| Arctic Shrub-Tussock Tundra | 6,025,008 | 15 | **18** | 10 | 16 | 8 | 17 | 15 | 0 | 1 | 0 | 0 | 0 |
| Arctic Wet Sedge Tundra | 2,688,252 | 19 | 8 | 4 | 14 | **21** | 16 | 16 | 1 | 1 | 0 | 0 | 0 |
| Boreal Black or White Spruce Forest and Woodland | 5,472,382 | **28** | 13 | 20 | 17 | 13 | 3 | 0 | 6 | 0 | 0 | 0 | 0 |
| Boreal Mesic Birch-Aspen Forest | 1,142,698 | **25** | 18 | 10 | 21 | 19 | 2 | 0 | 3 | 0 | 0 | 0 | 0 |
| Boreal White or Black Spruce - Hardwood Forest | 1,146,740 | **30** | 11 | 5 | 20 | 23 | 5 | 0 | 5 | 0 | 0 | 0 | 0 |
| Large River Floodplain | 307,277 | 1 | 1 | 2 | **48** | 40 | 3 | 0 | 6 | 0 | 0 | 0 | 0 |
| **Local Species** | | | | | | | | | | | | | |
| Arctic Char | 451 | 0 | 0 | **100** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Emperor Goose | 1,512,110 | **29** | 1 | 0 | 2 | 28 | 18 | 22 | 0 | 0 | 0 | 0 | 0 |
| Hudsonian Godwit | 25,093,501 | **21** | 12 | 12 | 20 | 13 | 8 | 6 | 8 | 1 | 0 | 0 | 0 |
| Kittlitz's Murrelet | 5,968,019 | **38** | 1 | 1 | 0 | 16 | 30 | 11 | 0 | 2 | 0 | 0 | 0 |
| McKay's Bunting | 12,082,313 | **37** | 3 | 10 | 10 | 19 | 8 | 0 | 12 | 0 | 0 | 0 | 0 |
| Red Knot | 6,341,049 | **34** | 2 | 6 | 0 | 23 | 28 | 7 | 0 | 1 | 0 | 0 | 0 |
| Spectacled Eider | 11,479,970 | 19 | 11 | 1 | 8 | **22** | 18 | 18 | 1 | 2 | 0 | 0 | 0 |
| **Terrestrial Landscape Species - Mammals** | | | | | | | | | | | | | |
| Alaskan Hare | 25,688,098 | **31** | 4 | 11 | 9 | 14 | 14 | 10 | 6 | 1 | 0 | 0 | 0 |
| Beaver | 34,224,063 | **23** | 11 | 12 | 18 | 14 | 11 | 4 | 6 | 1 | 0 | 0 | 0 |
| Black Bear | 15,639,312 | **23** | 14 | 18 | 21 | 13 | 4 | 0 | 7 | 0 | 0 | 0 | 0 |
| Brown Bear | 28,205,920 | **21** | 13 | 14 | 15 | 13 | 12 | 6 | 6 | 1 | 0 | 0 | 0 |
| Moose | 25,483,759 | 15 | 13 | 11 | **17** | 14 | 16 | 11 | 2 | 1 | 0 | 0 | 0 |
| Muskox | 19,432,908 | **21** | 11 | 15 | 11 | 8 | 20 | 13 | 2 | 1 | 0 | 0 | 0 |
| Western Arctic Caribou | 19,780,264 | 17 | 17 | **18** | 7 | 9 | 17 | 13 | 2 | 1 | 0 | 0 | 0 |
| **Terrestrial Landscape Species - Birds** | | | | | | | | | | | | | |
| Arctic Peregrine Falcon | 14,170,464 | 8 | 21 | 17 | **22** | 14 | 7 | 5 | 4 | 1 | 0 | 0 | 0 |
| Bar-tailed Godwit | 24,226,496 | **26** | 6 | 12 | 10 | 15 | 15 | 7 | 7 | 1 | 0 | 0 | 0 |
| Black Scoter | 21,191,119 | 18 | 8 | 3 | **26** | 20 | 10 | 9 | 5 | 1 | 0 | 0 | 0 |
| Bristle-thighed Curlew | 15,537,751 | **27** | 1 | 7 | 9 | 13 | 19 | 14 | 10 | 0 | 0 | 0 | 0 |
| Cackling Goose | 9,990,995 | 14 | 8 | 3 | **33** | 25 | 3 | 9 | 3 | 1 | 1 | 0 | 0 |
| Common Eider | 3,573,260 | 12 | 11 | 0 | 6 | 26 | 6 | **35** | 0 | 4 | 0 | 0 | 0 |
| King Eider | 11,385,722 | 26 | 2 | 4 | 0 | 16 | **29** | 23 | 0 | 0 | 0 | 0 | 0 |

| Element Name | Total Area of CE (acres) | Bureau of Land Management - Anchorage | Bureau of Land Management - Central Yukon | Area of Critical Environmental Concern | National Wildlife Refuge | Native Corporation Lands | Other State | National Preserve | Wilderness Area | National Monument | National Park | Stewart River Training Area | Wild & Scenic River |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yellow-billed Loon | 4,603,796 | 9 | 18 | 1 | 3 | 15 | 15 | **37** | 0 | 3 | 0 | 0 | 0 |
| **Species Assemblages** | | | | | | | | | | | | | |
| Marine mammal haul-out sites and concentration areas | 37,889 | 11 | 5 | 0 | 9 | **50** | 9 | 16 | 0 | 1 | 0 | 0 | 0 |
| Seabird Colonies | 361,908 | 19 | 4 | 0 | 3 | **48** | 7 | 9 | 0 | 10 | 0 | 0 | 0 |
| Waterfowl concentration areas | 10,321,473 | 11 | 6 | 2 | **35** | 23 | 4 | 14 | 3 | 1 | 0 | 0 | 0 |
| **Reindeer** | | | | | | | | | | | | | |
| Reindeer Grazing Allotments | 13,751,193 | **29** | 6 | 1 | 0 | 16 | 28 | 20 | 0 | 0 | 0 | 0 | 0 |
| **Caribou Habitat Ranges** | | | | | | | | | | | | | |
| WAH caribou migratory range | 3,076,610 | 0 | 21 | 0 | **39** | 21 | 1 | 4 | 8 | 6 | 0 | 0 | 0 |
| WAH caribou winter range | 14,140,318 | 21 | 15 | **26** | 11 | 7 | 13 | 7 | 0 | 0 | 0 | 0 | 0 |

**SEWARD PENINSULA – NULATO HILLS – KOTZEBUE LOWLANDS**
**RAPID ECOREGIONAL ASSESSMENT**
**FINAL REPORT II-3-c**

# Appendix D: Other Assessments in the Seward Peninsula – Nulato Hills – Kotzebue Lowlands Ecoregion

**REA Final Report for:**
Department of the Interior
Bureau of Land Management
Rapid Ecoregional Assessments

Version Date: 22 October 2012


**Submitted to:**
Scott Guyer, Ecoregional Assessment Project Manager
Department of the Interior
Bureau of Land Management
222 West 7th Avenue, Suite 13
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Arlington, VA 22203

Patrick Crist, Patrick Comer, Co-Principal Investigators

# Contents

# Tables



# Figures

# D OTHER ASSESSMENTS

The first two sections of this appendix contain substantial additional content relating to the socioeconomic and subsistence assessments; they address in detail a number of questions that were only broadly touched on or else not addressed at all in the main report due to space limitations. These sections also provide substantial additional background on the kind of data that were available to inform these assessments.

The final four chapters of this appendix address additional questions looking at the relationship between four CAs (climate, permafrost, fire, and development) and CEs and human communities. These, too, were generally not addressed in the main report (unless otherwise noted). Both detailed methods (as relevant) and discussion are included for all four of these appendix chapters.

## *D-1 Socioeconomic Assessment*

**16**. (a) What is the current socio-economic profile for each community? (b) How are they likely to change under development and climate change scenarios?

### D-1.1 Introduction

This section focuses on population, income and employment which are important elements of material well-being but don't give an accurate or complete picture of living conditions in remote rural Alaska. Taken alone, economic indicators would paint a dismal picture of some communities. However, a 2005 study using the Survey of Living Conditions in the Arctic showed that almost 90% of respondents were satisfied or very satisfied with their lives, and 66% had not considered moving away. According to estimates from the study, life satisfaction came from family ties, social support, and opportunities to socialize through shared activities such as subsistence hunting. Jobs were negatively related to life satisfaction, probably because they take time away from subsistence activities. Subsistence is the most important shared activity and is discussed in section D-2.

### D-1.2 Population and Demographic Structure

Table D-1 shows community populations from 1990 to 2010. Data for this table come from the US Census. Because the census is conducted once every 10 years, the most recent data are from 2010. The American Community Survey has replaced the US Census long form (detailed questions about income, housing, education, and migration) and produces annual results. However, the sample size for the ACS is too small for the results for rural Alaska communities to be useful. In 2010, total population was 17, 674, a very small increase of 312 people over 2000. In general, small places are losing population. Of the 10 communities with 500 or more people in 2000, one lost population between 2000 and 2010. Of the 2 communities with populations less than 100, both lost population. Population growth was higher from 1990 to 2000, than from 2000 to 2010, increasing by 1,711 from 15,651 to 17,362.

**Table D-1. Population by community for 1990, 2000, and 2010 and percentage change in population.**

| Community | 1990 | 2000 | 2010 | Annual change: 1990-2000 | Annual change: 2000-2010 | Annual change: 1990-2010 |
|---|---|---|---|---|---|---|
| Ambler | 311 | 309 | 258 | -0.1% | -1.8% | -0.9% |
| Anvik | 82 | 104 | 85 | 2.4% | -2.0% | 0.2% |
| Brevig Mission | 198 | 276 | 388 | 3.4% | 3.5% | 3.4% |
| Buckland | 318 | 406 | 416 | 2.5% | 0.2% | 1.4% |
| Deering | 157 | 136 | 122 | -1.4% | -1.1% | -1.3% |
| Elim | 264 | 313 | 330 | 1.7% | 0.5% | 1.1% |
| Golovin | 127 | 144 | 156 | 1.3% | 0.8% | 1.0% |
| Grayling | 208 | 194 | 194 | -0.7% | 0.0% | -0.3% |
| Holy Cross | 277 | 227 | 178 | -2.0% | -2.4% | -2.2% |
| Kaltag | 240 | 230 | 190 | -0.4% | -1.9% | -1.2% |
| Kiana | 385 | 388 | 361 | 0.1% | -0.7% | -0.3% |
| Kotzebue | 2751 | 3082 | 3201 | 1.1% | 0.4% | 0.8% |
| Koyuk | 231 | 297 | 332 | 2.5% | 1.1% | 1.8% |
| Koyukuk | 126 | 101 | 96 | -2.2% | -0.5% | -1.4% |
| Marshall | 273 | 349 | 414 | 2.5% | 1.7% | 2.1% |
| Mountain Village | 674 | 755 | 813 | 1.1% | 0.7% | 0.9% |
| Nome | 3500 | 3505 | 3598 | 0.0% | 0.3% | 0.1% |
| Noorvik | 531 | 634 | 668 | 1.8% | 0.5% | 1.2% |
| Nulato | 359 | 336 | 264 | -0.7% | -2.4% | -1.5% |
| Pilot Station | 463 | 550 | 568 | 1.7% | 0.3% | 1.0% |
| Pitkas Point | 135 | 125 | 109 | -0.8% | -1.4% | -1.1% |
| Russian Mission | 246 | 296 | 312 | 1.9% | 0.5% | 1.2% |
| Selawik | 596 | 772 | 829 | 2.6% | 0.7% | 1.7% |
| Shaktoolik | 178 | 230 | 251 | 2.6% | 0.9% | 1.7% |
| Shishmaref | 456 | 562 | 563 | 2.1% | 0.0% | 1.1% |
| Shungnak | 223 | 256 | 262 | 1.4% | 0.2% | 0.8% |
| St. Mary's | 441 | 500 | 507 | 1.3% | 0.1% | 0.7% |
| St. Michael | 295 | 368 | 401 | 2.2% | 0.9% | 1.5% |
| Stebbins | 400 | 547 | 556 | 3.2% | 0.2% | 1.7% |
| Teller | 151 | 268 | 229 | 5.9% | -1.6% | 2.1% |
| Unalakleet | 714 | 747 | 688 | 0.5% | -0.8% | -0.2% |
| Wales | 161 | 152 | 145 | -0.6% | -0.5% | -0.5% |
| White Mountain | 180 | 203 | 190 | 1.2% | -0.7% | 0.3% |

Figure D-1 shows the percentage change in population from 2000 to 2010. Communities were almost evenly split between gaining and losing population. Most changed very little, averaging less than 10% change over 10 years.

**Figure D-1. Population change by community, 2000 to 2010.**

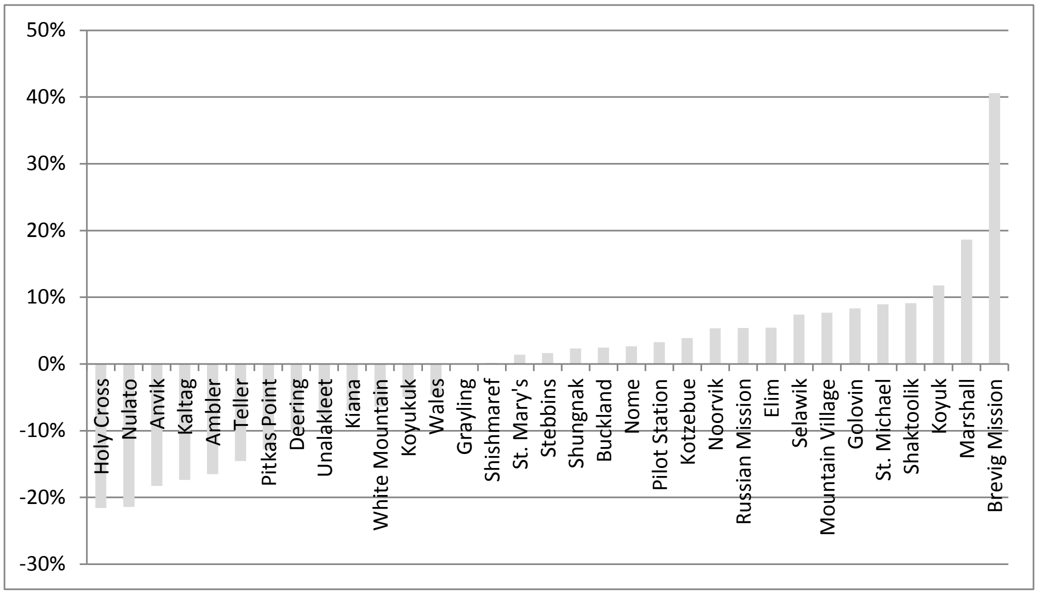
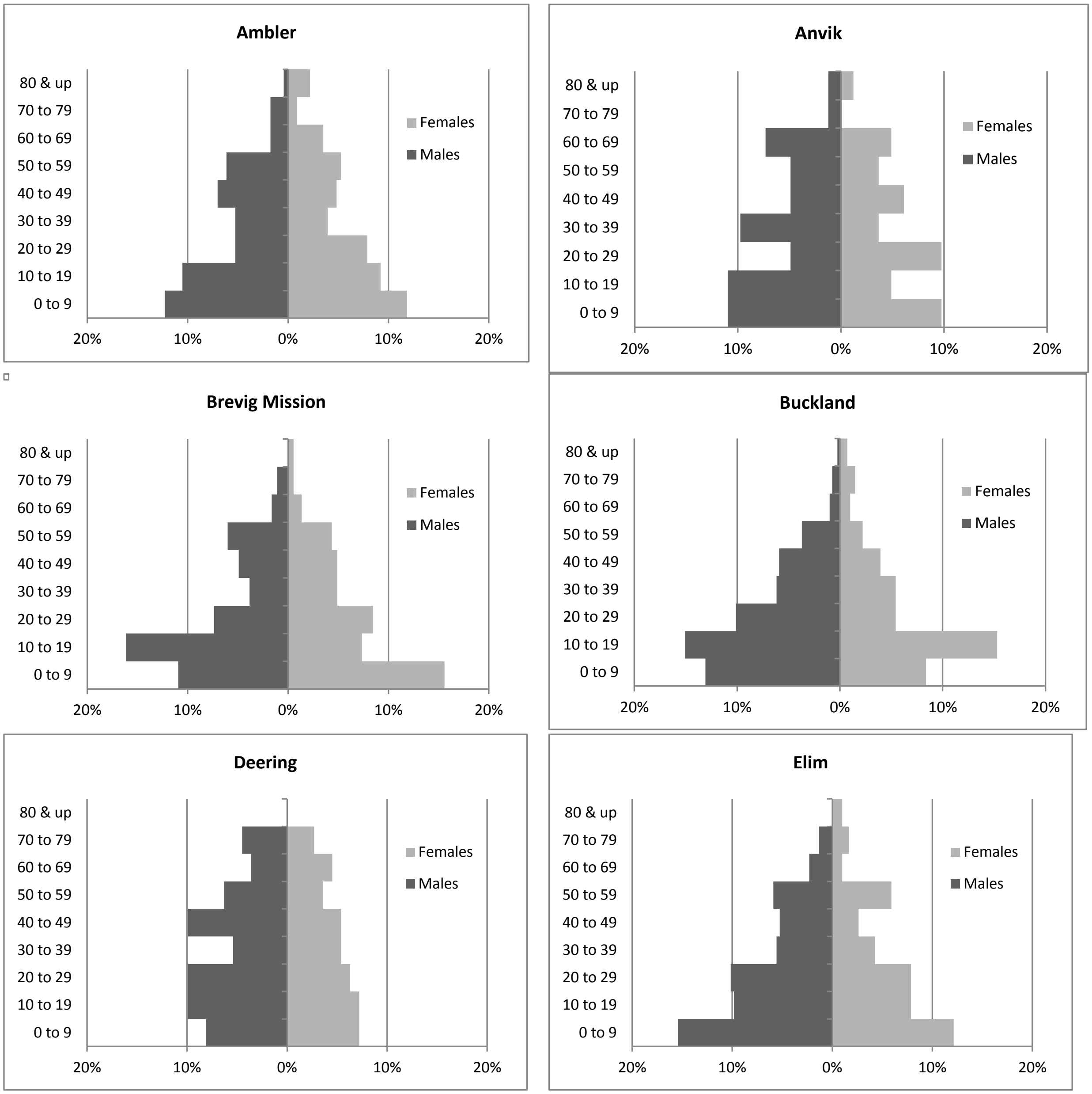
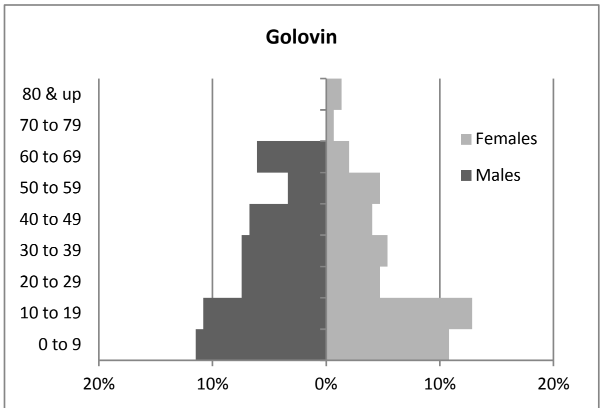


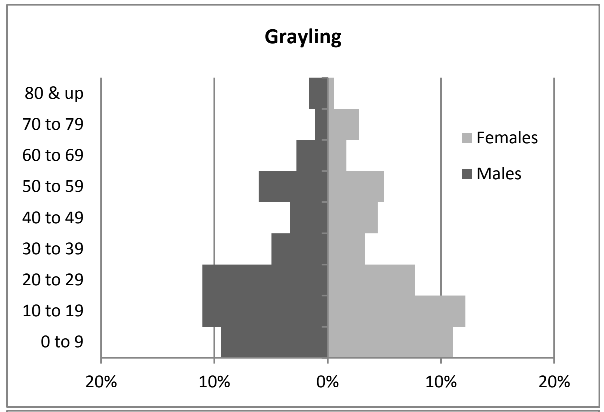
Figure D-2 shows the age-sex structure for Alaska Natives[1] of the 33 communities in 2010. The figure shows imbalanced gender ratios in several communities and unstable age structures in others. Where there are few young adults and high out-migration, the population is unable to grow.

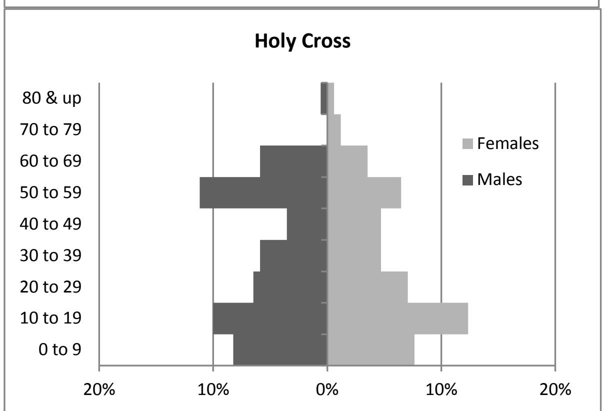
**Figure D-2. Age-sex structure of communities, 2010.**




[1] The figure combines two race categories from the US Census: 'American Indian/Alaska Native', and 'Two or more races'. Other races are not included because in most places, they are teachers and government workers, make up a small share of the population, and are a transient population.


Golovin
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
20%
10%
0%
10%
20%
Females
Males


Grayling
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
20%
10%
0%
10%
20%
Females
Males


Holy Cross
80 & up
70 to 79
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50 to 59
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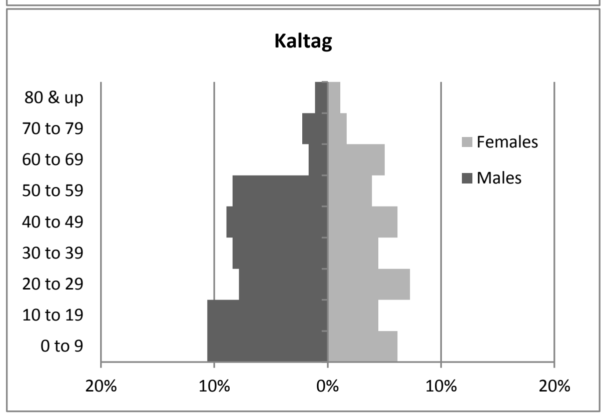
20%
Females
Males


Kaltag
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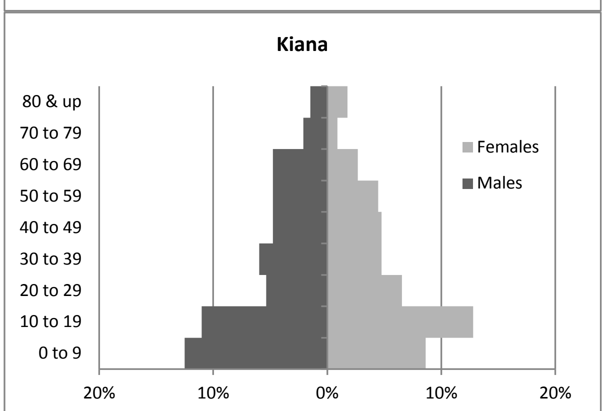
Females
Males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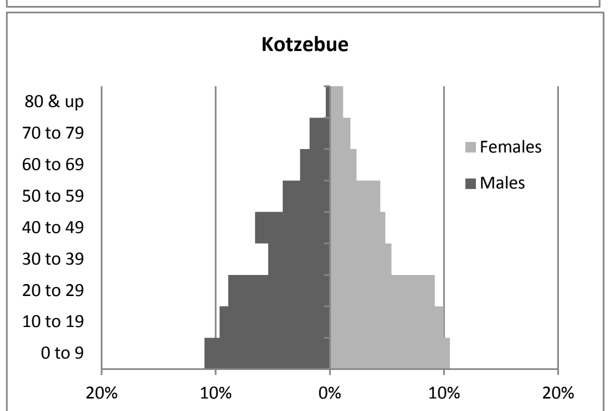
Females
Males


Kotzebue
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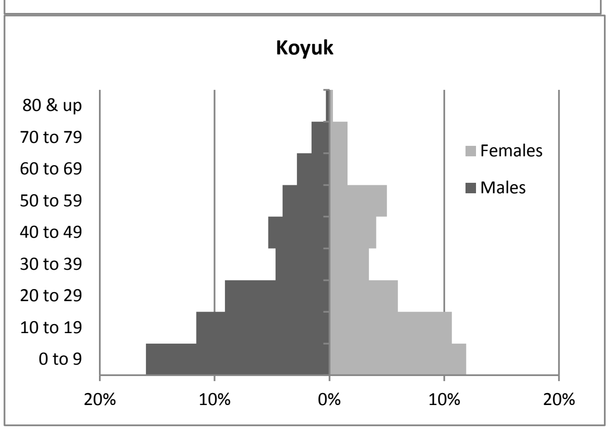
Females
Males


Koyuk
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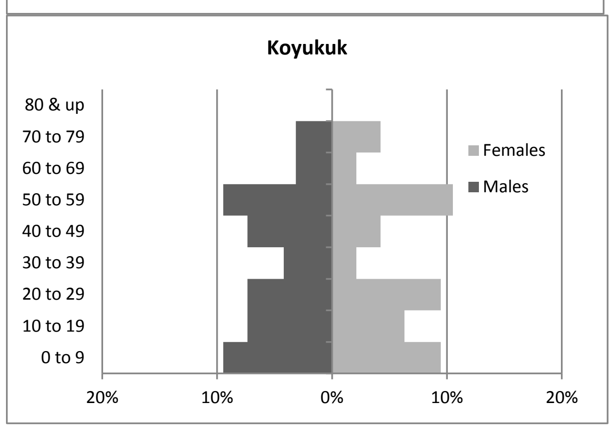
Females
Males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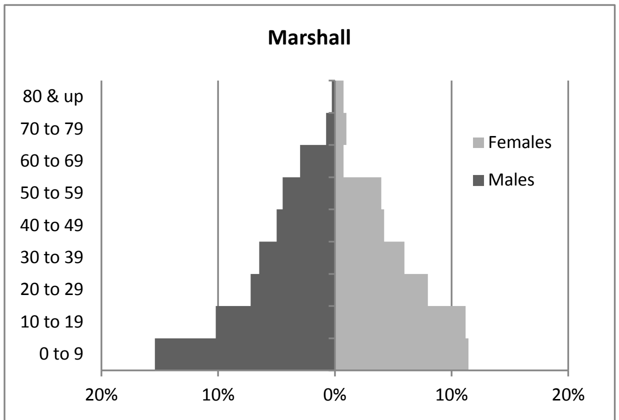
20%
Females
Males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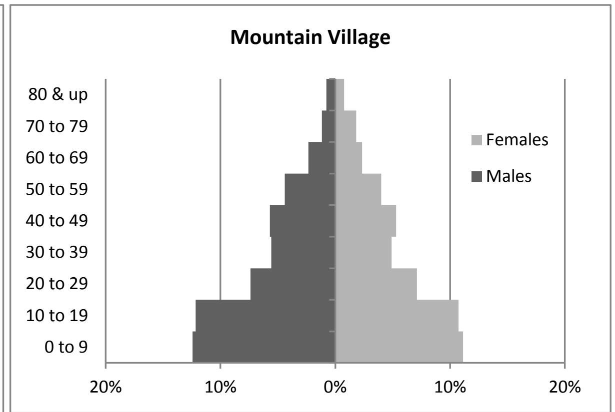
20%
Females
Males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70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
20%
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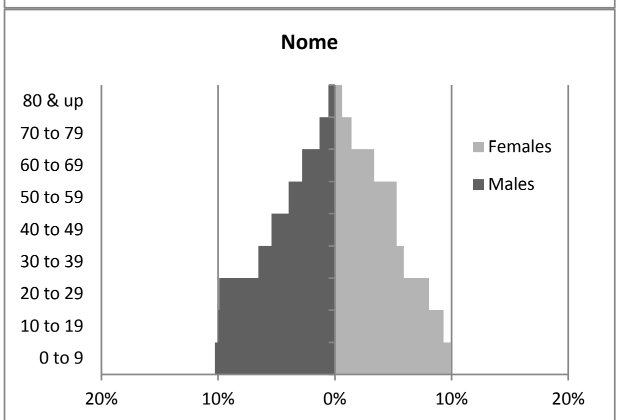
0%
10%
20%
Females
Males


Nome
80 & up
70 to 79
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50 to 59
40 to 49
30 to 39
20 to 29
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0 to 9
20%
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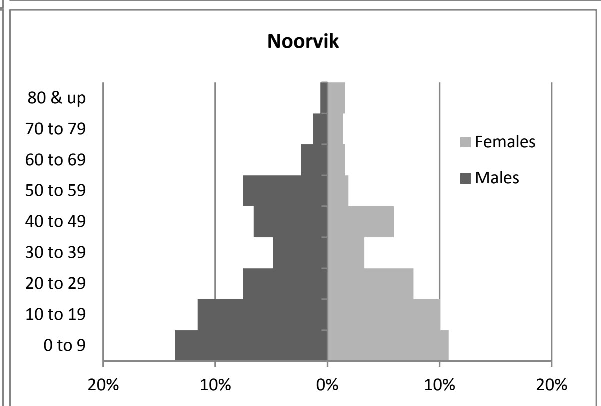
Females
Males


Noorvik
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
20%
10%
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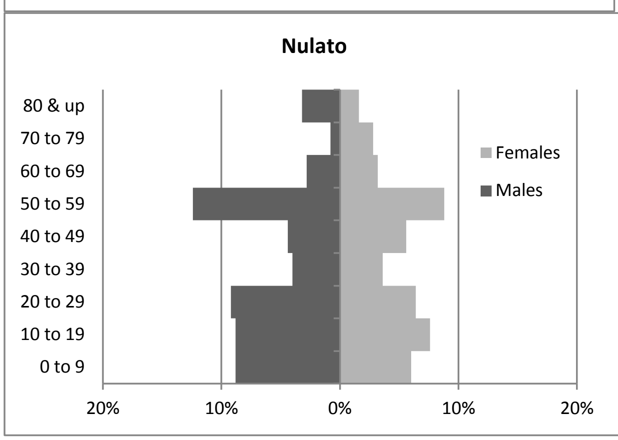
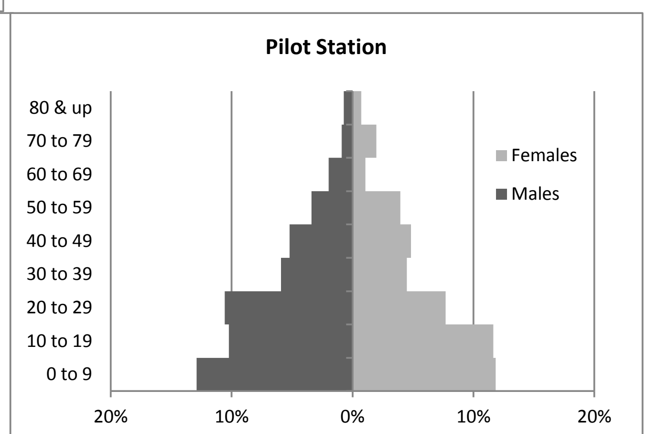
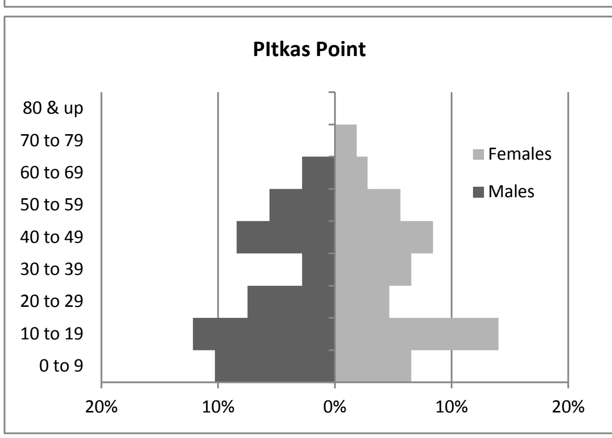
10%
20%
Females
Males


Nulato
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
20%
10%
0%
10%
20%
Females
Males


Pilot Station
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
20%
10%
0%
10%
20%
Females
Males


PItkas Point
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
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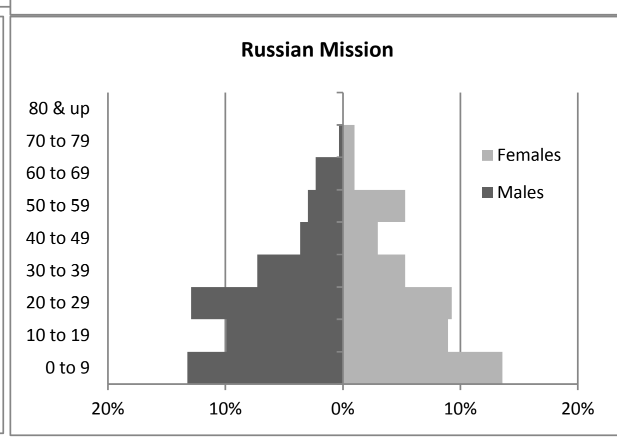
Females
Males


Russian Mission
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
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Females
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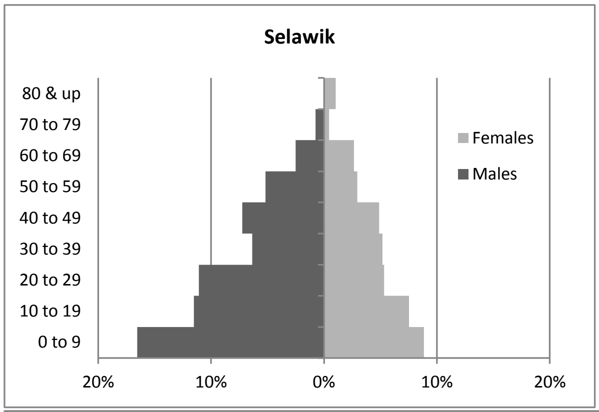
Selawik
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
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Females
Males
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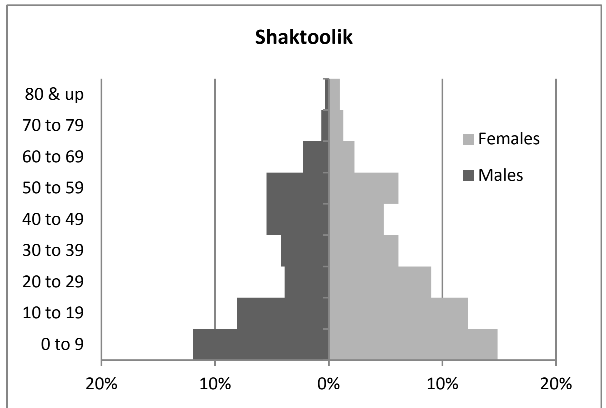
Shaktoolik
80 & up
70 to 79
60 to 69
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30 to 39
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Females
Males
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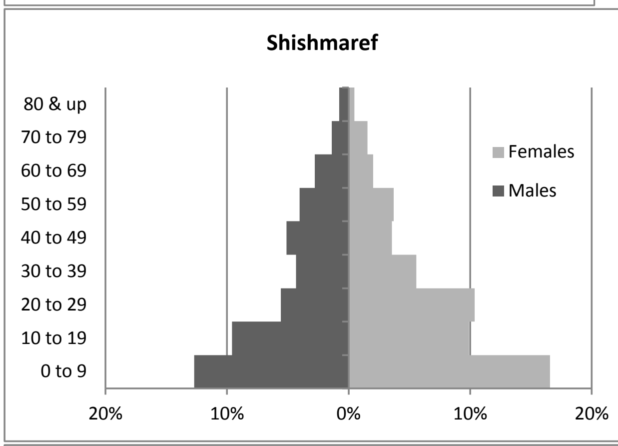
Shishmaref
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
Females
Males
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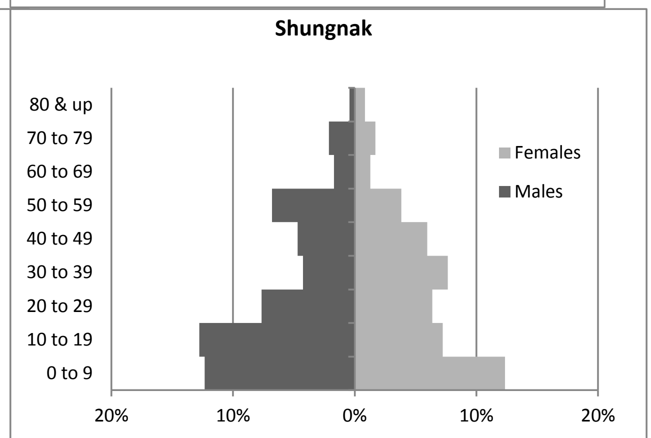
Shungnak
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
Females
Males
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0%
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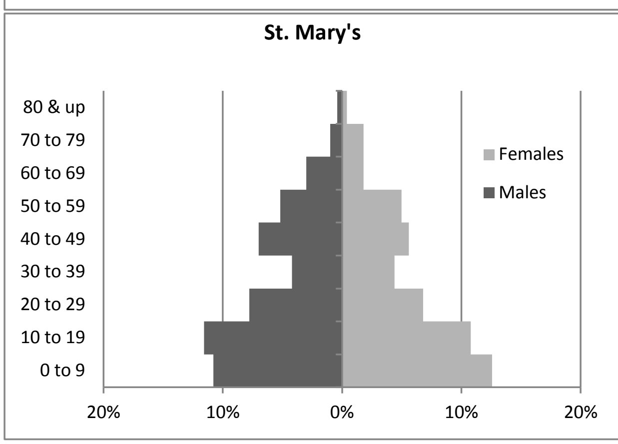
20%


St. Mary's
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
Females
Males
20%
10%
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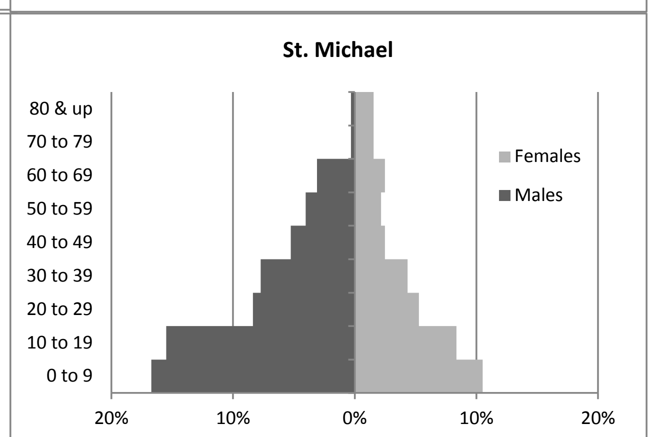
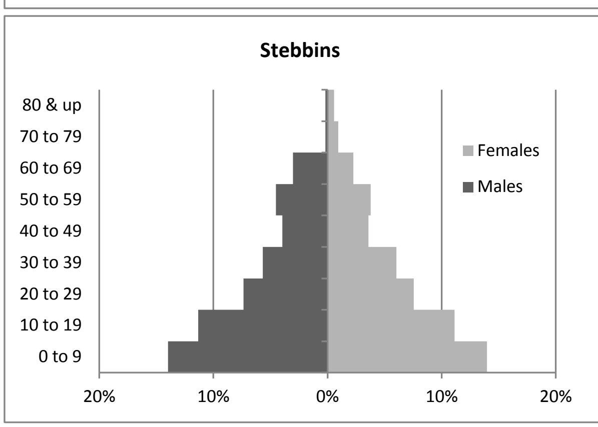
10%
20%


St. Michael
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
Females
Males
20%
10%
0%
10%
20%


Stebbins
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
Females
Males
20%
10%
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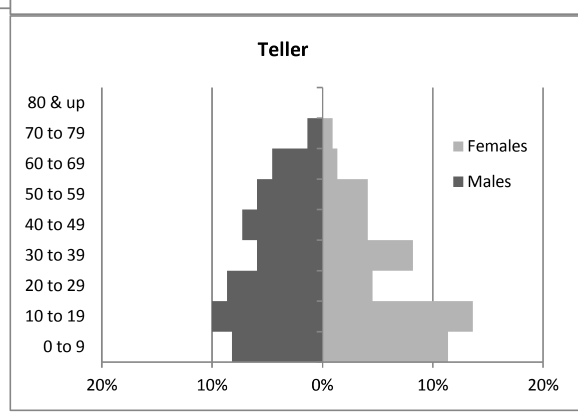
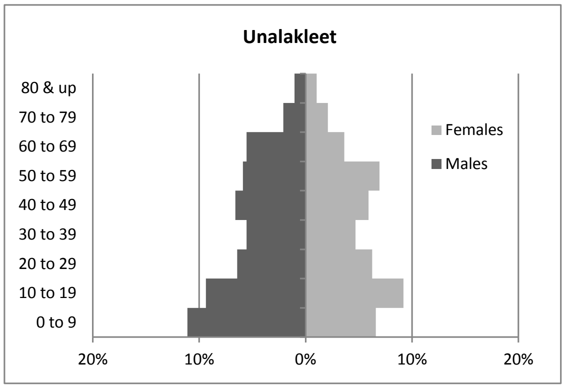
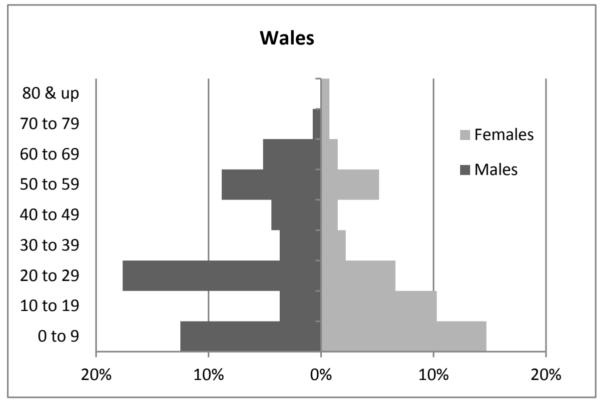
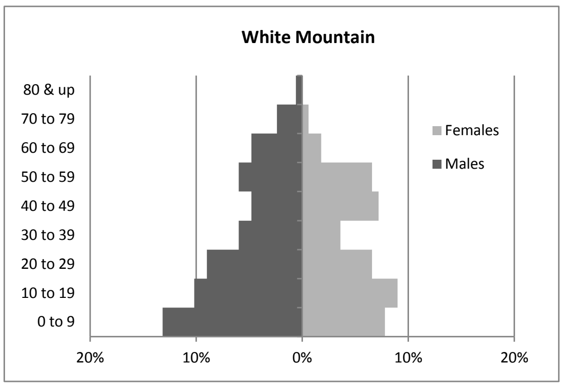
20%


Teller
80 & up
70 to 79
60 to 69
50 to 59
40 to 49
30 to 39
20 to 29
10 to 19
0 to 9
Females
Males
20%
10%
0%
10%
20%




## D-1.3 Employment, Income, Cost of Living

Villages have very small private sectors and nearly all jobs depend on state or federal spending. Nome and Kotzebue have more diverse economies and larger private sectors. Of the people with jobs, few have year-round full-time work (AKDoLWD 2012). Unalakleet and St. Mary's are sub-hubs within their regions, providing some regional services. The Bering Straits school district administration is located in Unalakleet. St. Mary's is a hub for Hageland Aviation.

Figure D-3 shows part- and full-time employment in the villages of the Northwest Arctic Borough, Nome, Wade Hampton, and Yukon-Koyukuk census areas. These data do not match exactly with the boundaries of the ecoregion because they are reported by borough and census area. In villages, full time employment has dropped since 2003. Part-time employment has been decreasing since 2000. Data in this figure are consistent with the idea that the end of state assistance to local governments in 2004 led to job loss, and that jobs did not fully recover. Some places gave up their municipal status because they could no longer staff offices. When the program was reinstated, those places did not receive as much funding as they would have as municipalities. It is also consistent with out-migration and population loss after 2004. Smaller populations generate fewer state-funded jobs. Figure D-4 shows steady growth in full-time employment in Nome and Kotzebue. Most of the growth has been in Nome.

**Figure D-3 Part- and full-time employment in villages.**

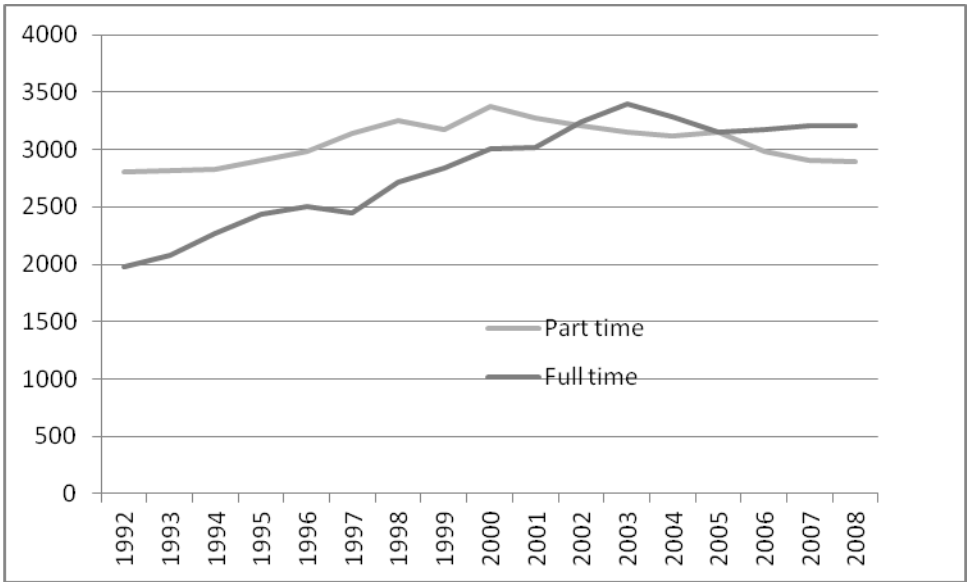



**Figure D-4 Part- and full-time employment in Nome and Kotzebue.**

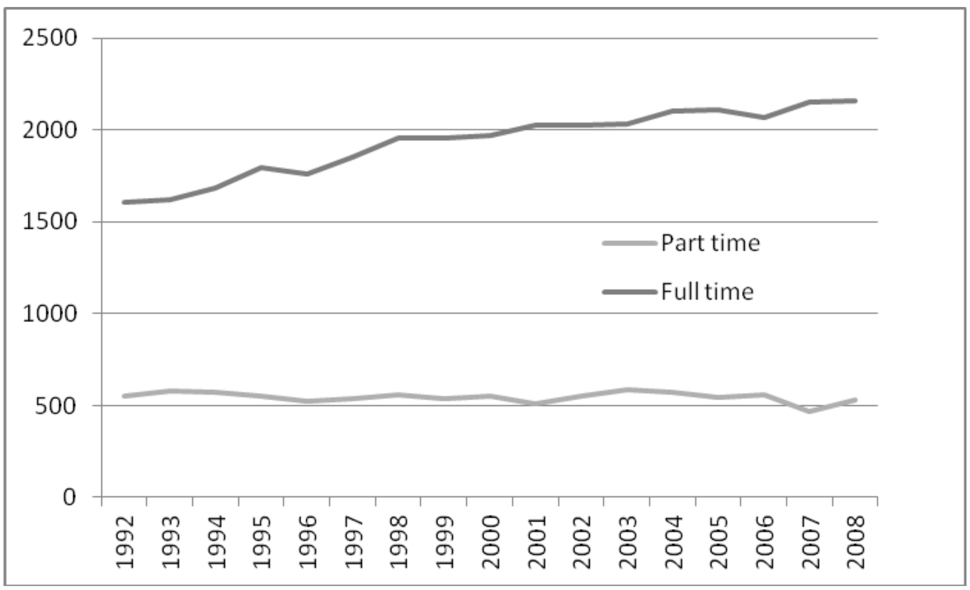



Table D-2 shows employment status and wages per worker for each community in 2010. Wages in Nome and Kotzebue were $41,200 in 2010, which is similar to Anchorage ($41,400). Village wages are less than half of regional centers, averaging about $19,000 per worker.

**Table D-2. Employment status and wages per worker by community, 2010.**

| Community | Residents age 16 & over | Residents employed | Share employed | Wages per worker |
|---|---|---|---|---|
| Anvik | 61 | 51 | 84% | $16,526 |
| Grayling | 128 | 92 | 72% | $11,321 |
| Holy Cross | 136 | 81 | 60% | $15,078 |
| Ambler | 178 | 122 | 69% | $25,873 |

| Community | Residents age 16 & over | Residents employed | Share employed | Wages per worker |
|---|---|---|---|---|
| Brevig Mission | 229 | 147 | 64% | $14,417 |
| Buckland | 288 | 203 | 70% | $23,245 |
| Deering | 85 | 67 | 79% | $21,864 |
| Elim | 199 | 144 | 72% | $15,744 |
| Golovin | 98 | 87 | 89% | $22,226 |
| Kaltag | 141 | 78 | 55% | $15,255 |
| Kiana | 250 | 182 | 73% | $18,628 |
| Kotzebue | 2,038 | 1,426 | 70% | $40,956 |
| Koyuk | 209 | 155 | 74% | $16,125 |
| Koyukuk | 75 | 50 | 67% | $19,095 |
| Marshall | 274 | 189 | 69% | $17,351 |
| Mountain Village | 523 | 378 | 72% | $18,781 |
| Nome | 2,449 | 1,778 | 73% | $41,428 |
| Noorvik | 447 | 268 | 60% | $23,921 |
| Nulato | 218 | 161 | 74% | $15,304 |
| Pilot Station | 387 | 233 | 60% | $13,328 |
| Pitkas Point | 57 | 46 | 81% | $12,802 |
| Russian Mission | 240 | 167 | 70% | $15,517 |
| St. Mary's | 374 | 261 | 70% | $21,989 |
| St. Michael | 258 | 169 | 66% | $17,373 |
| Selawik | 503 | 311 | 62% | $19,338 |
| Shaktoolik | 150 | 108 | 72% | $19,298 |
| Shishmaref | 381 | 246 | 65% | $16,454 |
| Shungnak | 171 | 105 | 61% | $20,418 |
| Stebbins | 352 | 236 | 67% | $13,343 |
| Shungnak | 171 | 105 | 61% | $20,418 |
| Teller | 154 | 114 | 74% | $17,768 |
| Unalakleet | 566 | 426 | 75% | $29,105 |
| Wales | 96 | 79 | 82% | $16,668 |
| White Mountain | 127 | 94 | 74% | $19,118 |

Nearly three-fourths of workers in Nome and Kotzebue work in private sector jobs. The largest employers (Table D-4) in the private sector are Teck Alaska (Red Dog mine, in Kotzebue), grocery stores, and airline companies. Employment in the private sector in villages is nearly the inverse of Nome and Kotzebue. Data in Table D-3 show the dependence of villages on state and federal spending for jobs. 'Local' government jobs in villages include tribal jobs—funded in large part by federal spending, and city jobs—funded in large part by state spending.

**Table D-3. Employment by sector by community, 2010.**

| Community | Private | Local government | State government |
|---|---|---|---|
| Anvik | 25% | 73% | 2% |
| Grayling | 33% | 66% | 1% |
| Holy Cross | 40% | 59% | 1% |
| Ambler | 56% | 43% | 2% |

| Community | Private | Local government | State government |
|---|---:|---:|---:|
| Brevig Mission | 26% | 74% | 0% |
| Buckland | 52% | 48% | 0% |
| Deering | 45% | 54% | 1% |
| Elim | 42% | 57% | 1% |
| Golovin | 52% | 47% | 1% |
| Kaltag | 44% | 55% | 1% |
| Kiana | 34% | 65% | 1% |
| Kotzebue | 72% | 23% | 5% |
| Koyuk | 35% | 65% | 0% |
| Koyukuk | 68% | 32% | 0% |
| Marshall | 27% | 70% | 3% |
| Mountain Village | 33% | 67% | 1% |
| Nome | 74% | 14% | 11% |
| Noorvik | 47% | 53% | 0% |
| Nulato | 48% | 52% | 0% |
| Pilot Station | 38% | 60% | 2% |
| Pitkas Point | 26% | 74% | 0% |
| Russian Mission | 43% | 56% | 1% |
| St. Mary's | 51% | 46% | 3% |
| St. Michael | 38% | 60% | 1% |
| Selawik | 42% | 58% | 0% |
| Shaktoolik | 35% | 64% | 1% |
| Shishmaref | 46% | 53% | 2% |
| Shungnak | 54% | 46% | 0% |
| Stebbins | 33% | 66% | 0% |
| Shungnak | 54% | 46% | 0% |
| Teller | 39% | 61% | 1% |
| Unalakleet | 46% | 51% | 3% |
| Wales | 39% | 59% | 1% |
| White Mountain | 34% | 65% | 1% |

## Table D-4. Main employers by community, 2010.

| Community | Main Employers | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Anvik | Iditarod Area School District | Anvik Traditional Council | Anvik City of | Deloy Ges Incorporated | Doyon Drilling Inc | | | | | |
| Grayling | Iditarod Area School District | Grayling City of | Interior Regional Housing Authority | Grayling Native Store | Tanana Chiefs Conference | Grayling Fuel Company | Hee Yea Lingde Corp | Kwikpak Fisheries LLC | HYLFuel LLC | Cruz Construction Inc |
| Holy Cross | Holy Cross Tribal Council | Iditarod Area School District | Tanana Chiefs Conference | Holy Cross City Council | Yukon Kuskokwim Health Corp 90 | Doyon Drilling Inc | Alaska Consumer Direct Personal Care LLC | Holy Cross Oil Inc | Interior Regional Housing Authority | |
| Ambler | NWAB School | NW Inupiat Housing Authority | City of Ambler Public Health Facs Proj | Maniilaq Association Inc | City of Ambler | NANA Management Services LLC | Ambler Traditional Council | Otz Telephone Cooperative Inc | Teck Alaska Incorporated | Kobuk River Lodge & General Store |
| Brevig Mission | City of Brevig Mission | Bering Strait School Dist | Brevig Mission Native Corp | Brevig Mission Traditional CNL | Kawerak Inc | Norton Sound Health Corp | Norton Sound Economic Development | Bering Straits Reg Housing Authority | | |
| Buckland | NWAB School | Buckland City Council | NW Inupiat Housing Authority | SoA Village Safe Water Buckland Project | Maniilaq Association Inc | Buckland IRA Council | Buckland Native Store | NANA Management Services LLC | Teck Alaska Incorporated | Selawik Ira Council |
| Deering | Deering IRA Council | NWAB School | Maniilaq Association Inc | Deering City Council | Ipnatchiaq Electric Co | Teck Alaska Incorporated | NANA Regional Corporation | Deering Native Cooperative Store | NANA Management Services LLC | |
| Elim | Bering Strait School Dist | City of Elim | Norton Sound Economic Development | Elim IRA Council | Kawerak Inc | Elim Native Store | Norton Sound Health Corp | Bering Straits Develop Corp | Elim Native Corp | Hageland Aviation Srvcs Inc |
| Golovin | Bering Strait School Dist | City of Golovin | Kawerak Inc | Bering Straits Reg Housing Authority | Norton Sound Health Corp | Golovin Native Corp | Chinik Eskimo Community | Golovin Fire Dept Bingo Acct | Norton Sound Economic Development | Golovin Power Utilities |
| Kaltag | Kaltag City of | Yukon Koyukuk School Dist | Kaltag Village Council | Tanana Chiefs Conference | Kaltag Cooperative Industries | Nanuq Inc | | | | |
| Kiana | Native Village of Kiana | NWAB School | Kiana City of | Maniilaq Association Inc | Teck Alaska Incorporated | NANA Management Services LLC | City of Kiana Public Health Facilities | NANA/Lynden Logistics LLC | AK Village Electric Coop Inc | State of AK (excludes U of A) |
| Kotzebue | Maniilaq Association Inc | NWAB School | AK Commercial Co | Kotzebue City of | Teck Alaska Incorporated | NANA Management Services LLC | Kotzebue IRA Council | State of AK (excludes U of A) | NW Inupiat Housing Authority | Alaska Interstate Const LLC |
| Koyuk | Bering Strait School Dist | Koyuk Native Corporation | Kawerak Inc | Koyuk Utilities Department | Norton Sound Economic Development | Koyuk Native Village of The | City of Koyuk | Norton Sound Health Corp | Koyuk Native Store | Pinetree Bingo |

| Community | Main Employers | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Koyukuk | Tanana Chiefs Conference | Koyukuk Tribal Council | Yukon Koyukuk School Dist | Doyon Drilling Inc | | | | | | |
| Marshall | Marshall Traditional Council | Marshall City Council | Lower Yukon School District | Fortuna Ledge Coop Assoc Inc | Ohogamiut Traditional Council | Maserculiq Inc | Yukon Kuskokwim Health Corp 90 | Neeser Construction Inc | Rural AK Comm Action Program | VSW Marshall Project |
| Mountain Village | Lower Yukon School District | Asa Carsarmiut Tribal Council | Mountain Village City of | Kwikpak Fisheries LLC | AK Commercial Co | Yukon Kuskokwim Health Corp 90 | Azachorok Inc | Rural AK Comm Action Program | SKW/Eskimos Inc | Dowland Construction Inc |
| Nome | Norton Sound Health Corp | State of AK (excludes U of A) | Kawerak Inc | Nome Public Schools | Nome City of | Bering Air Incorporated | Bering Straits Develop Corp | Nome Joint Utilities | Norton Sound Economic Development | Safeway Inc |
| Noorvik | Noorvik City of | NWAB School | Teck Alaska Incorporated | Maniilaq Association Inc | NANA Management Services LLC | Noorvik Native Store | Noorvik IRA Council | Bethel Services Inc | Morris Trading Post | AK Village Electric Coop Inc |
| Nulato | City of Nulato | Tanana Chiefs Conference | Nulato Tribal Council | Yukon Koyukuk School Dist | VSW - Nulato Water & Sewer | ASRC Energy Svcs-Houston Contracting Co | Brice Inc | Doyon Associated LLC | Tesoro Northstore Company | |
| Pilot Station | Lower Yukon School District | Pilot Station City of | Pilot Station Traditional Coun | Rural AK Comm Action Program | AVCP Housing Authority | Pilot Station Inc | Yukon Kuskokwim Health Corp 90 | Pilot Station Traditional Council | Association of Village Council Presidents | AK Commercial Co |
| Pitkas Point | Pitkas Point Village Council | Native Village of Pitka's Point | Lower Yukon School District | Yukon Kuskokwim Health Corp 90 | AVCP Housing Authority | | | | | |
| Russian Mission | Lower Yukon School District | Russian Mission City of | Iqurmiut Traditional Council | Russian Mission Native Corp | Bering Pacific Construc LLC | Association of Village Council Presidents | City of Russian Mission Bingo Gaming | Chiulista Camp Services Inc | Yukon Kuskokwim Health Corp 90 | City of Russian Mission Water & Sewer |
| St. Mary's | St Marys School District | St Marys City of | Yukon Kuskokwim Health Corp 90 | AVCP Housing Authority | Hageland Aviation Srvcs Inc | AK Commercial Co | Yupiit of Andreafski | Algaaciq Tribal Govt | State of AK (excludes U of A) | Native Village of Pitka's Point |
| St. Michael | St Michael IRA Council | Bering Strait School Dist | AK Commercial Co | City of Saint Michael | Kawerak Inc | St Michael Native Corp | Norton Sound Economic Development | City of Saint Michael Water & Sewer | Norton Sound Health Corp | Bering Straits Reg Housing Authority |
| Selawik | Selawik Ira Council | NWAB School | Selawik City Council | Selawik Ira Fuel Project | NANA Management Services LLC | Maniilaq Association Inc | Teck Alaska Incorporated | NW Inupiat Housing Authority | S&S Inc | Rural AK Comm Action Program |
| Shaktoolik | Bering Strait School Dist | Shaktoolik Ira Council | Norton Sound Economic Development | Shaktoolik Native Corp | Shaktoolik City of | Norton Sound Health Corp | Kawerak Inc | Shaktoolik Native Store | Bering Straits Reg Housing Authority | Hageland Aviation Srvcs Inc |

| Community | Main Employers | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Shishmaref | Bering Strait School Dist | City of Shishmaref | Kawerak Inc | Shishmaref Ira Self Det | Bering Straits Reg Housing Authority | City of Shismaref Bingo & Gamming | Norton Sound Health Corp | Nayokpuk General Store LLC | Shishmaref Ira Gaming | Shishmaref Native Store |
| Shungnak | NWAB School | NANA Management Services LLC | Maniilaq Association Inc | Native Village of Shungnak | Shungnak Native Store | Teck Alaska Incorporated | NANA Oilfield Services Inc | Bethel Services Inc | Shungnak City Council | Otz Telephone Cooperative Inc |
| Stebbins | Stebbins City Council | Bering Strait School Dist | Rural AK Comm Action Program | Stebbins Native Store | Stebbins Community Assn | Norton Sound Health Corp | Kawerak Inc | Stebbins Housing Authority | Bering Straits Reg Housing Authority | Norton Sound Economic Development |
| Shungnak | NWAB School | NANA Management Services LLC | Maniilaq Association Inc | Native Village of Shungnak | Shungnak Native Store | Teck Alaska Incorporated | NANA Oilfield Services Inc | Bethel Services Inc | Shungnak City Council | Otz Telephone Cooperative Inc |
| Teller | Bering Strait School Dist | City of Teller | Teller Native Corp | Kawerak Inc | Norton Sound Economic Development | Norton Sound Health Corp | Mary's Igloo Native Corporation | Bering Straits Develop Corp | Teller Traditional Council | Marys Igloo Traditional Council |
| Unalakleet | Bering Strait School Dist | Norton Sound Economic Development | Native Village of Unalakleet | Unalakleet Native Corp | Unalakleet City of | Norton Sound Health Corp | AK Commercial Co | Pro-West Contractors LLC | Kawerak Inc | State of AK (excludes U of A) |
| Wales | Bering Strait School Dist | Native Village of Wales | City of Wales | Kawerak Inc | Wales Native Corp | Norton Sound Health Corp | Wales Native Store | Norton Sound Economic Development | Bering Straits Reg Housing Authority | Bering Air Incorporated |
| White Mountain | Bering Strait School Dist | White Mountain City of | Kawerak Inc | White MTN IRA Council | Norton Sound Health Corp | White Mountain Native Store | City of White Mtn Utilities | Norton Sound Economic Development | Bering Straits Reg Housing Authority | |

Government transfers make up a large share of household income, and are another cause of communities' vulnerability to changes in government spending. In 2010, transfers made up about 15% of total personal income[2] (ISER estimate using BEA 2012).

Goods and services are more expensive in the ecoregion than in Anchorage. Higher fuel prices drive up the price of store-bought goods and increase both the need for subsistence and the cost of subsistence.

Unsubsidized electricity prices ($/kwh) are more than four times as high as Anchorage (Table D-5). The Power Cost Equalization program (PCE) lowers costs somewhat (Table D-5), but only covers electricity. Gasoline prices (2012) at around $6.25 are more than $2 higher than the national average (DCRA 2012).

**Table D-5. Subsidized and unsubsidized electricity prices ($/kwh).**

| Community | $/kwh with PCE subsidy | Unsubsidized $/kwh | Ratio of $/kwh (after PCE) to Anchorage | Ratio unsubsidized $/kwh to Anchorage |
|---|---|---|---|---|
| Ambler | $0.19 | $0.55 | 1.4 | 4.2 |
| Anvik | $0.24 | $0.65 | 1.9 | 5.0 |
| Brevig Mission | $0.19 | $0.52 | 1.5 | 4.0 |
| Buckland | $0.20 | $0.48 | 1.6 | 3.7 |
| Deering | $0.20 | $0.48 | 1.6 | 3.7 |
| Elim | $0.19 | $0.54 | 1.5 | 4.2 |
| Golovin | $0.27 | $0.57 | 2.0 | 4.4 |
| Grayling | $0.20 | $0.54 | 1.6 | 4.2 |
| Holy Cross | $0.23 | $0.57 | 1.8 | 4.4 |
| Kaltag | $0.22 | $0.56 | 1.7 | 4.3 |
| Kiana | $0.22 | $0.61 | 1.7 | 4.7 |
| Kotzebue | $0.13 | $0.43 | 1.0 | 3.3 |
| Koyuk | $0.22 | $0.55 | 1.7 | 4.2 |
| Koyukuk | $0.17 | $0.45 | 1.3 | 3.5 |
| Marshall | $0.27 | $0.54 | 2.1 | 4.2 |
| Mountain Village | $0.21 | $0.51 | 1.6 | 3.9 |
| Nome | $0.20 | $0.36 | 1.5 | 2.8 |
| Noorvik | $0.22 | $0.58 | 1.7 | 4.5 |
| Nulato | $0.21 | $0.52 | 1.6 | 4.0 |
| Pilot Station | $0.21 | $0.53 | 1.6 | 4.1 |
| Pitkas Point | $0.28 | $0.58 | 2.2 | 4.4 |
| Russian Mission | $0.21 | $0.50 | 1.6 | 3.9 |
| Selawik | $0.23 | $0.59 | 1.8 | 4.5 |
| Shaktoolik | $0.20 | $0.55 | 1.5 | 4.2 |
| Shishmaref | $0.24 | $0.60 | 1.8 | 4.7 |
| Shungnak | $0.13 | $0.59 | 1.0 | 4.5 |
| St. Mary's | $0.25 | $0.58 | 1.9 | 4.4 |

[2] Transfers include social security, unemployment insurance, Temporary Assistance to Needy Families (TANF), Supplemental Nutrition Program for Women, Infants and Children (SNAP), and the Alaska Permanent Fund dividend.

| Community | $/kwh with PCE subsidy | Unsubsidized $/kwh | Ratio of $/kwh (after PCE) to Anchorage | Ratio unsubsidized $/kwh to Anchorage |
|---|---|---|---|---|
| St. Michael | $0.19 | $0.48 | 1.4 | 3.7 |
| Stebbins | $0.21 | $0.54 | 1.6 | 4.2 |
| Teller | $0.22 | $0.58 | 1.7 | 4.5 |
| Unalakleet | $0.18 | $0.39 | 1.4 | 3.0 |
| Wales | $0.23 | $0.62 | 1.8 | 4.8 |
| White Mountain | $0.44 | $0.72 | 3.4 | 5.5 |

### D-1.4 Population Projections

Population projections for 2025 (Table D-6) apply the annual rate of change from 1990-2010 to the population in 2010. Projections to 2060 (Table D-6) use the same method but with far less certainty, and are not considered reliable because of the methods used. In forecasting, the base period should be longer than the forecast period. Changes in small populations, such as the communities in the SNK ecoregion, are difficult to project with a reasonable degree of accuracy. Forecasting accuracy increases with population size, and is higher for slow-growing places than places that are decreasing in size or undergoing rapid change. Because of the accuracy issues associated with developing projections for smaller communities, demographers for the State of Alaska project population by borough/census area using a more complicated cohort-component method. The state method uses birth-death data, income tax returns, and the Permanent Fund Dividend (PFD) registration files. None of these are available to researchers. However, based on their methods and available data, the projections to 2025 are plausible. Projections are consistent with those from AkDoLWD in that the current share of each census area comprising SNK villages in 2010 is the same projected share.

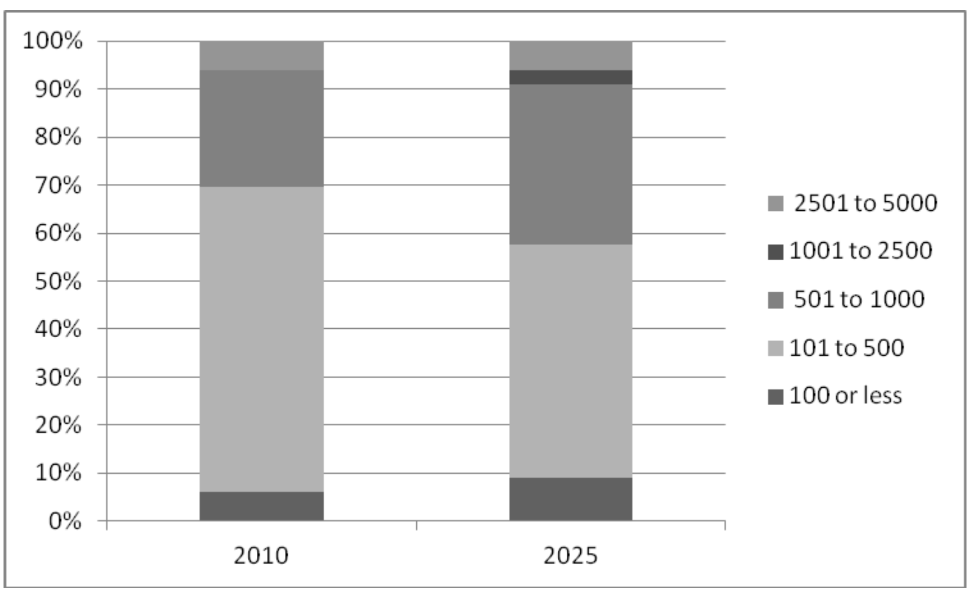
**Table D-6. Population projections by community, 2025 and 2060.**

| Community | Pop 2010 | Projected Population 2025 | Projected Population 2060 | Projected change 2025-60 |
|---|---|---|---|---|
| Ambler | 258 | 224 | 162 | -13% |
| Anvik | 85 | 87 | 93 | 3% |
| Brevig Mission | 388 | 643 | 2086 | 66% |
| Buckland | 416 | 509 | 814 | 22% |
| Deering | 122 | 101 | 65 | -17% |
| Elim | 330 | 390 | 576 | 18% |
| Golovin | 156 | 182 | 261 | 17% |
| Grayling | 194 | 184 | 163 | -5% |
| Holy Cross | 178 | 128 | 59 | -28% |
| Kaltag | 190 | 159 | 106 | -16% |
| Kiana | 361 | 344 | 307 | -5% |
| Kotzebue | 3201 | 3586 | 4675 | 12% |
| Koyuk | 332 | 436 | 822 | 31% |
| Koyukuk | 96 | 78 | 49 | -18% |
| Marshall | 414 | 566 | 1172 | 37% |
| Mountain Village | 813 | 936 | 1299 | 15% |

| Community | Pop 2010 | Projected Population 2025 | Projected Population 2060 | Projected change 2025-60 |
|---|---|---|---|---|
| Nome | 3598 | 3673 | 3855 | 2% |
| Noorvik | 668 | 793 | 1186 | 19% |
| Nulato | 264 | 210 | 122 | -21% |
| Pilot Station | 568 | 662 | 947 | 17% |
| Pitkas Point | 109 | 93 | 64 | -15% |
| Russian Mission | 312 | 373 | 565 | 20% |
| Selawik | 829 | 1062 | 1892 | 28% |
| Shaktoolik | 251 | 325 | 593 | 29% |
| Shishmaref | 563 | 659 | 954 | 17% |
| Shungnak | 262 | 296 | 392 | 13% |
| St. Mary's | 507 | 563 | 719 | 11% |
| St. Michael | 401 | 505 | 864 | 26% |
| Stebbins | 556 | 712 | 1267 | 28% |
| Teller | 229 | 313 | 649 | 37% |
| Unalakleet | 688 | 669 | 627 | -3% |
| Wales | 145 | 134 | 112 | -8% |
| White Mountain | 190 | 198 | 217 | 4% |

Figure D-5 shows community populations in 2010 and projected to 2025 by size category. It shows the mix of community sizes if small places continue to lose population and larger places continue to gain. More communities will have fewer than 100 people and more will have between 500 and 1000 people.

**Figure D-5. 2010 and projected 2025 populations by size category.**



## D-1.5 Schools

Table D-7 shows current school enrollment by community for 2011-12.

**Table D-7. School enrollment by community, 2011-12.**

| Community | Enrollment 2011-2012 |
|---|---|
| Ambler | 68 |
| Anvik | 20 |
| Brevig Mission | 126 |
| Buckland | 167 |
| Deering | 37 |
| Elim | 75 |
| Golovin | 46 |
| Grayling | 45 |
| Holy Cross | 46 |
| Kaltag | 29 |
| Kiana | 123 |
| Kotzebue | 701 |
| Koyuk | 127 |
| Koyukuk | 14 |
| Marshall | 133 |
| Mountain Village | 256 |
| Nome | 763 |
| Noorvik | 183 |
| Nulato | 49 |
| Pilot Station | 178 |
| Pitkas Point | 10 |
| Russian Mission | 158 |
| Selawik | 269 |
| Shaktoolik | 54 |
| Shishmaref | 207 |
| Shungnak | 85 |
| St. Mary's | 195 |
| St. Michael | 176 |
| Stebbins | 185 |
| Teller | 88 |
| Unalakleet | 187 |
| Wales | 42 |
| White Mountain | 56 |

## Future Projections: Employment, Population, Sources of Income, Costs of Living

Employment is driven internally by population change and local demand for goods and services, or externally driven by projects originating outside the local area. School jobs are an example of internally driven employment. More people mean more children and more schools. Mining projects are an example of externally driven jobs. The number of people hired in the mine is independent of the size of the local population. Because population growth rates are very low (less than 1% per year) and state and federal spending is decreasing, there is not likely to be a significant increase in internally driven jobs. Any change in employment will come from externally driven jobs. With externally driven jobs, if local labor supply cannot meet the employment needs, people will move in for work. However, because of high unemployment and local hire preference in the region, it is likely that projects (at least on tribal land) will hire local people. This minimizes in-migration for work. In addition, externally driven jobs, such as mining and roads will most likely be fly-in/fly-out. Enclave developments are the worldwide model for resource development.

In expanding communities, population growth is limited by housing supply. Nearly all housing is funded by HUD and provided by regional housing authorities. Housing grants are provided to individual communities but are not large enough to build many houses at once. Communities pool their grants through a regional housing authority and several houses are built at a time in each community on a rotating schedule.

Development of the Ambler mining district is not likely to take place before 2025 because a road/railroad is needed to access the region. Permafrost thaw is affecting the Dalton Highway; it is likely that permafrost will increase the construction and maintenance cost of a new road in the ecoregion. Several road routes have been proposed and are included elsewhere in this report. Besides engineering challenges and negotiating access over multiple complicated land tenure arrangements, decisions regarding a road to the mining district have become tied to decisions about ports. Senator Mark Begich (2012) favors development of a deep water Arctic port. The city of Kotzebue is considering developing a port at Point Blossom that would be deeper than the current port and be more suitable for fuel delivery. However, Point Blossom is not a true deep water port, so could not serve both purposes. The final decision regarding port location could impact whether the road would go from the mines to the port or from the mines to the Dalton Highway. At this time, no funding has been committed for construction of either roads or ports.

Scientists, government agencies and Arctic researchers have started discussions of how airships could improve movement of cargo and resources in and out the Arctic, and provide relief from high costs as well as increase the feasibility of development projects. Pawlowski (2011) discusses opportunities for rural Alaska but specifics about timeline, cost, type of cargo, and effects on individual communities are unknown.

The US Army Corps of Engineers (USACE 2009) assessed “risk priority” to categorize communities' exposure to erosion (Table D-8). Criteria included in the assessment are: critical infrastructure, human health and safety, subsistence and shoreline use, community setting/geographic location, housing and population affected, housing in parallel, environmental hazard, cultural importance, and commercial/non-residential. Several measures are used for each criterion; criteria are then scored and weighted to create the categorization. Communities were assigned to the categories of 1) imminent danger, 2) erosion damage within 10-20 years, and 3) erosion damage after 20 years or more.

**Table D-8. Army Corps erosion risk category by community (USACE 2009).**

| Community | Imminent danger | Erosion damage 10-20 years | Erosion damage 20+years |
|---|---|---|---|
| Ambler | | | |
| Anvik | | | |
| Brevig Mission | | | X |
| Buckland | | | X |

| Community | Imminent danger | Erosion damage 10-20 years | Erosion damage 20+years |
|---|---|---|---|
| Deering | | X | X |
| Elim | | | X |
| Golovin | | X | X |
| Grayling | | | |
| Holy Cross | | | |
| Kaltag | | | |
| Kiana | | | |
| Kotzebue | | | |
| Koyuk | | | |
| Koyukuk | | | X |
| Marshall | | | |
| Mountain Village | | | |
| Nome | | | |
| Noorvik | | | |
| Nulato | | | |
| Pilot Station | | | |
| Pitkas Point | | | |
| Russian Mission | | | X |
| Selawik | | X | X |
| Shaktoolik | X | X | X |
| Shishmaref | X | X | X |
| Shungnak | | | |
| St. Mary's | | | |
| St. Michael | | X | X |
| Stebbins | | | |
| Teller | | | |
| Unalakleet | X | X | X |
| Wales | | | |
| White Mountain | | | |

Alaska renewable energy projects are currently funded under a state grant program. The Alaska legislature indicated that it intends to continue to fund the program for the next 15 years at least. However, in places with renewable energy projects, conservation projects to recapture energy are the most common, followed by wind energy. In places with wind generation, wind contributes about 3% to community energy supply (Alaska Energy Statistics 2010). Diesel fuel prices are expected to increase by another 30% (over inflation) by 2025 (ISER 2012).

## D-1.6 Recreation: Tourism and Hunting

**45**: What are the patterns of current tourism including hunting and fishing (e.g., total revenue, total visitors, types of ecotourism)?

**15**: Where is hunting and tourism taking place and how frequently?

The patterns of tourism, hunting, and fishing are high concentrations of visitors in small areas over short lengths of time. Tourism is concentrated in Nome in the summer months and during the Iditarod in

March, and hunting is concentrated over 3-4 weeks in the fall. Annual tourism totals over the entire ecoregion are low, especially compared to other ecoregions across the US. Few detailed studies on tourism are available for areas within the ecoregion. The Nome tourism study (2004) estimates that tourism brings in $3.7 million per year. An estimated 9,800 people visited Nome in 2003. Most of the tourism visitor counts are from visitor centers, so hunters are probably included in the totals. About 1,500 people per year visit Nome for the Iditarod, but the average length of stay is two nights. Birders make up a large share of ecotourism in Nome, and an estimated 750 visited Nome in 2003.The Nome study estimates that visitors in 2003 spent $200 per day ($232 in 2012 prices). Figure D-6 shows visitors to Nome and Kotzebue visitor centers, and declines since 2007. Tourism growth is limited by transportation infrastructure, distance, and high cost. The Nome tourism study sees expedition cruises as a potential market.

**Figure D-6. Visitors to Nome and Kotzebue visitor centers 2000-2010.**

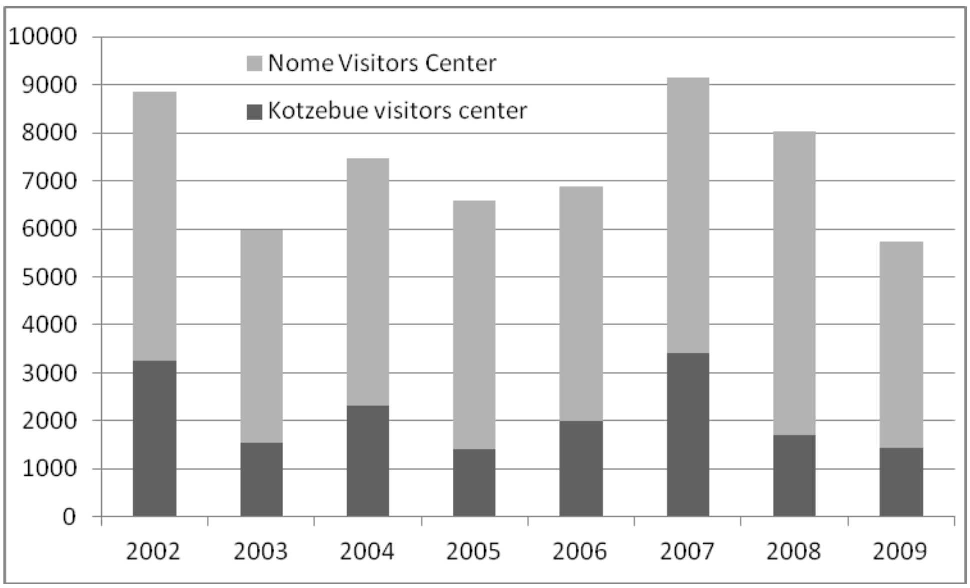
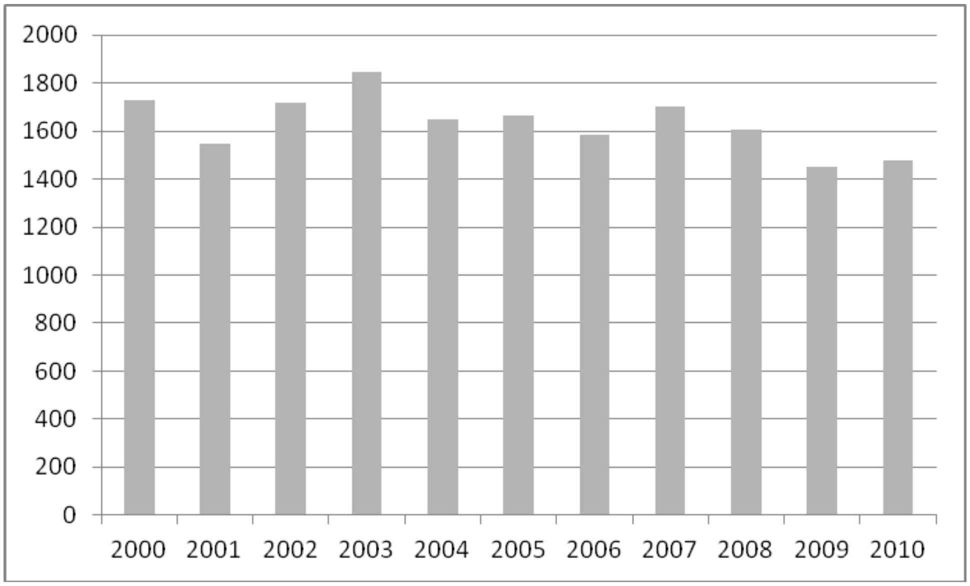



Figure D-7 shows the number of hunters in Game Management Units (GMUs) that overlap or are contained in the ecoregion. Totals include non-resident sport hunters, not local hunters; most sport hunters come from out of state. The number of sport hunters has decreased since 2007. This likely reflects the downturn in the US economy. Nearly all hunters are in the ecoregion from mid-September to early October.

**Figure D-7. Sport hunters 2000 to 2010.** Note: most sport hunters come from out of state.




**18:** How are changes in climate likely to affect tourism destination sites, numbers of tourists and revenues?

In the short term, climate change could directly affect tourism adversely by damaging roads (around Nome) and other infrastructure. Roads and buildings (hotels, restaurants, visitor centers) are vulnerable to erosion from permafrost loss. Infrastructure damage will affect tourism in the same way it affects local residents. Climate change also has indirect effects on tourism through higher global prices; particularly higher costs of air travel. This area is primarily accessed via air and is already expensive to reach; increased costs of air travel could potentially decrease tourism.

On the other hand, over the longer term, road and port development and increased access to the Arctic could increase tourism, as well as changing industrial development and trade in the area. Climate change has reduced sea ice in the Arctic, making transport and shipping in the Northwest Passage a virtual certainty in the near future (Pharand 2007). Between 1968 and 2008, summer sea ice cover has decreased by between 5% and 11% per decade in Hudson Bay, the Canadian Arctic Archipelago, Baffin Bay, and the Beaufort Sea (Tivy et al. 2011). Under these circumstances, Nome (or other coastal communities) has the potential to become a major shipping port for international trade and tourism. Cruise ships might dock there, as well as freighters.

These potential changes have ramifications for development of infrastructure at multiple levels, including roads, airports, docks, and import/export facilities. Such changes would impact livelihoods, subsistence activities, ecosystems, and local economies. The opening of these waters would also allow for marine species to move from east to west and vice versa; bowhead whale populations from Alaska and Greenland have already been observed to be mixing (Heide-Jorgensen et al. 2012).

In addition, tourism that is primarily directed toward hunting and fishing opportunities may be strongly affected by changes in ecosystems and species availability due to the direct impacts of rising temperatures and the climate-linked impacts of altered permafrost, changing hydrology, ocean acidification, loss of shore-fast ice, and new fire patterns. These potential shifts are discussed under Climate Change below.

## D-1.7 Livestock: Reindeer

**MANAGEMENT QUESTIONS**

**102**: Where are the current populations of reindeer? What is the current and historic herd size?

**106**: How have reindeer herds changed over time? How do herds affect grazing areas?

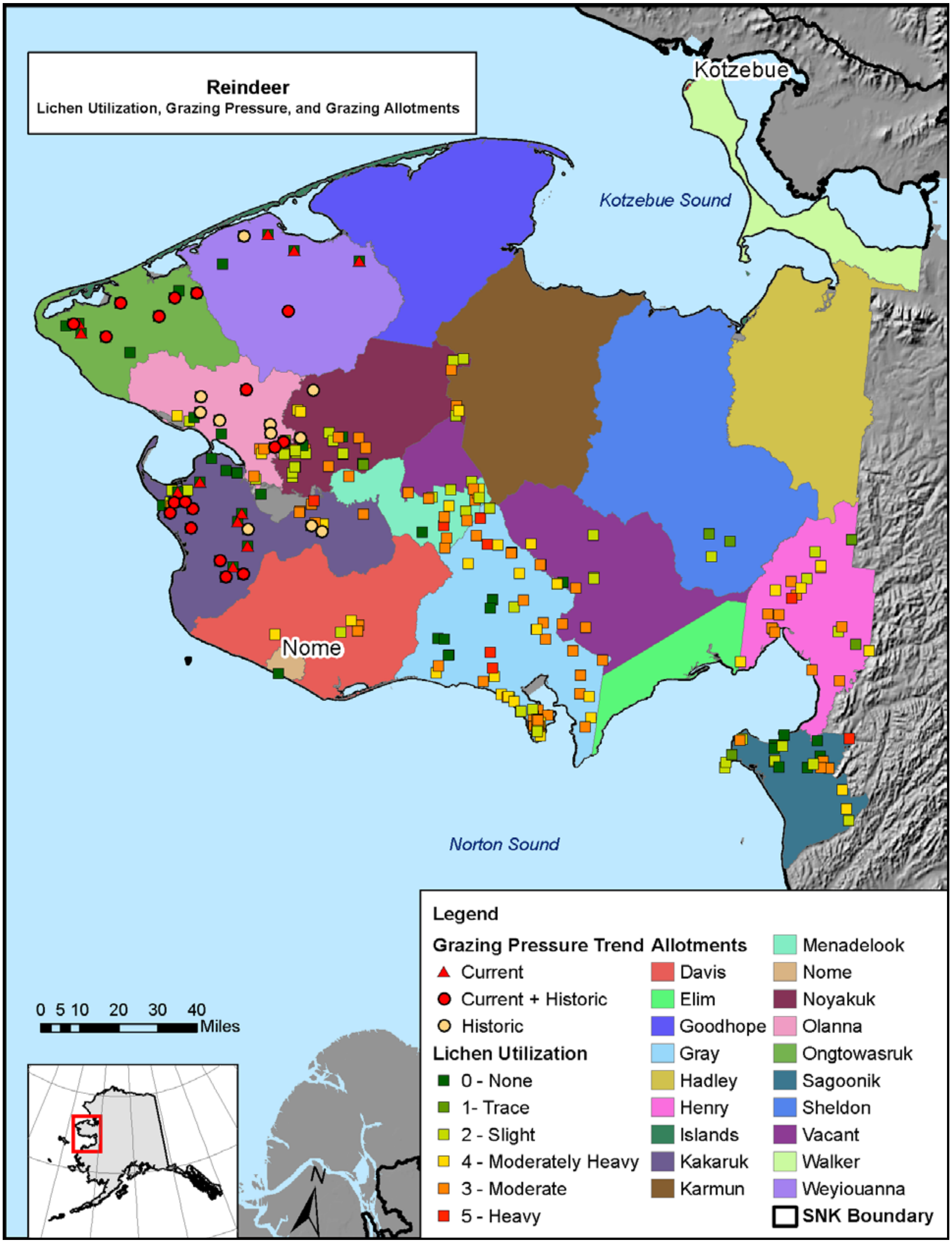
**105**: Where will current populations of reindeer experience overlap with change agents?

Reindeer allotments (Figure D-8) are all located on the Seward Peninsula. Reindeer on the Seward Peninsula now number less than 10,000, down from 600,000 animals in the 1920s. Over the last decade, over 17,000 reindeer have migrated away with caribou herds. Table D-9 summarizes reindeer herd sizes by grazing allotment on the Seward Peninsula (Finstad et al. 2006). Holt, McCune, and Neitlich (2008) cite extensive research and write that grazing (trampling and consumption) reduces lichen cover and biomass. With overall decreasing numbers in reindeer herds, impacts from reindeer are likely decreasing. Climate change and fire, in conjunction with factors such as caribou grazing, are documented to impact lichen forage areas (Joly et al. 2009).

**Table D-9. Reindeer herd sizes and losses.**

| Herd | Peak herd size | Peak year | 2004 herd size | Losses | Percent lost |
|---|---|---|---|---|---|
| Davis | 6,384 | 1997 | 3,500 | 2,884 | 45% |
| Gray | 2,418 | 1993 | 350 | 2,068 | 86% |
| Hadley | 2,310 | 1987 | - | 2,310 | 100% |
| Henry | 1,397 | 1987 | - | 1,397 | 100% |
| Karmun | 2,155 | 1995 | - | 2,155 | 100% |
| Menadelook | 1,473 | 1995 | - | 1,473 | 100% |
| Noyakuk | 1,046 | 1996 | 150 | 896 | 86% |
| Sagoonik | 1,815 | 1992 | - | 1,815 | 100% |
| Sheldon | 1,582 | 1991 | - | 1,582 | 100% |
| Weyiouanna | 1,081 | 1991 | 100 | 981 | 91% |
| **Total** | **21,661** | | **4,100** | **17,561** | **81%** |

**Figure D-8. Reindeer grazing allotments shown with data on lichen utilization and estimates of grazing pressure.**



Rattenbury et al.2009 describe the array of changes that reindeer herders face: expansion of the WACH, delayed freeze-up, early break-up or storms, which limit herder access to reindeer, predation, reindeer and range health, and economic difficulties for herders in the form of low meat prices and rising fuel and equipment costs. Herders have started to corral their reindeer to keep them from migrating away and have access to information about animal health and herd location.

Reindeer herd allotments, present only on the Seward Peninsula, were included in the intersection of development change agents with CEs (described later in this appendix, in the section **Development CA Overlap with CEs: Current and Future**). With the current development footprint, only approximately 0.5% of the allotment areas overlap with communities and trails. With the addition of proposed roads and other features, an additional 1.8% of the allotments are estimated to overlap with proposed recreation areas in the future. The allotment boundaries are likely not an accurate reflection of the distribution of reindeer herds on the Seward Peninsula. However, given herding practices and reindeer forage needs, it is unlikely that there is substantial overlap of the actual spatial extent of reindeer grazing areas with development infrastructure. As shown in the Boreal ALFRESCO modeling results in Appendix A, increases in fire frequency are most likely in the eastern part of the SNK ecoregion, not on the Seward Peninsula. Relative to other change agents, climate change and its associated pervasive impacts throughout the ecoregion is likely to have the greatest effect on reindeer herds.

## D-1.8 Effects of Non-Development Change Agents on Communities

A series of management questions address the impacts of changes in permafrost, fire regimes, and related change agent impacts on human communities. The first two management questions are currently located with their relevant change agent section later in this appendix as summarized below (because they are treated with CA effects on aquatic CEs as well).

**Appendix D, Permafrost: 159:** Where are predicted changes in soil thermal regimes associated with communities?

**Appendix D, Permafrost: 30:** Where will losses of lakes potentially affect water supply to villages?

**132**: What is the probability of fire, based on model scenarios, near existing communities?

Fire risk is highest for human communities located in forested areas on the eastern side of the ecoregion. ALFRESCO results show fire frequency increasing fairly dramatically in such areas, from annual risk (probability of fire) of 1-2% to annual risks as high as 4-5% by 2060 (Figure D-9). The areas of significantly increased fire risk include areas around all of the communities along the Yukon River, from Koyukuk down to Mountain Village. It also includes Ambler and Shungak along the northern border of the REA, as well as Selawik, Kiana, and Noorvik. Communities on the Seward Peninsula itself, including Buckland and Koyuk, generally appear to not have a noticeably increased risk of fire. Kotzebue is similarly in an area without significantly increased probability of fire.

While it may be expected that fires immediately surrounding communities would continue to be suppressed, the effects of fire go beyond the threat of losing housing and infrastructure. Smoke can cause serious air quality problems. Huntington et al. (2006) describes effects of fire on a village in the interior of Alaska: Downed trees and the dense brush that grows following fires cut off hunting trails. Cabins for hunter travel, hunting and trapping, (some were built on federal land long before land claims) burn down. Fire demonstrates strong connections between human thought and action and the natural world. In their work in Huslia, Huntington et al. (2006) heard from an elder that "she had been instructed not to speak of what a fire might do because speaking in that way might cause the fire to do exactly as she had said." Fire also has political dimensions, in that fire policy is one of many areas where local people are affected by consequences but are unable to control such policies (Huntington et al. 2006).

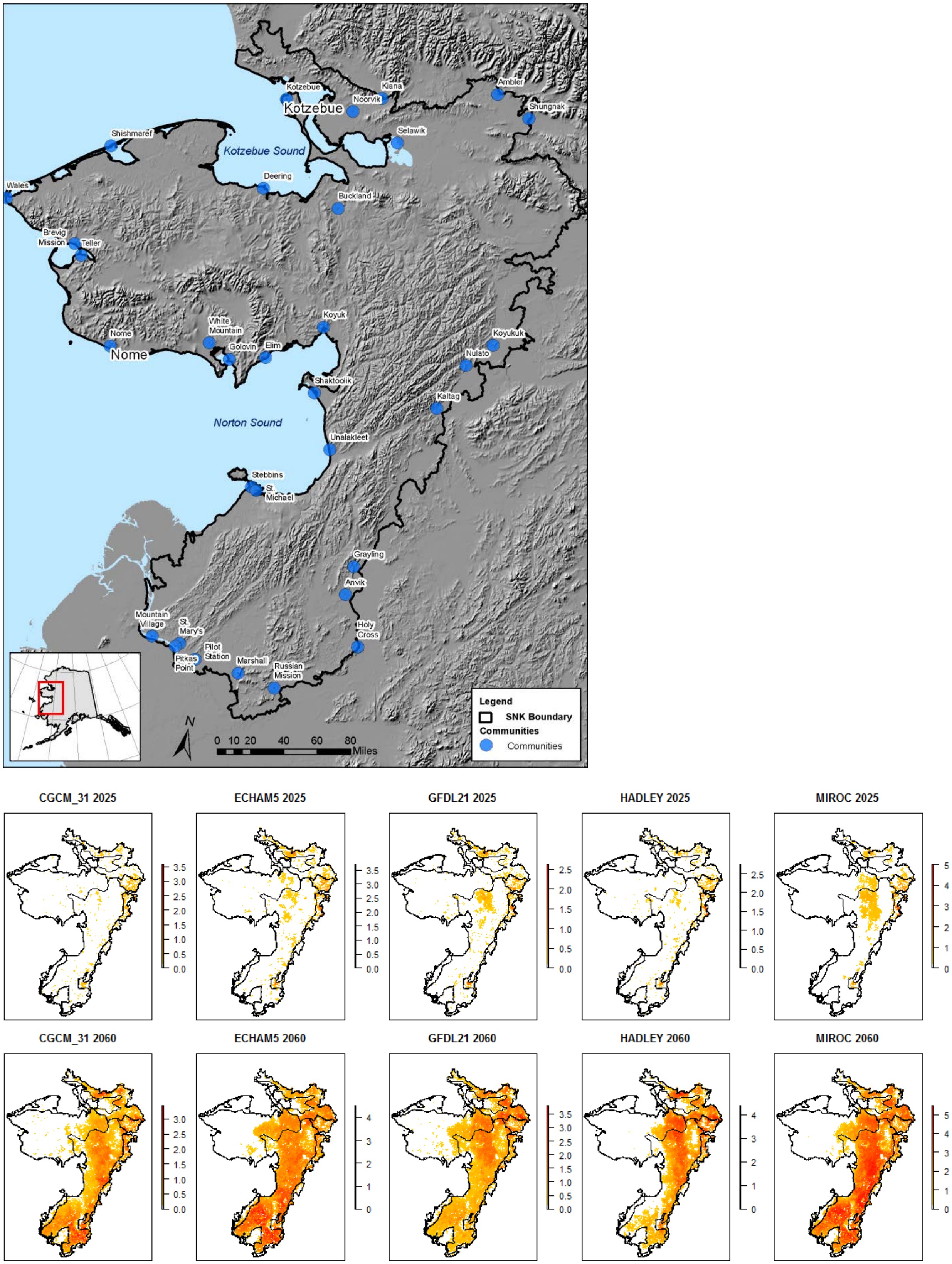
## D-1.9 Mining and Permafrost Thaw

**33**: Will the changes to permafrost and hydrologic resources affect mining practices or opportunities (e.g., the NPDES permits for waste water)?

Permafrost thaw could increase the cost of providing and maintaining infrastructure to support mines. Arctic roads are built on thick gravel beds to dissipate heat and maintain underlying permafrost. Permafrost thaw causes roads to buckle. Flooding related to permafrost thaw may increase and frequency of extreme weather events may also increase. These shorten the life of a road and increase maintenance costs (Walker 1983). Road travel may be restricted to days when the ground is frozen, generally shortening the season in which roads may be used. According to the U.S. Arctic Research Commission (2003), thawing permafrost increases construction costs 10% or more.

Erosion of riverbanks due to permafrost thaw may increase the amount of exposed gold, and result in more placer mining and/or more production from mine sites. It is unclear how these projected environmental changes will ultimately influence regulatory decisions and frameworks, but they are likely to alter the economics of mining in this region.

**Figure D-9. Community locations shown in conjunction with the five sets of fire risk models generated from ALFRESCO.**



## *D-2 Subsistence Assessments*

This section provides background information on the ADFG subsistence harvest data that were used to inform answers to many of the subsistence-related questions.

It then addresses the additional management questions that were identified relating to subsistence. Each question or small group of related questions has its own section, and the management question being addressed is highlighted again at the beginning of the section.

**9:** How have hunting and fishing regulations affected general hunting and fishing harvests?

**7**: Given current and estimates of future subsistence species populations, are harvest regulations adequate to protect subsistence species populations?

**2**: How could changes in sea mammal harvests potentially affect land-based hunting and fishing?

**44:** How are transporters, tourism, sport hunting and fishing affecting the migration patterns of caribou?

### D-2.1 Information and Data Used for Subsistence Assessments

Since 1978, ADFG's subsistence division has been conducting community-level case studies. ADFG is directed by statute to conduct harvest surveys and report traditional and customary use practices in rural communities. Most are case studies of individual or small groups of communities. ADFG collects harvest information from each household in a community (or a random sample of households). Harvests, attempts, and use are reported by species by surveyed community, rather than by specific harvest location. In some cases, species reported in a community were not harvested near there because hunters travel and hunt with friends and relatives in other communities. From these surveys, ADFG has created a community level harvest database and issued technical reports. The data and reports are available on their website (http://www.adfg.alaska.gov/index.cfm?adfg=subsistence.harvest). The ADFG database covers 29 years from 1980 through part of 2009. Many ADFG technical reports present data from comprehensive surveys (Ahmasuk 2007, Magdanz 2002, Magdanz et al. 2007, Wolfe and Scott 2010), but some of these data are not yet included in the ADFG database because they are in the process of being reviewed, coded, and merged with the statewide data. This section provides additional background on the content of the harvest database and technical reports, as well as summary data from the harvest database.

Table D-10 presents the complete list of subsistence species that have been included in harvest surveys. However, not all species are included in all surveys.

**Table D-10. Complete list of subsistence species included in ADFG harvest surveys. Surveys have varied over time; not all species listed have been included in all surveys.**

**Large Land Mammals**

1. Black Bear
2. Brown Bear
3. Caribou
4. Caribou, Female
5. Caribou, Male
6. Caribou, Sex Unknown
7. Dall Sheep
8. Goat
9. Large Land Mammals
10. Moose
11. Moose, Sex Unknown
12. Moose, Male
13. Muskox

**Feral Land Mammals**

1. Reindeer - Feral

**Marine Mammals**

1. Adult Bearded Seal
2. Bearded Seal
3. Belukha
4. Bowhead
5. Gray Whale
6. Harbor Porpoise
7. Minke (bottlenose)
8. Polar Bear
9. Porpoise
10. Ribbon Seal
11. Ringed Seal
12. Sea Otter
13. Spotted Seal
14. Steller Sea Lion
15. Walrus
16. Young Bearded Seal

**Small Land Mammals**

1. Arctic Fox
2. Arctic Hare
3. Beaver
4. Fox
5. Hare
6. Land Otter
7. Lynx
8. Marmot
9. Marten
10. Mink
11. Muskrat
12. Parka Squirrel (ground)
13. Porcupine
14. Red Fox
15. Red Fox - Red Phase
16. Snowshoe Hare
17. Squirrel
18. Weasel
19. Wolf
20. Wolverine

**Salmon**

1. Chinook Salmon
2. Chum Salmon
3. Coho Salmon
4. Fall Chum
5. Pink Salmon
6. Salmon
7. Sockeye Salmon
8. Summer Chum

**Non-Salmon Fish**

1. Arctic Cod
2. Bering Cisco
3. Blackfish
4. Broad Whitefish
5. Burbot
6. Capelin (grunion)
7. Char
8. Cisco
9. Cod
10. Dolly Varden
11. Eel
12. Eulachon (hooligan, candlefish)
13. Flounder
14. Grayling
15. Halibut
16. Herring
17. Herring Sac Roe
18. Herring Spawn on Kelp
19. Humpback Whitefish
20. Lake Trout
21. Least Cisco
22. Non-Salmon Fish
23. Pacific Tom Cod
24. Pike
25. Rainbow Smelt
26. Round Whitefish
27. Saffron Cod
28. Sculpin
29. Sheefish
30. Smelt
31. Sole
32. Stickleback (needlefish)
33. Sucker
34. Trout
35. Whitefish
36. Wolffish

**Marine Invertebrates**

1. Blue Mussels
2. Clams
3. Crabs
4. Giant Scale Worm
5. King Crab
6. Mussels
7. Pinkneck Clams
8. Razor Clams
9. Sea Cucumber
10. Shrimp
11. Tanner Crab
12. Whelk

**Migratory Birds**

1. American Wigeon
2. Arctic (Pacific) Loon
3. Arctic Tern
4. Auklet
5. Black Guillemot
6. Black Scoter
7. Brant
8. Bufflehead
9. Cacklers
10. Canada Geese
11. Canvasback
12. Common Eider
13. Common Goldeneye
14. Common Loon
15. Common Merganser
16. Common Murre
17. Common Snipe
18. Cormorants
19. Crane
20. Ducks
21. Eider
22. Emperor Geese
23. Geese

24. Glaucous Gull
25. Goldeneye
26. Greater Scaup
27. Green-Winged Teal
28. Guillemots
29. Gulls
30. Harlequin
31. Herring Gull
32. King Eider
33. Lesser Canada Geese (taverner/parvipes)
34. Lesser Scaup
35. Long-tailed Duck (Oldsquaw)
36. Loons
37. Mallard
38. Merganser
39. Mew Gull
40. Migratory Birds
41. Murre
42. Northern Pintail
43. Northern Shoveler
44. Plover
45. Red-Breasted Merganser
46. Red-Throated Loon
47. Sabines Gull
48. Sandhill Crane
49. Scaup
50. Scoter
51. Snow Geese
52. Spectacled Eider
53. Steller Eider
54. Surf Scoter
55. Swan
56. Teal
57. Thick-Billed Murre
58. Tundra Swan (whistling)
59. White-fronted Geese
60. White-winged Scoter
61. Wigeon
62. Yellow-Billed Loon

**Other Birds**

1. Grouse
2. Owl
3. Ptarmigan
4. Rock Ptarmigan
5. Snowy Owl
6. Upland Game Birds
7. Willow Ptarmigan

**Bird Eggs**

1. American Wigeon Eggs
2. Arctic (Pacific) Loon Eggs
3. Arctic Tern Eggs
4. Bird Eggs
5. Black Guillemot Eggs
6. Black Scoter Eggs
7. Brant Eggs
8. Cackler Eggs
9. Canvasback Eggs
10. Common Eider Eggs
11. Common Loon Eggs
12. Common Murre Eggs
13. Common Snipe Eggs
14. Crane Eggs
15. Duck Eggs
16. Emperor Geese Eggs
17. Geese Eggs
18. Glaucous Gull Eggs
19. Greater Scaup Eggs
20. Green-Winged Teal Eggs
21. Gull Eggs
22. Harlequin Eggs
23. Herring Gull Eggs
24. King Eider Eggs
25. Lesser Canada Geese Eggs
26. Mallard Eggs
27. Mew Gull Eggs
28. Murre Eggs
29. Northern Pintail Eggs
30. Northern Shoveler Eggs
31. Oldsquaw Eggs
32. Plover Eggs
33. Puffin Eggs
34. Red-Throated Loon Eggs
35. Sabines Gull Eggs
36. Sandhill Crane Eggs
37. Shorebird Eggs
38. Snow Geese Eggs
39. Snowy Owl Eggs
40. Spectacled Eider Eggs
41. Swan Eggs
42. Tern Eggs
43. Thick-Billed Murre Eggs
44. Tundra Swan Eggs
45. Upland Game Bird Eggs
46. White-fronted Geese Eggs

**Plants and Berries**

1. Berries
2. Plants/Greens/Mushrooms
3. Seaweed/Kelp
4. Vegetation
5. Wood

Not all communities are surveyed regularly. Table D-11 shows communities in the REA and survey years. Most of the complete harvest surveys were done in the 1980s and 1990s. Some recent surveys are part of the Western Arctic Caribou Herd survey project and ask about mammal harvests only. Some ask about non-salmon fish. A total of 67 surveys were available to cover 33 communities over more than 40 years.

Most of the complete harvest surveys that are included in the database were done in the 1980s and 1990s. Subsistence harvest survey data are not adequate to conclusively answer management questions, but in conjunction with traditional and local knowledge, past and current trends in subsistence harvests can be qualitatively estimated and described.

**Table D-11. ADFG subsistence harvest data availability by year, community, and harvest type**

| | 80 | 85 | 86 | 89 | 90 | 91 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 01 | 02 | 03 | 04 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ambler | | | | | | | | | | | b | | | | l | | | 2 |
| Anvik | | | | | a | | | | | | | | | | A | m | m | 4 |
| Brevig Mission | | | | a | | | | | b | | | | | | | | | 2 |
| Buckland | | | | | | | | | | b | | | | | | | | 1 |
| Deering | | | | | | | | a | | | b | | | | | | | 2 |
| Elim | | | | | | | b | | | | | | a | | | | | 2 |
| Golovin | | | | a | | | | | | | | | | m | | | | 2 |
| Grayling | | | | | a | | | | | | | | | | fm | m | m | 4 |
| Holy Cross | | | | | a | | | | | | | | | | fm | m | m | 4 |
| Kaltag | | A | | | | | | | | l | l | l | l | l | l | | | 7 |
| Kotzebue | | | a | | | a | | | | | b | | | | | | | 3 |
| Koyuk | | | | | | | | | b | | | m | | | | | | 2 |
| Koyukuk | | | | | | | | | | | | | | | f | | | 1 |
| Nome | | | | | | | | | b | | | | | | | | | 1 |
| Noorvik | | | | | | | | | | b | | | | | m | | | 2 |
| Nulato | | | | | | | | | | l | l | l | l | l | | | | 5 |
| Russian Mission | | Sl | | | | | | | | | | | | | | | | 1 |
| Saint Michael | | | | | | | | | | | | | | | | m | | 1 |
| Selawik | | | | | | | b | | | | b | | m | | | | | 3 |
| Shageluk | | | | | a | | | | | | | | | | fm | m | m | 4 |
| Shaktoolik | | | | | | | b | | | | | m | m | | | m | | 4 |
| Shishmaref | | | | a | | | | | a | | | | | | | | | 2 |
| Stebbins | a | | | | | | b | | | | | | | | m | | | 3 |
| Teller | | | | | | | | | b | | | | | | | | | 1 |
| Unalakleet | | | | | | | | | b | | | | | | m | | | 2 |
| Wales | | | | | | | a | | | | | | | | | | | 1 |
| White Mountain | | | | | | | | | b | | | | m | | | | | 2 |
| Total | 1 | 2 | 1 | 3 | 4 | 1 | 5 | 1 | 7 | 4 | 5 | 4 | 6 | 3 | 10 | 6 | 4 | 67 |

a=all subsistence species
b=birds only
f=non-salmon fish
s=salmon
l=large mammals
m=large and small mammals

Table D-12, containing data from ADFG's subsistence division, illustrates how much edible food (in pounds) is obtained from an individual animal, for the subsistence species listed. For example, a single coho salmon will yield approximately five pounds of edible meat. Table D-13 shows conversions from unconventional measurements of the quantity of a species (e.g., a dog food sack) to the approximate number of individual animals or plants contained in that quantity.

**Table D-12. Edible weight of subsistence species in conventional units. Animal units are shown as individual animals (Ind), gallons (Gal), or in pounds (Lbs).**

| Resource | Species | Unit | Edible Weight (lbs) | Round Weight (lbs) |
|---|---|---|---|---|
| Fish | | | | |
| | Chum Salmon | Ind | 6.00 | 8.50 |
| | Coho Salmon | Ind | 5.20 | 7.40 |
| | Chinook Salmon | Ind | 12.40 | 17.70 |
| | Pink Salmon | Ind | 2.10 | 3.00 |
| | Sockeye Salmon | Ind | 5.00 | 7.20 |
| | Unknown Salmon | Ind | 6.00 | 8.50 |
| | Whitefish, Humpback | Ind | 2.10 | 3.00 |
| | Whitefish, Round | Ind | 0.70 | 1.00 |
| | Whitefish, Broad | Ind | 3.20 | 4.50 |
| | Unknown Whitefish | Ind | 1.40 | 2.00 |
| | Cisco, Least | Ind | 1.22 | 1.75 |
| | Sheefish | Ind | 11.14 | 15.91 |
| | Dolly Varden | Ind | 3.30 | |
| | Northern Pike | Ind | 3.30 | 4.70 |
| | Grayling | Ind | 0.90 | 1.25 |
| | Burbot | Ind | 4.20 | 6.00 |
| | Longnose Sucker | Ind | 1.40 | 2.00 |
| | Alaska Blackfish | Ind | | |
| | Herring | Ind | 0.18 | 0.26 |
| | Herring | Gal | 6.00 | |
| | Smelt | Ind | 0.14 | 0.20 |
| | Smelt | Gal | 4.20 | 6.00 |
| | Saffron Cod | Ind | 0.21 | 0.30 |
| | Flounder | Ind | 1.10 | 1.50 |
| Shellfish | | | | |
| | Unknown Clams | Ind | 0.10 | 0.15 |
| | Unknown Clams | Lbs | 0.70 | 1.00 |
| | Unknown Clams | Gal | 2.00 | 3.00 |
| | Unknown Crab | Ind | 2.10 | |
| | Blue Mussels | Ind | | |
| | Blue Mussels | Lbs | 1.00 | 3.85 |
| | Blue Mussels | Gal | 1.00 | |
| | King Crab, Unknown | Ind | 2.10 | |
| Large land mammals | | | | |
| | Brown Bear | Ind | | 286.00 |
| | Black Bear | | | |
| | Caribou | Ind | 136.00 | 226.00 |
| | Moose | Ind | 538.00 | 840.00 |
| | Dall Sheep | Ind | 104.00 | 174.00 |

| Resource | Species | Unit | Edible Weight (lbs) | Round Weight (lbs) |
|---|---|---|---|---|
| Marine Mammals | | | | |
| | Belukha | Ind | 995.00 | 2650.00 |
| | Bearded Seal | Ind | 420.00 | 612.00 |
| | Ringed Seal | Ind | 74.00 | 116.00 |
| | Spotted Seal | Ind | 98.00 | 165.00 |
| | Young Bearded Seal | Ind | 176.00 | 275.00 |
| | Walrus | Ind | calculated | |
| | Walrus (first harvested) | Ind | 770.00 | |
| | Walrus (second harvested) | Ind | 385.00 | |
| | Walrus (all successive harvested) | Ind | 192.50 | |
| | Polar Bear | Ind | 372.00 | 775.00 |
| Furbearers | | | | |
| | Beaver | Ind | 20.00 | 40.00 |
| | Arctic Hare | Ind | 6.30 | 9.00 |
| | Snowshoe Hare | Ind | 2.50 | 3.50 |
| | Porcupine | Ind | 8.00 | 16.00 |
| | Parka Squirrel (ground) | Ind | 0.50 | |
| Birds | | | | |
| | Snowy Owl | Ind | 2.80 | |
| | unknown ptarmigan | Ind | 1.00 | |
| | Harlequin | Ind | 1.00 | |
| | Mallard | Ind | 1.95 | |
| | Pintail | Ind | 1.56 | |
| | Oldsquaw | Ind | 1.34 | |
| | Shoveler | Ind | 1.09 | |
| | Canvasback | Ind | 1.99 | |
| | Eider, Unknown | Ind | calculated | |
| | Spectacled Eiders | Ind | 2.43 | |
| | King Eiders | Ind | 2.67 | |
| | Common Eiders | Ind | 4.15 | |
| | Green Winged Teal | Ind | 0.52 | |
| | Scoter, Unknown | Ind | 1.69 | |
| | Greater Scaup | Ind | 1.68 | |
| | american wigeon | Ind | 1.31 | |
| | Ducks, Unknown | Ind | 1.88 | |
| | Emperor Geese | Ind | 4.64 | |
| | Snow Geese | Ind | 3.99 | |
| | White-fronted Geese | Ind | 4.24 | |
| | Canada Geese, Unknown | Ind | 3.42 | |
| | Black Brant | Ind | 2.28 | |
| | Tundra Swan (Whistling) | Ind | 11.21 | |
| | Sandhill Crane | Ind | 6.75 | |
| | Unknown Seabirds | Ind | 0.50 | |

| Resource | Species | Unit | Edible Weight (lbs) | Round Weight (lbs) |
|---|---|---|---|---|
| | unknown loon | Ind | 5.44 | |
| | unknown puffin | Ind | 1.14 | |
| | unknown gull | Ind | 1.00 | |
| | unknown murre | Ind | 1.65 | |
| | unknown auklet | Ind | 0.29 | |
| Eggs | | | | |
| | Pintail | Ind | 0.15 | |
| | Oldsquaw | Ind | 0.15 | |
| | Eider, Unknown | Ind | 0.15 | |
| | King Eiders | Ind | 0.15 | |
| | Common Eiders | Ind | 0.15 | |
| | Ducks, Unknown | Ind | 0.15 | |
| | Canada Geese, Unknown | Ind | 0.25 | |
| | Tundra Swan | Ind | 0.63 | |
| | Sandhill Crane | Ind | 0.33 | |
| | Unknown Loon | Ind | 0.18 | |
| | Unknown Puffin | Ind | 0.3 | |
| | Unknown Gull | Ind | 0.16 | |
| | Unknown Murre | Ind | 0.18 | |
| | Unknown Auklet | Ind | 0.05 | |
| Plants | | | | |
| | Berries | Gal | 6.50 | 6.50 |
| | Unknown Greens, from land | Gal | 1.00 | 1.00 |
| | Stinkweed Medicine | Gal | 0.00 | 1.00 |
| | Masu Roots | Gal | 4.00 | 4.00 |
| | Wood | Crd | | |
| Reindeer | | | | |
| | Reindeer | Ind | 150.00 | |
| | Reindeer | F qt. | 40.00 | |
| | Reindeer | H qt. | 35.00 | |

**Table D-13. Conversion table showing unconventional measures of subsistence harvest quantities and corresponding number of individual animals or eggs.**

| Unconventional unit of measure | Subsistence Species | Individuals |
|---|---|---|
| One Washtub | | |
| | Salmon, Chum | 12 |
| | Salmon, Pink | 33 |
| | Whitefish, Humpback | 71 |
| | Whitefish, Round | 100 |
| | Whitefish, Broad | 22 |
| | Whitefish (95% HB, 5% Rnd) | 72 |
| | Cisco, Least | 100 |
| | Sheefish | 6 |
| | Dolly Varden Trout | 21 |
| | Northern Pike | 21 |
| | Grayling | 80 |
| | Burbot | 17 |
| | Smelt, Rainbow | 500 |
| | Eggs, Murre | 480 |
| One Dog Food Sack | | |
| | Salmon, Chum | 15 |
| | Whitefish, Humpback | 42 |
| | Whitefish, Round | 125 |
| | Whitefish, Broad | 28 |
| | Whitefish, Unknown | 63 |
| | Cisco, Least | 71 |
| | Sheefish | 8 |
| | Dolly Varden Trout | 27 |
| | Northern Pike | 27 |
| | Grayling | 100 |
| | Burbot | 21 |
| One 5-Gallon Bucket | | |
| | Eggs, Murre | 160 |
| | Eggs, Gull | 160 |
| One Bundle Dry Fish | | |
| | Salmon, Chum | 25 |
| One String Dry Fish | | |
| | Salmon, Chum | 25 |

Table D-14 shows the top five species harvested in each community by year. In general, sea mammals make up the largest share of harvests in coastal communities, caribou and moose in inland communities, and salmon on Yukon River communities. There are notable exceptions. Even though Kotzebue is on the coast, the proportions of sea mammals, caribou, and fish harvested are nearly equal. Yukon River communities have been hard hit by weak salmon runs and are increasing their harvest of non-salmon fish.

### Table D-14. Top five species harvested in each community by year.

| Community | year | place fip | High harvest 1 | lbs per cap1 | High harvest 2 | lbs per cap2 | High harvest 3 | lbs per cap3 | High harvest 4 | lbs per cap4 | High harvest 5 | lbs per cap5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ambler | 1997 | 1970 | Mallard | 2 | Whitefronted Geese | 2 | Willow Ptarmigan | 2 | Northern Pintail | 1 | Longtailed Duck | 1 |
| Ambler | 2003 | 1970 | Caribou | 176 | Moose | 23 | BlackBear | 2 | | | | |
| Anvik | 1990 | 3880 | Moose | 364 | Beaver | 109 | ChinookSalmon | 88 | Whitefish | 67 | SummerChum | 42 |
| Anvik | 2002 | 3880 | Moose | 104 | Eel | 72 | BroadWhitefish | 39 | Sheefish | 24 | Pike | 20 |
| Anvik | 2003 | 3880 | Moose | 79 | | | | | | | | |
| Anvik | 2004 | 3880 | Moose | 112 | BlackBear | 1 | | | | | | |
| Brevig Mission | 1989 | 8740 | Walrus | 193 | BeardedSeal | 59 | RingedSeal | 40 | Whitefish | 36 | SockeyeSalmon | 35 |
| Brevig Mission | 1995 | 8740 | Brant | 2 | LesserCanadaGeese | 1 | GlaucousGullEggs | 1 | CommonEider | 1 | SnowGeese | 1 |
| Buckland | 1996 | 9600 | LesserCanadaGeese | 4 | WhitefrontedGeese | 2 | NorthernPintail | 2 | Mallard | 1 | Cacklers | 1 |
| Deering | 1994 | 18510 | AdultBeardedSeal | 176 | ChumSalmon | 133 | Caribou | 131 | Moose | 56 | DollyVarden | 28 |
| Deering | 1997 | 18510 | CommonMurreEggs | 1 | NorthernPintail | 1 | GlaucousGullEggs | 1 | Mallard | 1 | WillowPtarmigan | 1 |
| Elim | 1993 | 22250 | NorthernPintail | 2 | UnkGullEggs | 1 | Cacklers | 1 | LesserCanadaGeese | 1 | WillowPtarmigan | 1 |
| Elim | 1999 | 22250 | Caribou | 99 | Moose | 25 | | | | | | |
| Golovin | 1989 | 29180 | Belukha | 80 | Moose | 68 | PinkSalmon | 67 | ChumSalmon | 58 | SpottedSeal | 57 |
| Golovin | 2001 | 29180 | Caribou | 30 | | | | | | | | |
| Grayling | 1990 | 30060 | Moose | 289 | SummerChum | 182 | FallChum | 99 | Whitefish | 77 | ChinookSalmon | 59 |
| Grayling | 2002 | 30060 | Eel | 131 | Moose | 100 | BroadWhitefish | 56 | HumpbackWhitefish | 37 | Sheefish | 27 |
| Grayling | 2003 | 30060 | Moose | 106 | BlackBear | 2 | Caribou | 1 | BrownBear | 1 | | |
| Grayling | 2004 | 30060 | Moose | 87 | Caribou | 2 | BlackBear | 1 | | | | |
| Holy Cross | 1990 | 33030 | Moose | 314 | ChinookSalmon | 83 | Beaver | 63 | Whitefish | 31 | Pike | 28 |
| Holy Cross | 2002 | 33030 | Moose | 138 | BroadWhitefish | 14 | Eel | 8 | Pike | 6 | Caribou | 1 |
| Holy Cross | 2003 | 33030 | Moose | 100 | | | | | | | | |
| Holy Cross | 2004 | 33030 | Moose | 66 | | | | | | | | |
| Kaltag | 1985 | 37430 | SummerChum | 596 | ChinookSalmon | 38 | FallChum | 31 | | | | |
| Kaltag | 1996 | 37430 | Moose | 74 | Caribou | 9 | BlackBear | 2 | | | | |
| Kaltag | 1997 | 37430 | Moose | 87 | Caribou | 4 | BlackBear | 1 | | | | |
| Kaltag | 1998 | 37430 | Moose | 118 | Caribou | 4 | BlackBear | 2 | | | | |
| Kaltag | 1999 | 37430 | Moose | 108 | BlackBear | 1 | | | | | | |
| Kaltag | 2001 | 37430 | Moose | 104 | BlackBear | 1 | BrownBear | 1 | | | | |
| Kaltag | 2002 | 37430 | Moose | 90 | BlackBear | 1 | | | | | | |
| Kotzebue | 1986 | 41830 | Caribou | 97 | Salmon | 73 | BeardedSeal | 69 | Sheefish | 49 | Moose | 13 |
| Kotzebue | 1991 | 41830 | Caribou | 141 | Sheefish | 117 | BeardedSeal | 111 | ChumSalmon | 73 | Moose | 35 |
| Kotzebue | 1997 | 41830 | WhitefrontedGeese | 2 | WillowPtarmigan | 2 | Mallard | 1 | | | | |
| Koyuk | 1995 | 41940 | SandhillCrane | 7 | LesserCanadaGeese | 3 | NorthernPintail | 2 | WhitefrontedGeese | 1 | WillowPtarmigan | 1 |

| Community | year | place fip | High harvest 1 | lbs per cap1 | High harvest 2 | lbs per cap2 | High harvest 3 | lbs per cap3 | High harvest 4 | lbs per cap4 | High harvest 5 | lbs per cap5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Koyuk | 1998 | 41940 | Caribou | 129 | Moose | 45 | | | | | | |
| Koyukuk | 2002 | 42050 | BroadWhitefish | 38 | Sheefish | 22 | Pike | 7 | HumpbackWhitefish | 1 | Burbot | 1 |
| Nome | 1995 | 54920 | WillowPtarmigan | 1 | SandhillCrane | 1 | | | | | | |
| Noorvik | 1996 | 55140 | WhitefrontedGeese | 3 | Mallard | 3 | WillowPtarmigan | 2 | LesserCanadaGeese | 1 | Cacklers | 1 |
| Noorvik | 2002 | 55140 | Caribou | 182 | Moose | 41 | BlackBear | 2 | BrownBear | 1 | | |
| Nulato | 1996 | 56350 | Moose | 78 | Caribou | 5 | BlackBear | 1 | | | | |
| Nulato | 1997 | 56350 | Moose | 117 | Caribou | 1 | BlackBear | 1 | | | | |
| Nulato | 1998 | 56350 | Moose | 109 | Caribou | 3 | BlackBear | 1 | | | | |
| Nulato | 1999 | 56350 | Moose | 129 | BlackBear | 1 | | | | | | |
| Nulato | 2001 | 56350 | Moose | 72 | | | | | | | | |
| Russian Mission | 1985 | 65700 | ChinookSalmon | 135 | Moose | 98 | SummerChum | 51 | FallChum | 22 | CohoSalmon | 18 |
| Saint Michael | 2003 | 66360 | Caribou | 16 | Moose | 6 | | | | | | |
| Selawik | 1993 | 68230 | WhitefrontedGeese | 2 | LesserCanadaGeese | 2 | Cacklers | 1 | WillowPtarmigan | 1 | NorthernPintail | 1 |
| Selawik | 1997 | 68230 | WillowPtarmigan | 1 | Mallard | 1 | WhitefrontedGeese | 1 | BlackScoter | 1 | NorthernPintail | 1 |
| Selawik | 1999 | 68230 | Caribou | 249 | Moose | 49 | BlackBear | 1 | | | | |
| Shageluk | 1990 | 68670 | SummerChum | 137 | Moose | 126 | Whitefish | 74 | Pike | 51 | ChinookSalmon | 21 |
| Shageluk | 2002 | 68670 | Moose | 134 | BroadWhitefish | 87 | Sheefish | 41 | Pike | 31 | Burbot | 1 |
| Shageluk | 2003 | 68670 | Moose | 112 | BlackBear | | | | | | | |
| Shageluk | 2004 | 68670 | Moose | 77 | BlackBear | | | | | | | |
| Shaktoolik | 1993 | 68890 | SandhillCrane | 7 | LesserCanadaGeese | 3 | Cacklers | 1 | CommonMurreEggs | 1 | NorthernPintail | 1 |
| Shaktoolik | 1998 | 68890 | Caribou | 97 | Moose | 48 | Wolf | | | | | |
| Shaktoolik | 1999 | 68890 | Caribou | 73 | Moose | 32 | BrownBear | | | | | |
| Shaktoolik | 2003 | 68890 | Caribou | 122 | Moose | 25 | Beaver | 1 | | | | |
| Shishmaref | 1989 | 69770 | BeardedSeal | 170 | Walrus | 144 | SpottedSeal | 75 | Caribou | 57 | RingedSeal | 56 |
| Shishmaref | 1995 | 69770 | AdultBeardedSeal | 203 | YoungBeardedSeal | 100 | Caribou | 83 | ChumSalmon | 74 | Moose | 65 |
| Stebbins | 1980 | 72960 | ChinookSalmon | 201 | Herring | 176 | ChumSalmon | 169 | Belukha | 111 | Walrus | 79 |
| Stebbins | 1993 | 72960 | SnowGeese | 11 | TundraSwan | 6 | SandhillCrane | 5 | NorthernPintail | 4 | LesserCanadaGeese | 2 |
| Stebbins | 2002 | 72960 | Moose | 17 | | | | | | | | |
| Teller | 1995 | 75930 | LesserCanadaGeese | 1 | CommonEider | 1 | Mallard | 1 | TundraSwan | 1 | NorthernPintail | 1 |
| Unalakleet | 1995 | 80660 | LesserCanadaGeese | 3 | SandhillCrane | 3 | NorthernPintail | 1 | WillowPtarmigan | 1 | | |
| Unalakleet | 2002 | 80660 | Caribou | 30 | Moose | 21 | CaribouMale | 20 | MooseMale | 20 | CaribouFemale | 10 |
| Wales | 1993 | 82860 | Bowhead | 188 | AdultBeardedSeal | 162 | Walrus | 105 | YoungBeardedSeal | 55 | RingedSeal | 38 |
| White Mountain | 1995 | 84070 | Brant | 9 | LesserCanadaGeese | 7 | NorthernPintail | 4 | SandhillCrane | 3 | WillowPtarmigan | 3 |
| White Mountain | 1999 | 84070 | Caribou | 60 | Moose | 43 | BrownBear | | | | | |

## D-2.2 Hunting and Fishing Regulations and Harvests

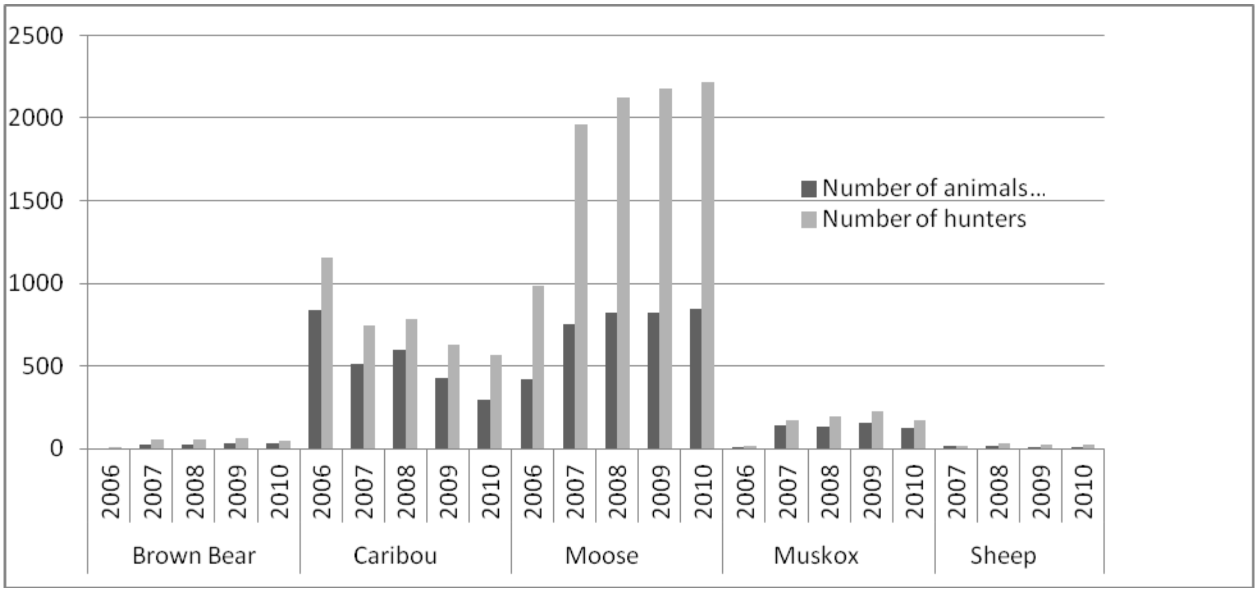
**9:** How have hunting and fishing regulations affected general hunting and fishing harvests?

Hunting regulations have had a bigger effect on reporting than on actual hunting. This section presents general hunting data from ADFG for GMUs that overlap the ecoregion. The boundaries of GMUs and the ecoregion do not match exactly. However, these data give a rough estimate general hunting harvest levels and trends in the ecoregion. Figure D-10 shows that the number of moose hunters more than doubled between 2006 and 2007, and has continued to increase. Reported moose harvests have doubled from around 425 in 2006 to 850 in 2010. The increase is largely a result of changes in reporting, rather than changes in actual harvests (personal conversation with Jim Magdanz, ADFG). The change is due to registration hunts which started around 2006 and extend from August 1 thru December 31. In registration hunts, hunters are allowed to take cows or bulls, must be an Alaska resident, are required to obtain a permit in the region where the hunt takes place, and registration takes place prior to the hunt from June 15 to July 15. The effect of this is that most of the hunters in registration hunts are local residents. Registration hunters are required to report their hunt whether or not they harvested any moose. Hunters who do not report receive fines and are ineligible to have a permit the following year. Enforcement became stricter in 2010. This corresponds to an uptick in harvest totals and hunter numbers. The moose hunter and harvest totals include local subsistence hunters and harvests. The general moose hunt, in which trophy hunters participate, is still open 3 weeks. But trophy hunters are limited to bulls with 50” antlers. This minimizes conflict over animals because the trophy season is during male rut when subsistence hunters do not want to take bulls, because they are inedible. However, there still may be conflicts over access to animals.

Caribou permitting and hunt reporting is less rigorous. Local hunts are not reported (personal conversation Jim Magdanz ADFG) Figure D-10 presents caribou hunters and harvests. The totals and changes in the figure may be due to data collection and not reflect actual harvests. Data in the table indicate that the number of caribou hunters has dropped by two-thirds since 2006, from around 840 to around 300. Caribou harvests have dropped by half to less than 600.

Restrictions on subsistence salmon fishing do not appear to have improved salmon populations. As part of a large group of research projects on causes of salmon decline, Howe and Martin (2010) and Magdanz et al. (2005) show that historically, subsistence harvests levels are uncorrelated with changes in salmon populations. Subsistence harvests have occurred under a range of restrictions; harvest levels may have changed in response to restrictions, but salmon populations did not. Other possible causes of salmon decline are changes in ocean conditions and by-catch from trawlers. Closure of commercial salmon fisheries has affected subsistence harvests. Most subsistence fishermen also fish commercially and use their gear for both. Without cash from commercial fishing, people can't afford to repair gear, maintain boats, or pay for fuel for subsistence fishing.

**Figure D-10. Harvests and general hunters 2006 to 2010**




| |
|---|
| **7**: Given current and estimates of future subsistence species populations, are harvest regulations adequate to protect subsistence species populations? |

Scientists studying the decline of the Porcupine caribou herd (Kofinas 2002) have not been able to determine a reason for the decline. According to their research, birth rate, calving distribution, and harvest levels are uncorrelated with the decline. Local hunters cited predation, human disturbance, or overgrazing (over-population) as other possible reasons for herd decline. In many places, local hunters doubt the accuracy of agency counts of animals and the necessity for regulations (Kofinas 2002, Georgette and Loon 1991). Burch (1999) describes caribou management in northwest Alaska as a mix of disaster and good luck, noting that the growth of the herd to over 400,000 animals was during a period of no bag limits and little predator control. For other species, especially where subsistence harvest counts are dated, accurate and up-to-date surveys of harvest and population would be needed to reassess hunting regulations.

Most large land mammals migrate over large areas, multiple land ownerships, and regulatory regimes. Regulations for migrating birds, salmon, and sea mammals are even more complicated. The WACH working group recommends simplifying regulations (WACH 2003). Georgette and Loon (1991) suggest reviewing regulations when populations are healthy because the discussion among user groups is less contentious.

## D-2.3 Relationship Between Sea-based and Land-based Subsistence Harvests

| |
|---|
| **2**: How could changes in sea mammal harvests potentially affect land based hunting and fishing? |

### D-2.3.1 Reasons for change in sea mammal harvests

Population decline or changes in migration patterns could result from oil development or increased ship traffic in the Arctic. The effects of an oil spill would be very serious but noise from ships and industrial activity is also stressful for marine mammals (Schoof 2012).

As sea ice conditions changes, hunting for marine mammals is becoming more dangerous, expensive and time consuming. Marine mammals may follow sea ice retreat, altering their distribution and taking them out of range for some hunters (Huntington and Fox 2005; Callaway 1999).

#### D-2.3.2 Factors affecting shift in food preferences

Many factors affect harvests: Animal health and populations, access to animals, time available to hunt, cost of hunting, and hunting skills. It is likely too, that if climate change conditions are affecting sea mammal harvests, that there are changes in other subsistence species going on at the same time. Loss of a sea mammal species or access to that species would have devastating effects for communities. The traditions and practices around preparing for hunts, harvesting, and sharing cannot be replaced by substituting land mammals.

Kinship ties and sharing mean that changes in sea mammal harvests indirectly affect almost all communities. It is conceivable that ties to other communities will strengthen and land mammals may be harvested and shared with sea mammal communities. Full understanding of the impact would require information about other animal populations, migrations, harvest practices and levels; wages and job opportunities; and government transfers.

In coastal communities of the SNK region, whales, seals, and walruses make up a large share of subsistence harvests, followed by large land mammals (mostly caribou). Subsistence foods are a large part of household food consumption. According to the Survey of Living Conditions in the Arctic, subsistence foods make up between half and three-quarters of all food consumed by the household (Martin 2005). In communities that are located near caribou and moose ranges and already harvest land mammals (Deering and Kotzebue), a decline in sea mammal harvests could result in a shift to higher land mammal harvests.

Subsistence foods are not perfect substitutes for each other. A pound for pound replacement of sea mammals with land mammals or fish is unlikely. Studies show that shifts in subsistence foods have occurred in response to shortages, but the movement has been between similar species (sheep to caribou and salmon to non-salmon fish). In these past documented shifts, hunters and fishermen could use the same gear and similar navigation and hunting/fishing skills, they were familiar with harvest areas and harvest seasons, cultural values did not prohibit eating the animal, and it was something people wanted to eat. Studies document the shift from salmon to non-salmon fish in lower-middle Yukon River communities of Grayling, Anvik, Shageluk, and Holy Cross. Notably, in these places there was not a significant increase in the harvest of large land mammals following the loss of salmon. Other research shows that in the mid 20$^{th}$ century, people in the Ambler and Shungnak areas shifted from sheep to caribou when the WACH migration starting coming near the communities. Sheep and caribou are considered similar and there no special rules about consumption (Georgette and Loon 1999).

Cultural tradition and personal taste determine which animals are considered food. Inland communities eat bears but coastal communities do not. In some places bears are not considered to be food because bears are believed to have descended from humans (Georgette 2001). In coastal areas, bears eat sea mammal carcasses and consequently do not taste good (Georgette 2001). Similarly, sheefish are in better condition on the lower Yukon River than upper. Upper Yukon River communities have not compensated for the loss of salmon with an increased harvest of sheefish.

Both caribou and moose populations are expected to decline in the future (Magdanz et al. 2004). Not only could subsistence users in the ecoregion be affected by fewer caribou, but caribou are less likely to accessible. Potential contraction of the bioclimate envelope for caribou winter grounds, as modeled for this REA, indicate the possibility that caribou might no longer migrate within the ecoregion.

Declining caribou populations and potentially more limited access to caribou will make a shift from sea mammals to land mammals more difficult and less likely. Hunter access to land mammals is also changing. Kofinas et al. (2010) note that hunters customarily use rivers as their primarily access routes for moose, and the slow freeze-up of rivers has lengthened the interval of unsafe river ice in autumn. In addition, wildfires burn shelter cabins (Kofinas et al. 2010). Winters of unusually deep snow, which are projected to become more frequent with climate warming, can create massive mortality of moose, particularly if they are nutritionally stressed (Huntington et al. 2005). Rain-on-snow events, which are also expected to occur more frequently with climate warming, reduce access by caribou to lichens during winter, creating a critical food stress (Joly, Klein et al. 2011). These indirect effects of climate change on subsistence resources are currently recognized as important but their future impacts remain highly speculative (Huntington et al. 2005).

Other possible adaptations to a decrease in sea mammal harvests include travel or seasonal moves to animal migration routes, increased consumption of store-bought foods, and increased sharing within and among communities. Change could take one or more generations as knowledge about sea mammals, habitat and hunting are not transmitted to younger people. In the 1970s during the caribou crash and implementation of bag limits restrictions, residents of Anaktuvuk Pass (which is outside of the study region but nonetheless informative) shifted consumption from caribou to store-bought foods.

#### D-2.3.3 Effects of loss of sea mammal harvests

Besides its impact on household food supply, loss of sea mammal harvest would damage cultural continuity. Whaling, walrus and seal hunting practices date back thousands of years. Subsistence is essential for transmitting culture. Transmission of knowledge about a species ties generations together. Loss of the species means loss of huge parts of culture. Large sea mammal harvests involve the entire community and are essential for individual and community well-being (Martin 2005, Kruse 1982).

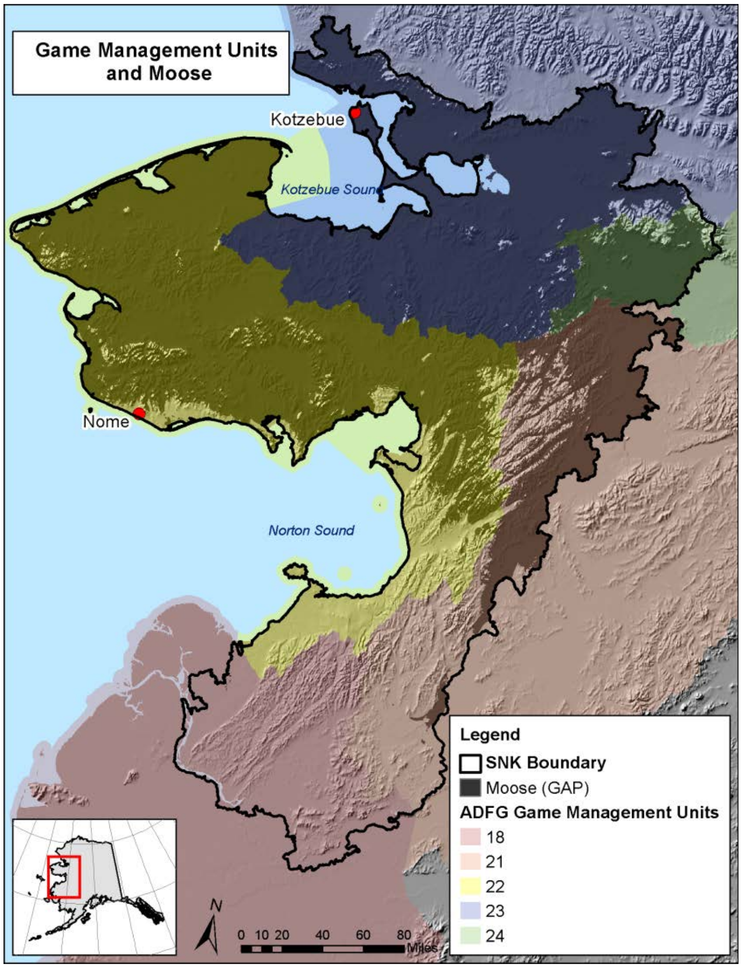
## D-2.4 Population Trends for Moose, Caribou, Muskox

**3:** What is the current population and range of moose?

**178**: For game units that overlap the REA, what are the current populations and trends in population for muskox, caribou, and moose?

Given the projected trends in climate variables and fire risk modeled in this assessment (as described in the Future Conditions chapter, there is potential for increased early successional vegetation suitable for moose browse. The current range of moose is estimated through the predicted habitat modeled by the AK GAP program and used in this REA (Figure D-11).

**Figure D-11. Modeled potential habitat for moose in the SNK ecoregion shown in relation to Alaska Department of Fish and Game's Game Management Units.**




Population summaries and trends organized by Game Management Units (GMUs) are compiled directly from ADFG's moose species profile (ADFG 2012) below. The GMU summaries don't always correspond well to the SNK ecoregional boundary, so an overall population estimate is not readily calculated.

- **GMU 22, Seward Peninsula**: From the first documented observations of moose in this area in the 1930s, the population increased and eventually reached a maximum size of 7,000 — 10,000 moose during the mid to late 1980s. Subsequent declines due to predation, winter mortality, reduced productivity and recruitment reduced the population to an estimated 4,500 to 6,500 animals. The population estimate in 2005 was 8,340 moose, plus or minus 1,000. The harvest in the 2004-05 season was 192. Compliance with regulations and harvest reporting is thought to be reasonably high in the Nome area and has improved as a result of education efforts associated with the new registration hunts.
- **GMU 21D, Yukon River from Blackburn to Ruby and Koyukuk River drainage below Dulbi Slough**: Population estimate is 8,342 ± 1,000.
- **GMU 21E, Yukon River from Paimiut up to Blackburn Creek and Innoko River down from the Iditarod River**: Moose population estimates are 7,000 to 9,000. The total harvest was estimated at 135-145 in the 2006-07 season. The Yukon-Innoko Moose Management Plan suggests the non-reporting rate is 50 percent in Unit 21E.

- **GMU 23, Western Brooks Range and Kotzebue Sound**: Numbers are summarized for this GMU as a whole; **however, only a small portion of 23 overlaps with the SNK ecoregion**. This summary is for the entire GMU: "The population estimate is that there are at least 0.1–0.6 adult moose per square mile. The reported harvest has averaged 174 moose/year for the five year period from 2000 to 2005, with an additional 412 moose/year harvested by Unit 23 villagers (from community harvest estimates)."
- **GMU 18, Yukon-Kuskokwim Delta**: Numbers are summarized for this GMU as a whole; **however, only a small portion of 18 overlaps with the SNK ecoregion.** This summary is for the entire GMU: "The lower Yukon River moose population is estimated to be 2,500 to 3,500 moose; the lower Kuskokwim River moose population is estimated to be 75 to 250 moose. The population estimate for the Paimiut area (just north of Hooper Bay) is: 994 ± 19.7 percent. Although much of Unit 18 is lowland tundra unsuitable as moose winter habitat, moose could be present in higher numbers because areas of riparian habitat remain unoccupied and in most areas where moose are present, their numbers are lower than the habitat could support. The illegal harvest, particularly of cows and particularly within the Kuskokwim River drainage, has decreased dramatically during this reporting period."
- **GMU 24, Koyukuk River drainage above Dulbi River**: Numbers are summarized for this GMU as a whole; **however, only a small portion of 24 overlaps with the SNK ecoregion.** This summary is for the entire GMU: "The population estimate is 8,467 ±1,460. The reported hunter harvest in 2005-06 was 162, with an additional harvest of 100 moose unreported. Hunting activity was typically concentrated in areas accessible by boat, with the potential for creating conflicts between local subsistence hunters and non-local hunters."

The approximate seasonal ranges of the Western Arctic Caribou Herd are shown in conjunction with the predicted habitat modeled by the Alaska GAP program as well as Game Management Units in Figure D-12. However, AFDG does not provide a breakdown of caribou populations by GMUs. As noted elsewhere in this assessment, the WACH as a whole has decreased from 490,000 animals in 2004 to 325,000 in 2011 (Woodford 2012). Subsistence harvests are generally higher than sport hunter harvests – between 14,000 and 16,000 animals per year for subsistence compared to 800 for sport harvest. The WACH working group[3] has been carefully monitoring the herd and is increasing the frequency of population counts of the herd. Joly et al. (2011) indicate that WACH populations appear to be positively correlated with the climatic cycle known as the Pacific Decadal Oscillation and cite research suggesting the PDO may be shifting back to a negative phase. Climate change, and interacting effects between climate and fire regimes, is expected to result in increased burning of forage lichens, increases in rain-on-snow events, and other changes as noted elsewhere in this report; these changes are expected to negatively impact caribou populations.

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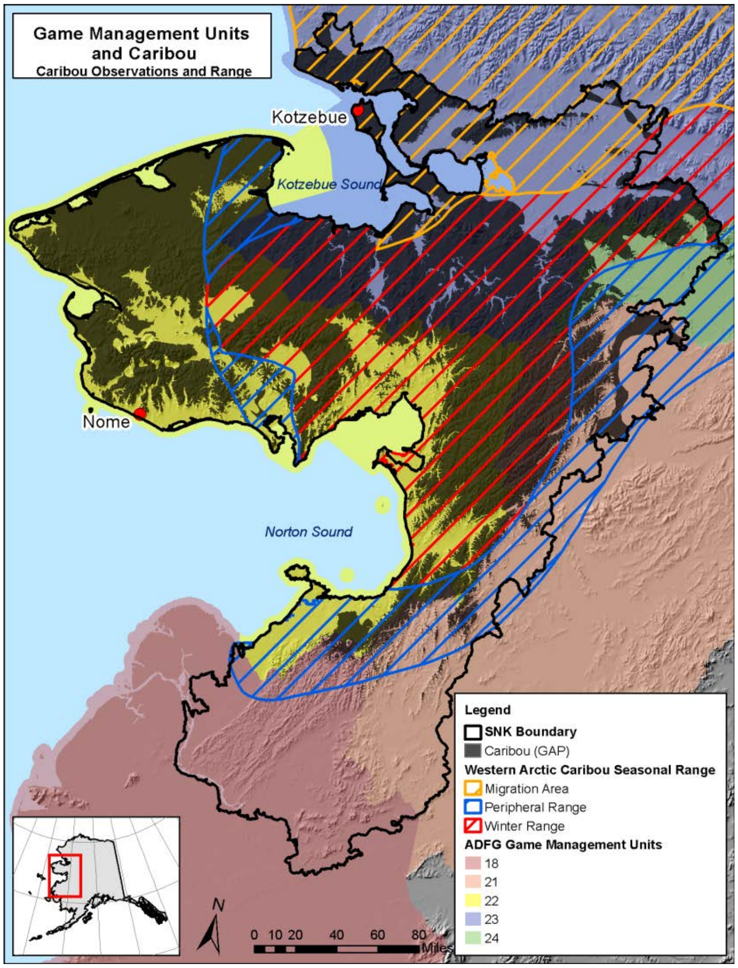
[3] The group includes subsistence users, other Alaskan hunters, reindeer herders, hunting guides, transporters, conservationists, biologists, and natural resource managers.

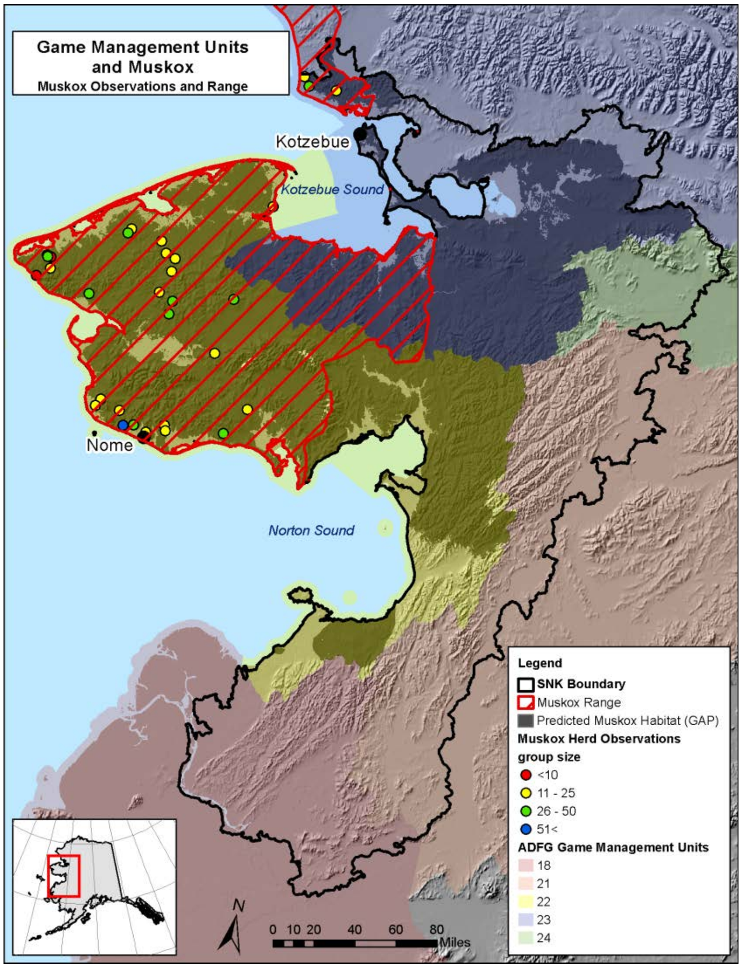
**Figure D-12. Modeled potential habitat for caribou in the SNK ecoregion shown in relation to ADFG's seasonal range extents for the Western Arctic Herd and Game Management Units.**




The predicted muskox habitat modeled by the Alaska GAP program is shown in conjunction with point locations of herd observations, ADFG's estimated muskox range, and Game Management Units in Figure D-13. The population summary by Game Management Unit (GMU) is compiled directly from ADFG's muskox species profile (ADFG 2012) and provided below. Muskox were re-introduced to Alaska around 1930, and the population as a whole as of the year 2000 was estimated to be approximately 4,000 animals. The portion of the population located within the SNK ecoregion appears to be increasing and the most recent population estimate is 2,688. However, changes in climate, such as changes in winter snowfall, may affect population growth; it requires shallow or no snow to access winter forage.

- **GMU 22 and Southwest 23, Seward Peninsula and Nulato Hills**: "In 1970, 36 muskox were reintroduced to the southern portion of the Seward Peninsula from the population on Nunivak Island. In 1981, an additional 35 muskox were introduced. Muskox have extended their range to suitable habitat throughout the Seward Peninsula and as far east as Ruby on the Yukon River, and northeast into GMU 23 (see the next section). A 2007 census count in Unit 22 indicated 2,688 muskox, an increase since 2005, when 2,387 were counted. The population has been increasing since 2000. The total harvest, including subsistence, registration and drawing hunts, for 2007-08 season was 123 muskox."

**Figure D-13. Modeled potential habitat for muskox in the SNK ecoregion shown in relation to ADFG's estimated range, point locations of herd observations, and Game Management Units**




## D-2.5 Hunting and Caribou

**44:** How are transporters, tourism, sport hunting and fishing affecting the migration patterns of caribou?

In the 1980s following the caribou crash, when the WACH began to recover and were abundant along the Noatak River, guides were transporting hunters to that area. Local residents were overrun by non-local hunters and approached the Alaska Board of Game. The board responded by creating a controlled use area along the Noatak river. Guides and hunters moved their activities to the Squirrel River area (which is outside of the ecoregion). Now most use conflicts center in the Squirrel River area. Residents there have approached the board to request a controlled use area, but their request was denied. The rationale behind the denial was that closing areas just moves conflicts and intensifies use in other areas (conversation with Jim Magdanz).

The WACH planning group writes that people who come to see and photograph caribou may adversely affect the herd. Excessive over flights add stress during the summer when caribou are trying to gain fat reserves for winter. During the summer caribou gather into huge masses to avoid insects. Airplane noise disrupts the group. Regulation of non-consumptive activities may be required in the future (WACH 2003).

Other user conflicts involve sport fishermen and non-salmon fish in GASH area along the Yukon River. In the wake of low salmon harvests, non-salmon fish have become increasingly important to subsistence in the region. Anvik reports increased competition from sport hunters for moose.

## *D-3 Climate Trends and CEs*

Significant warming is expected across the REA, particularly in the winter months (Table D-15). By the 2060s, more than 50% of months may fall outside historical norms, as defined at the 95% level (see Appendix A). Precipitation is also expected to increase across the region, although the impacts of additional moisture are likely to be offset by temperature-driven increases in evapotranspiration.

**Table D-15: Mean projected temperature (°C) by month and ecoregion.**

| Kotzebue Sound Lowlands | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec | MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1901-1981 | -20.3 | -20.4 | -17.9 | -8.9 | 2.3 | 9.6 | 13.0 | 10.5 | 4.9 | -5.2 | -13.9 | -19.3 | -5.5 |
| 2020-2029 | -16.9 | -19.3 | -15.1 | -8.3 | 3.6 | 10.5 | 14.0 | 11.6 | 5.7 | -3.8 | -11.5 | -15.0 | -4.0 |
| 2050-2059 | -15.7 | -17.3 | -14.4 | -7.3 | 3.7 | 10.6 | 14.2 | 11.9 | 7.0 | -1.8 | -9.3 | -13.2 | -2.9 |
| 2060-2069 | -13.6 | -15.1 | -13.9 | -6.7 | 4.3 | 11.2 | 15.1 | 13.0 | 7.3 | -1.5 | -7.7 | -12.9 | -2.0 |
| **Nulato Hills** | **Jan** | **Feb** | **March** | **April** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **MEAN** |
| 1901-1981 | -19.0 | -18.2 | -13.3 | -4.6 | 5.0 | 11.0 | 13.0 | 10.9 | 5.6 | -4.5 | -12.7 | -18.7 | -3.8 |
| 2020-2029 | -15.5 | -16.8 | -10.3 | -4.0 | 6.0 | 11.7 | 13.8 | 12.1 | 6.2 | -3.4 | -10.6 | -14.4 | -1.9 |
| 2050-2059 | -14.3 | -15.1 | -9.6 | -2.9 | 6.4 | 11.9 | 14.3 | 12.4 | 7.6 | -1.6 | -9.0 | -13.2 | -0.9 |
| 2060-2069 | -12.7 | -12.7 | -9.2 | -2.1 | 6.9 | 12.3 | 15.1 | 13.6 | 7.8 | -1.3 | -7.5 | -13.3 | 0.0 |
| **Seward Peninsula** | **Jan** | **Feb** | **March** | **April** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **MEAN** |
| 1901-1981 | -18.2 | -19.3 | -16.6 | -8.4 | 1.5 | 8.4 | 11.3 | 9.8 | 5.0 | -4.1 | -11.6 | -18.6 | -5.1 |
| 2020-2029 | -14.9 | -18.2 | -13.6 | -7.9 | 2.7 | 9.2 | 12.2 | 10.9 | 5.6 | -2.8 | -9.1 | -14.0 | -3.3 |
| 2050-2059 | -13.5 | -16.1 | -13.0 | -7.0 | 2.8 | 9.3 | 12.5 | 11.2 | 6.9 | -1.0 | -7.2 | -12.3 | -2.3 |
| 2060-2069 | -11.5 | -14.0 | -12.3 | -6.1 | 3.4 | 9.9 | 13.5 | 12.3 | 7.2 | -0.7 | -5.7 | -12.0 | -1.3 |
| **Upper Kobuk - Koyukuk** | **Jan** | **Feb** | **March** | **April** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **MEAN** |
| 1901-1981 | -22.7 | -21.7 | -18.0 | -7.6 | 4.7 | 12.6 | 14.7 | 10.9 | 4.2 | -7.4 | -16.9 | -21.6 | -5.7 |
| 2020-2029 | -19.4 | -20.5 | -15.6 | -7.2 | 6.3 | 13.6 | 15.6 | 12.0 | 4.8 | -6.1 | -14.8 | -17.8 | -3.5 |
| 2050-2059 | -18.5 | -18.6 | -14.8 | -6.1 | 6.3 | 13.7 | 15.9 | 12.3 | 6.2 | -4.0 | -12.8 | -16.3 | -2.3 |
| 2060-2069 | -16.6 | -16.5 | -14.5 | -5.6 | 6.9 | 14.2 | 16.7 | 13.5 | 6.5 | -3.7 | -11.2 | -16.2 | -1.5 |
| **Yukon River Lowlands** | **Jan** | **Feb** | **March** | **April** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **MEAN** |
| 1901-1981 | -20.0 | -18.7 | -13.6 | -4.1 | 6.3 | 12.9 | 14.8 | 12.3 | 6.7 | -3.9 | -13.1 | -19.7 | -3.3 |
| 2020-2029 | -16.5 | -17.3 | -10.9 | -3.6 | 7.5 | 13.6 | 15.6 | 13.5 | 7.2 | -2.8 | -11.2 | -15.8 | -1.9 |
| 2050-2059 | -15.5 | -15.6 | -10.0 | -2.6 | 7.8 | 13.8 | 16.0 | 13.9 | 8.6 | -1.0 | -9.8 | -14.7 | -0.9 |
| 2060-2069 | -14.0 | -13.3 | -9.7 | -1.8 | 8.3 | 14.2 | 16.9 | 15.0 | 8.9 | -0.8 | -8.2 | -14.7 | 0.0 |
| **Yukon - Kuskokwim Delta** | **Jan** | **Feb** | **March** | **April** | **May** | **June** | **July** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **MEAN** |
| 1901-1981 | -15.5 | -15.7 | -11.7 | -5.2 | 4.3 | 10.6 | 12.9 | 11.7 | 7.0 | -2.0 | -9.2 | -15.5 | -2.4 |
| 2020-2029 | -11.8 | -14.4 | -8.3 | -4.5 | 5.2 | 11.2 | 13.7 | 12.8 | 7.6 | -1.0 | -7.0 | -11.0 | -0.9 |
| 2050-2059 | -10.4 | -12.5 | -7.7 | -3.5 | 5.6 | 11.4 | 14.1 | 13.1 | 8.9 | 0.7 | -5.5 | -9.8 | 0.1 |
| 2060-2069 | -8.9 | -10.0 | -7.1 | -2.4 | 6.1 | 11.9 | 15.0 | 14.3 | 9.2 | 1.0 | -4.0 | -9.8 | 1.0 |

In addition to the primary management question on CEs and climate change – **63**: Where will the distribution of CEs and wildlife ranges likely experience significant change in climate? – there are additional management questions on linkages between climate change and CEs. Considering climate change as a whole, the bioclimate envelope models indicate where altered climate has the potential to affect subsistence species (MQ 11), by illustrating how the climate envelope will shift in the future (Future Conditions chapter). However, predicting areas with increased risk of specific climate change-related weather events, such as rain-on-snow, or more frequent coastal storms, is not possible with available data and modeling tools. These possibilities are further qualitatively discussed below. The bioclimate envelope model was intended to help address MQ 103 as well; additional qualitative discussion is provided here as well.

> **11**: In which locations are climate change events likely to affect subsistence species?
>
> **103**: Will suitable habitat for caribou be available with climate change??

Impacts of temperature change on subsistence resources, wildlife ranges, caribou, and reindeer will be both direct, due to potential heat stress and behavior changes, and indirect, via temperature's impacts on fire or permafrost (also discussed in the appropriate sections below), vegetation, and ocean conditions. These impacts will be species-specific.

In general, species with broader, more plastic habitat requirements may fare better than those with limited dispersal ability and narrow niches. For example, migratory birds may be able to select new nesting sites if former sites have undergone hydrologic or vegetative shift, whereas species such as marmots that are locked into high-elevation cold-climate niches may find their habitat shrinking and their ability to disperse or find mates curtailed.

Encroachment by invasive species is likely, as warmer winters will no longer serve as a barrier to cold-intolerant species. However, few data are available regarding specific species and their potential impacts to endemic species.

Since warming temperatures are projected to increase shrubbiness and cause treeline to encroach in many areas, forest species may be expected to gain territory at the expense of tundra species. However, these effects are likely to occur in conjunction with fire and permafrost impacts discussed below.

Due to disparity in dispersal ability and species flexibility, trophic mismatches may occur. With regard to the timing of key ecological processes such as reproduction, green-up, growth, flowering, hatching, and seed formation, some species are triggered by day length, while others are triggered by temperature thresholds or growing degree days. Since day length will not change, while temperature cues are likely to shift substantially, predator-prey relationships may be altered or thrown out of balance.

SNAP climate models do not directly address off-shore changes, including ocean temperature and acidification. However, ongoing research indicates that ocean acidification and other climate-associated shifts may play an important role in the health of aquatic resources, including many of the species of fish and marine mammals relied upon for subsistence or sought by tourists who visit the area to fish. In recent years, corrosive water has been documented in the northeast Pacific, as a result of a rapid decline in seawater pH over the past decade (Pfister et al. 2011). Simulated changes in primary productivity, species ranges, zooplankton community size structure, ocean acidification, and ocean deoxygenation indicate that there is likely to be a decline in fisheries landings and total fish biomass, although some invertebrates are predicted to increase (Ainsworth et al. 2011).

Marine mammals may be impacted by fish declines, and may also be affected by declines in shore-fast ice. Moore and Huntington (2008) suggest that for ice-dependent species such as polar bears and ringed seals, some may shift their populations to ice refugia, some may adapt to ice-free coastal conditions, and some may face competition from seasonally migrant species that are likely to encroach up their habitats.

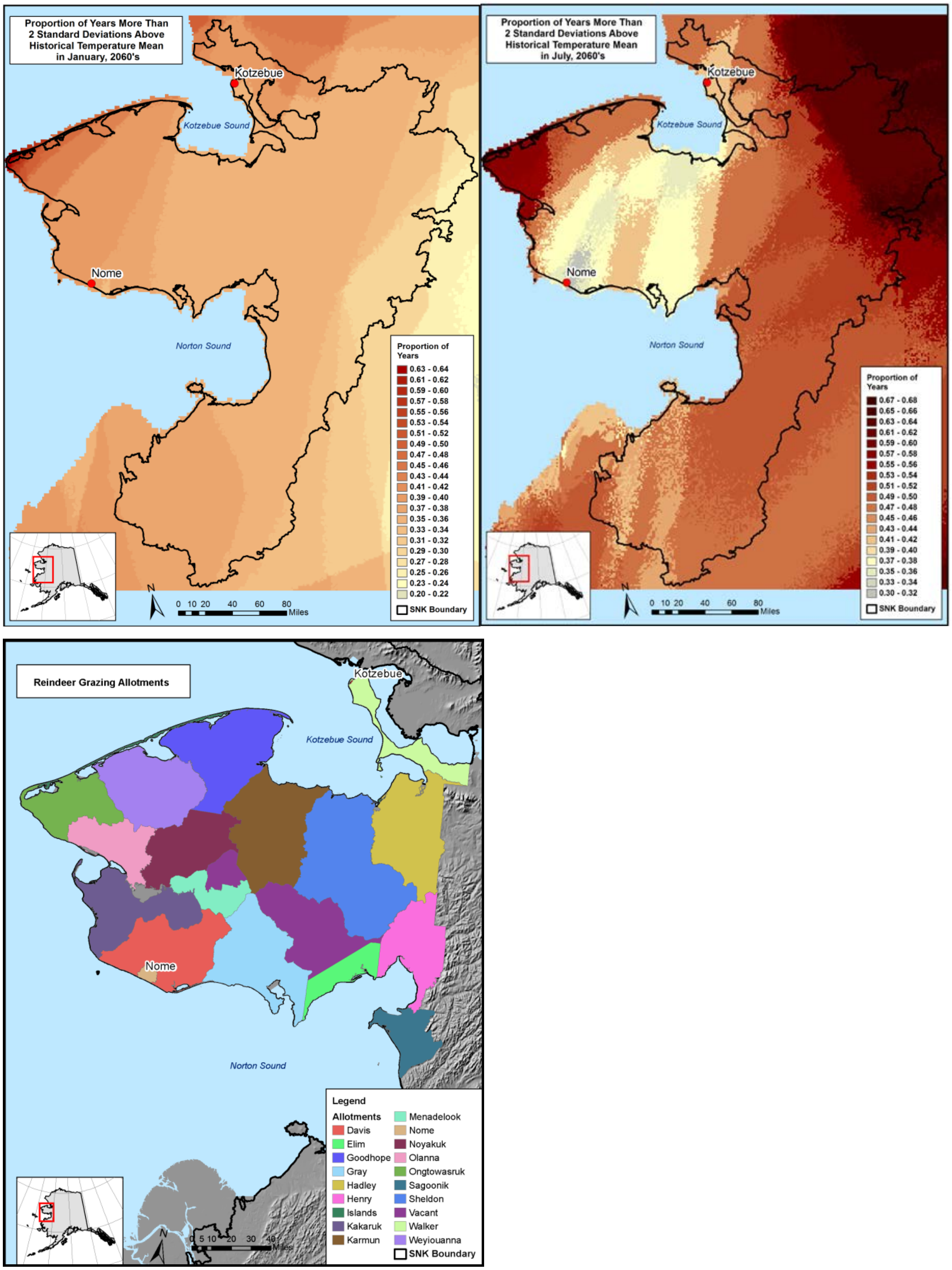
For some species, including caribou, specific weather events may be more appropriate predictors of habitat suitability than overall trends. Although climate projections cannot provide data on the locations of individual weather events, they can provide some indication of what events may become more or less likely. For example, rain-on-snow events have a strongly adverse effect on caribou, since such events can lead to icy conditions in which it becomes very difficult for caribou to reach their food sources. Given the changes in winter temperatures shown in Table D-15, it is clear that temperatures at or above freezing during winter months will become more likely. With winter precipitation remaining the same or seeing slight increases, rain-on-snow events are likely to increase in frequency.

Fire-driven vegetative change may be at least as important as change directly driven by temperature increases. Shorter fire cycles and more frequent burning (see below) in areas that previously saw little fire will result in an overall shift toward early-succession vegetation. Species such as willow, birch, and aspen may gain precedence over older-succession spruce in forested areas, and in tundra, faster-growing grasses may prevail over slower-growing lichens (Jandt et al.2008). As a result, species that rely on early-succession vegetation are likely to gain a competitive advantage over those that require late-succession vegetation. For example, moose browse and willow ptarmigan habitat may increase, while reindeer and caribou habitat decreases. Habitat requirements must be examined on a species by species basis in order to estimate potential impacts to wildlife in general, and to subsistence populations in particular. Of particular note are habitat types that support species during times of stress or limited resources (e.g. winter or droughts), or areas that serve as calving or breeding habitats.

**104**: Where will current reindeer grazing areas experience climate completely outside their normal range?

As described at the beginning of this **Climate Trends and CEs** section, significant warming is expected across the REA, particularly in the winter months (Table D-15). By the 2060s, more than 50% of months may fall outside historical norms (see Appendix A). At least for parts of the year, temperatures are projected to be two standard deviations or more, for approximately half of the years during the 2060s, in many parts of the Seward Peninsula, as illustrated in Figure D-14. Precipitation is also expected to increase across the region, although the impacts of additional moisture are likely to be offset by temperature-driven increases in evapotranspiration. As with the rest of the ecoregion, the Seward Peninsula, where grazing allotments are located, is expected to undergo a significant degree of change.

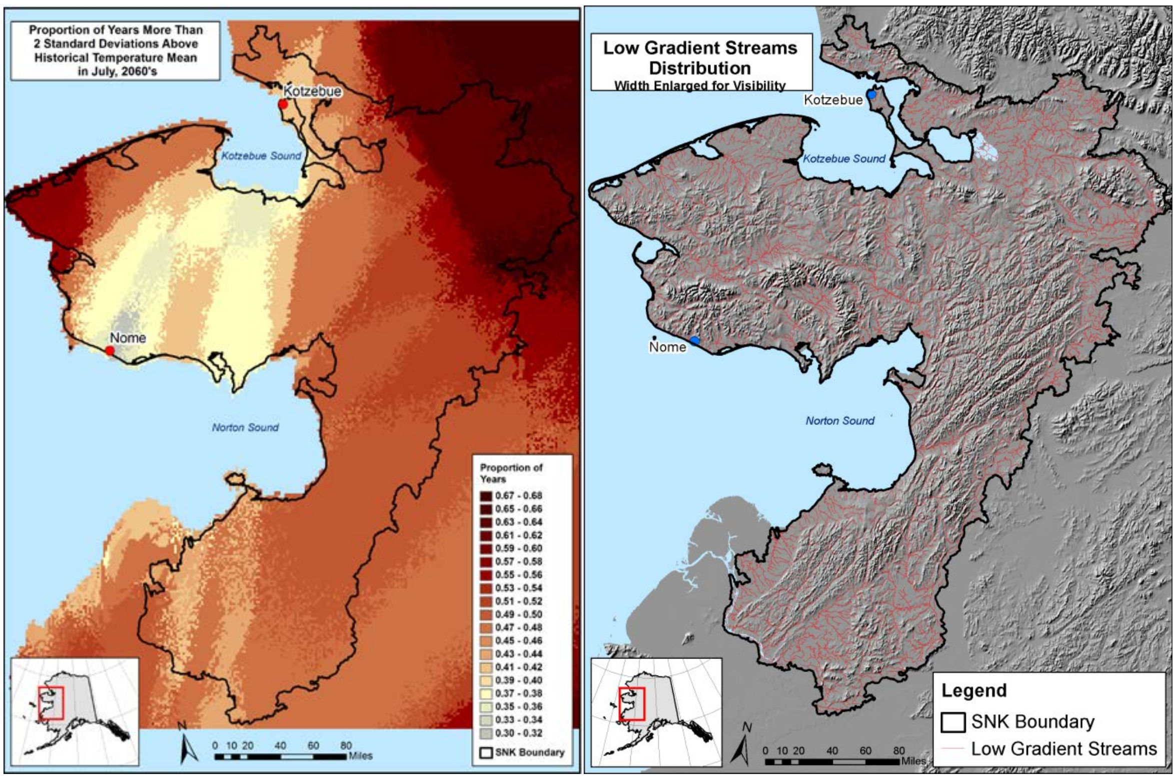
**Figure D-14. Estimates of degree of change in temperature by 2060s (January in upper left, July upper right) shown in conjunction with reindeer grazing allotments (lower left).**



**117:** Where are predicted changes in air temperature associated with important aquatic resources?

Hydrologic change may also be spurred by temperature changes in the shoulder seasons, as snowfall and freeze-up occur later in the fall, and thaw occurs earlier in the spring (Table D-15 ). For example, in the Yukon-Kuskokwim Delta ecoregion, current October mean temperatures are below freezing, but they are projected to rise about freezing by the 2060s. Increased summer temperatures (e.g., per Figure D-15) may also contribute to hydrologic change, depending on the combination of increased temperature and changes in evapotranspiration (which could not be modeled). Changes in air temperature may affect aquatic resources indirectly, through associated increases in water temperature as well as through changes in vegetation and hydrology.

**Figure D-15. Projected changes in July temperatures (left) shown in conjunction with the distribution of the low-gradient streams CE (right).**




## *D-4 Permafrost Changes: CEs and Human Communities*

Projected climate change is expected to have far-reaching and inter-related impacts on the ecosystems and human communities in the ecoregion. Its effects on permafrost are expected to impact aquatic ecosystems, which will affect both the biota and the human communities which depend on those ecosystems. Following is a series of inter-related management questions on the impacts of changing permafrost on aquatic systems and human communities. These questions are addressed by comparing the results of the permafrost modeling summarized in Appendix A with the spatial distribution of the aquatic systems and human communities. The discussion of these questions is followed by a series of figures illustrating areas of changing soil thermal regime, shown in conjunction with lakes, estuaries, hot springs, and human communities (Figure D-16). Areas with MAGT above freezing (at one meter depth) are shown in pink or red in these figures. Note that these areas are likely to still have deeper permafrost, due to lag times in thaw.

> **157**: Where are predicted changes in soil thermal regimes associated with aquatic communities?
>
> **116:** Where are predicted changes in hydrologic regime associated with important aquatic resources?
>
> **29**: Where are predicted changes in river erosion associated with relevant CEs?

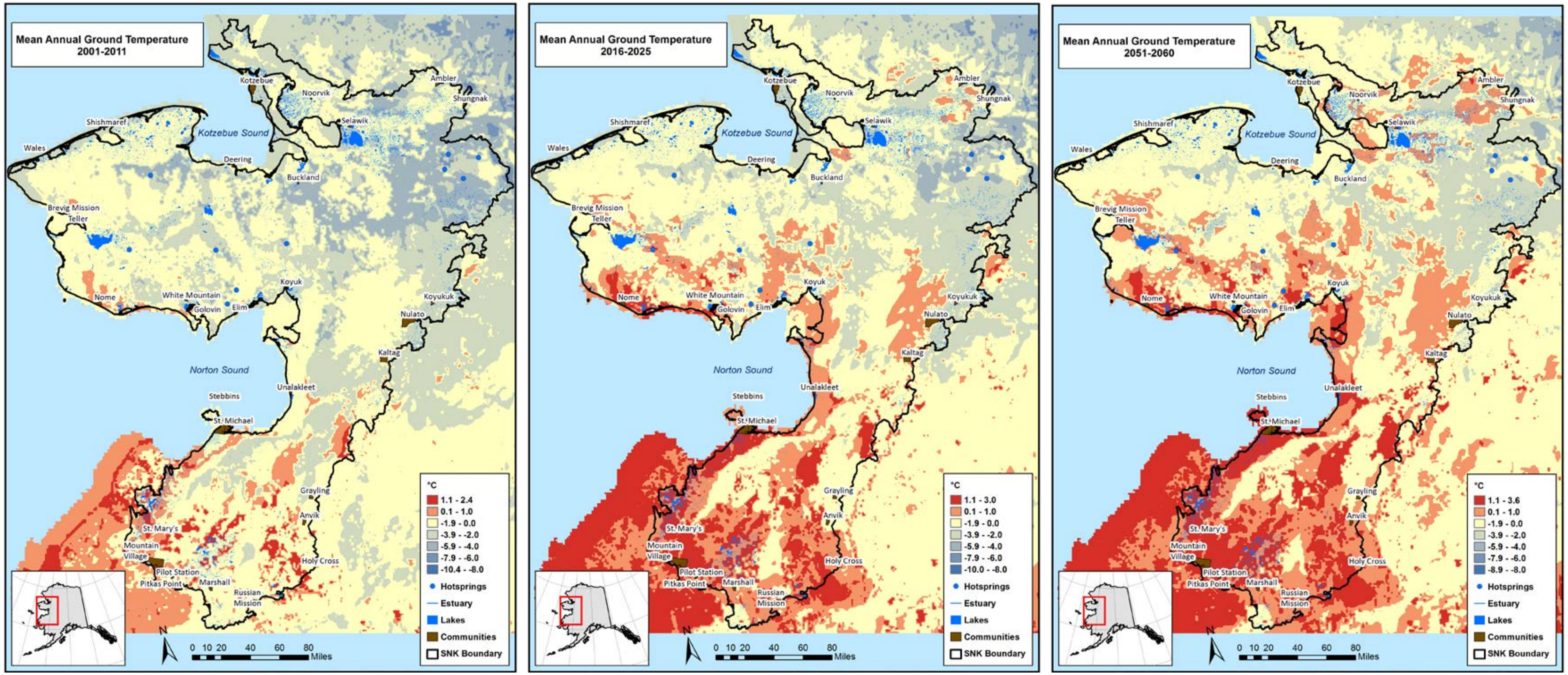
Changes in hydrologic regime are likely in areas currently underlain by permafrost but projected to undergo partial or total permafrost thaw. Reviewing the overlaps shown in Figure D-16, the northern portion of the study area appears likely to be more hydrologically stable, between now and 2060. The largest lakes in the region are in the northern inland areas, and are thus less likely to be impacted by permafrost thaw. However, many smaller water bodies and rivers are located in warmer areas with more unstable permafrost. Water bodies located in areas where MAGT is likely to shift from below freezing to above freezing may be at risk for drainage or other hard-to-predict shifts in flow patterns. Many smaller lakes in the southern portion of the study area fall into this category, although it should be kept in mind that permafrost analysis, while downscaled to the extent possible, is still reliant upon climate data at a 2-kilometer resolution. Thus, areas that appear to be frozen in the current time period are likely to have localized thaw regions, while areas that appear to be thawed in future time periods will still have localized permafrost. Site-specific knowledge of particular water bodies, when coupled with this analysis, can help further inform management questions relating to the impacts of thawing permafrost on aquatic systems.

> **159**: Where are predicted changes in soil thermal regimes associated with communities/villages?
>
> **30**: Where will losses of lakes potentially affect water supply to villages?

The greatest hydrological changes are expected to be in southern and coastal areas; associated damage to water supply and other infrastructure could be severe. Along the coast, changes in the seasonality of frozen ground and shore-fast ice are already having profound effects, as thawed soils become subject to erosion. Shishmaref is one clear example of this phenomenon. Although this area is not projected to undergo complete permafrost thaw, the loss of frozen ground in the shoulder seasons and the loss of shore-fast ice have already led to extreme erosion, making total loss of the current community site likely. Erosion of coastal land could reshape the coastline and fundamentally change coastal habitats and suitability for communities.

Koyukuk, Nulato, Kaltag, Kotzebue, Ambler, and Selawik, and other nearby villages all appear to be in a more hydrologically stable region in the northern portion of the study area. However, this does not make communities immune from damage due to hydrological change. An enormous thermokarst in 2004 has clouded the water in Selawik. The community is often notified to boil water (ANTHC 2012). Communities located in areas that are projected to be shifting from below freezing to above freezing ground temperatures, such as Marshall, Russian Mission, and Aniak, may be at high risk for hydrologic change, since new drainage patterns can emerge in talik layers. Erosion and loss of land around communities due to permafrost thaw could limit their ability to conduct subsistence activities, or in worst cases, force communities to relocate.

**Figure D-16. Current (left) and 2025 projected (middle) and 2060 projected (right) mean annual ground temperature (MAGT) shown in relation to aquatic CEs and communities. Stream CEs are not shown for map readability; they are distributed in high densities throughout the ecoregion, and making the detailed stream network visible on the map would make the MAGT difficult to view.**



## *D-5 Fire and Other CAs and CEs*

Appendix A details the results of modeling future fire risk and potential impacts on major vegetation types using Boreal ALFRESCO. The results of that modeling and additional literature review are used to inform discussion of additional management questions relating to fire as a change agent.

**120**: How is the potential future fire regime anticipated to impact permafrost?

Areas projected to experience increased risk of fire are generally in the eastern portion of the ecoregion – all areas except the Seward Peninsula and the Kotzebue Lowlands (Figure D-17). Areas projected to have their mean annual ground temperature cross the freezing threshold cover many parts of the ecoregion by 2060: southern Seward Peninsula, southern and eastern Nulato Hills, and some areas in the northern portion of the ecoregion (Figure D-18). Increases in fire frequency may accelerate the thaw of permafrost in the region, given that in areas where burns are severe and the organic layer is consumed, more rapid thaw has been observed immediately afterwards. In cases where most of the organic layer burns during an intense fire, subsequent heat transfer to the ground will be increased (Yoshikawa et al. 2002). Thus, estimates of permafrost thaw are likely to be conservative in areas projected to be strongly influenced by fire. Areas of the northern Nulato Hills and surrounding areas that aren't projected to have as much permafrost thaw are expected to have a noticeably increased risk of fire; as a result of increased fire frequency, these areas may have more permafrost thaw than the GIPL model indicates. The variable of fire is not directly included in the permafrost model used for this project. Given that GIPL models already predict increased permafrost thaw across the region, the coupled effects of fire and permafrost may have profound impacts on the ecosystem.

**Figure D-17. Projections of annual fire risk for two time periods (2025 and 2060) based on five different climate models. Annual fire risk is calculated as the % of times a pixel is projected to burn, averaged across 60 ALFRESCO replicates and over a 15-year time period prior (i.e., 2010 to 2025, and 2045 to 2060). The legend scale to the right of each graphic refers to % annual fire risk.**

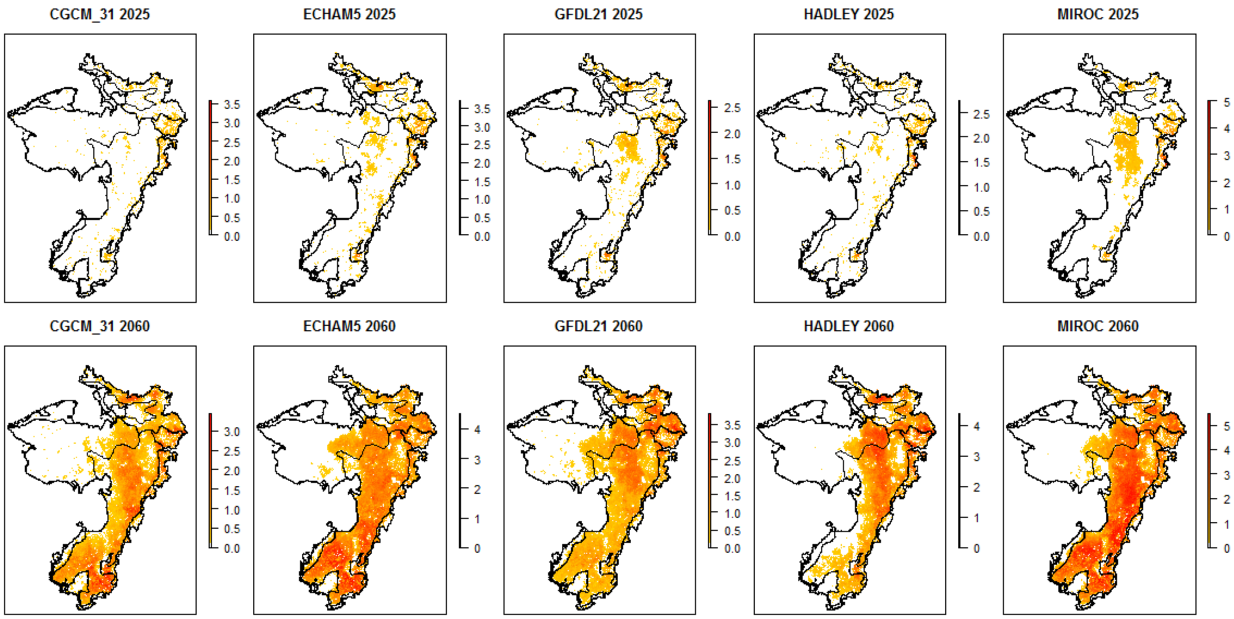
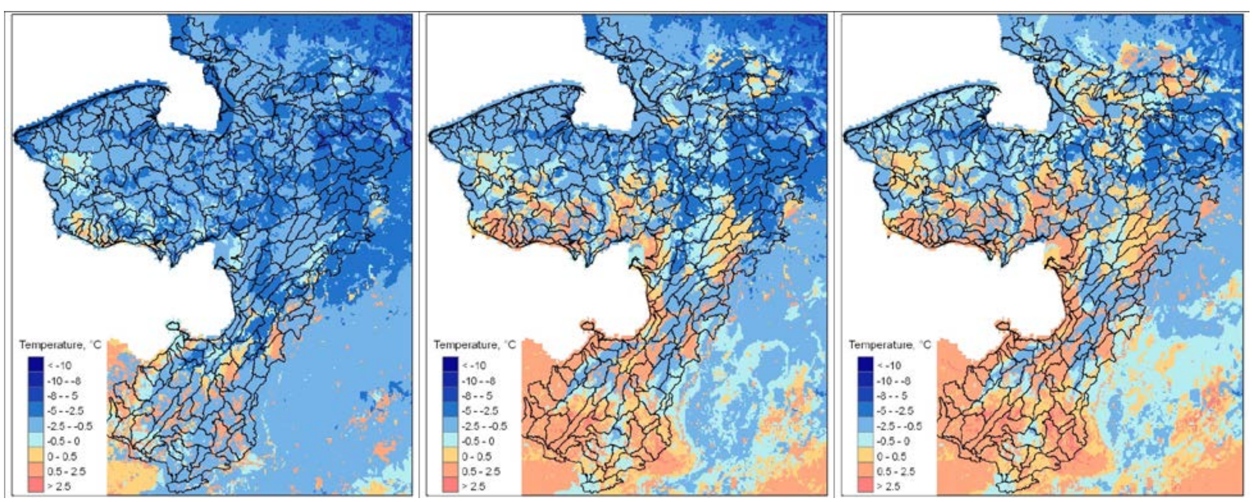



**Figure D-18. Modeled mean annual ground temperature (MAGT) at 1 m depth in 2011 (left), 2025 (center), and 2060 (right).**



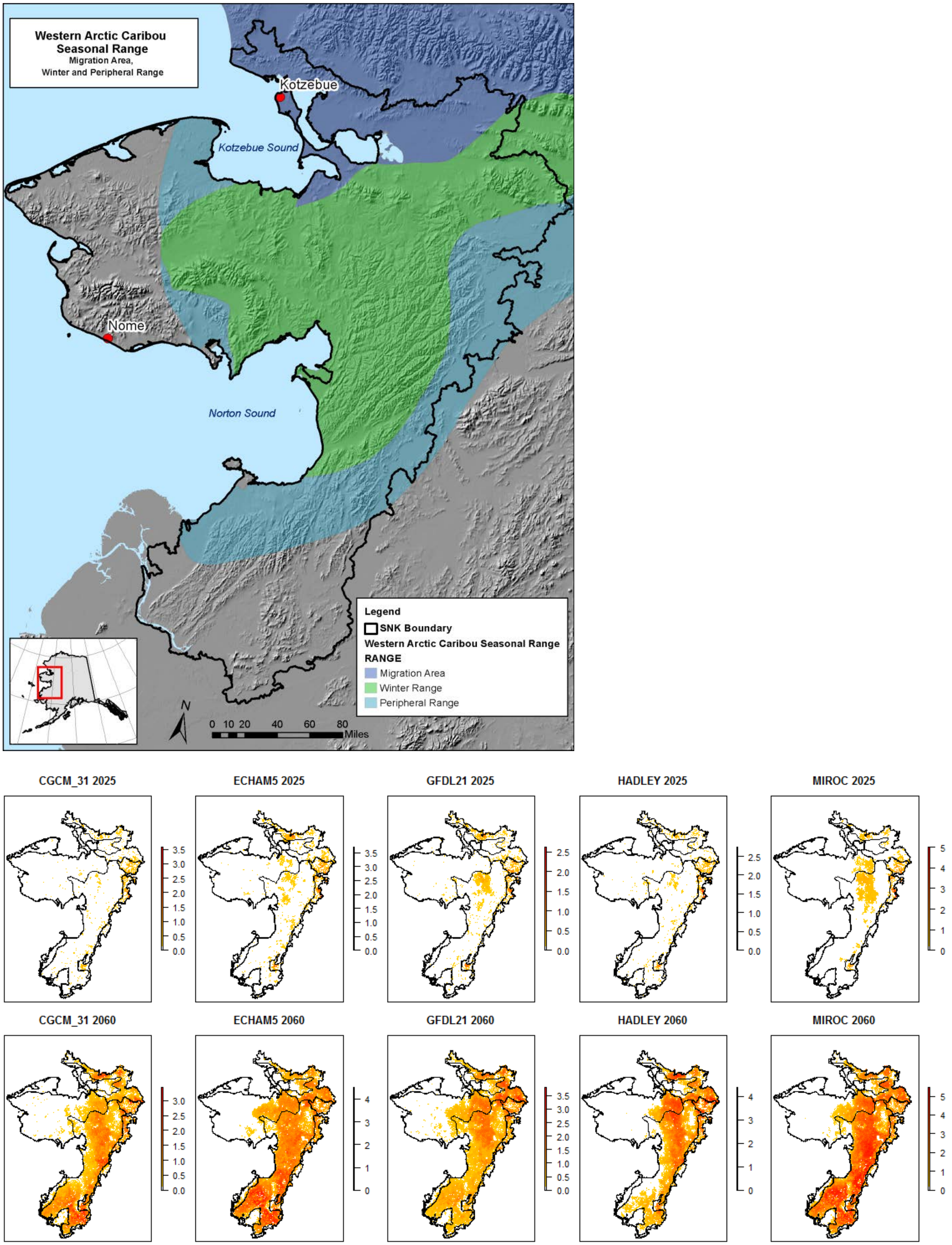
**130**: Where are areas of predicted high future fire risk associated with current caribou habitat, winter range, and calving sites?

More frequent tundra fires are likely to have direct ramifications for caribou. ALFRESCO provided five sets of predictions of fire risk based on the five climate models used; the illustration of those five sets of results are replicated in Figure D-19 in conjunction with caribou range to permit a visual comparison of the different results. In general, the fire model results all show increased risk of fire by 2060, increasing from a current annual risk (probability of fire) of 1-2% to annual risks as high as 4-5% in much of the Nulato Hills. This area of increased risk overlaps with the eastern extent of caribou winter range (as mapped by ADFG) within the SNK ecoregion. There is similarly increased risk in the northern portion of the ecoregion around parts of the Kotzebue Lowlands; this overlaps with the extent of caribou migration habitat in the northern part of the SNK. Calving grounds are outside the SNK ecoregion, and fire was only modeled within the ecoregion; therefore, no model information is available for the calving grounds.

In forested areas specifically, more frequent fires may reduce caribou wintering habitat and increase browse for moose and other species dependent on early-succession vegetation. Kofinas et al. 2010 note that fire destroys caribou habitat but the growth following a fire is favorable for moose. In forested areas, more frequent fires may reduce caribou wintering habitat and increase browse for moose and other species dependent on early-successional vegetation.

For caribou, lichen is an important food source. In tundra, lichens are slow to regrow after fire, with lichen cover of only 3-4% 24-25 years post-fire on the Seward Peninsula (Jandt et al. 2008). Recent decades have seen marked change in Arctic tundra ecosystems due to the interplay of climate change, wildfire, and disturbance by caribou and reindeer; these interdependent changes are all implicated in the observed significant reduction of terricolous lichen ground cover and biomass (Joly et al. 2009). Fire can also lead to vegetation shift, which can also impact caribou and other species. In one study on the Seward Peninsula, it was found that shrub cover was higher on the burned plots than the unburned plots, and that cover of cottongrass (*Eriophorum vaginatum*) initially increased following the fire, and remained so for more than 14 years (Jandt et al. 2008).

**Figure D-19. WAH caribou habitats shown in conjunction with the five sets of fire risk models generated from ALFRESCO.**



**122**: Where are predicted changes in future fire regime associated with rivers?

As previously illustrated in Appendix A, ALFRESCO modeling shows projected fire risk in 2025 and 2060 across a series of models. River and stream networks permeate the entire ecoregion, as illustrated here for reference by the mapped distributions of two of the four stream CEs (Figure D-20). Given the scale and level of certainty of modeling results generated by ALFRESCO, broad conclusions on fire regimes and rivers in the SNK can be drawn: By 2060, rivers in the eastern portion of the ecoregion, including the Yukon and Koyukuk rivers, will be in places experiencing relatively more frequent fire. For example, the reddest pixels in the MIROC 2060 model (right-most graphic in bottom row of Figure D-21), representing 60 repeated runs of the model for the years 2045-2060, are predicted to have a roughly **20 to 30-year** fire return interval (the inverse of a 3-5% annual probability of fire) as compared to a fire return interval of roughly **50 years** based on 60 model runs for the years 2010-2025 (MIROC 2025 graphic). In general, rivers throughout the Nulato Hills are in areas of increased fire probability, as well as rivers in the far east portion of the Seward Peninsula ecoregion and in the small portion of the Kobuk Ridges and Valleys ecoregion that extends into the northern portion of the SNK REA area.

**Figure D-20. River and stream distributions as modeled for this REA (headwater streams not shown).**

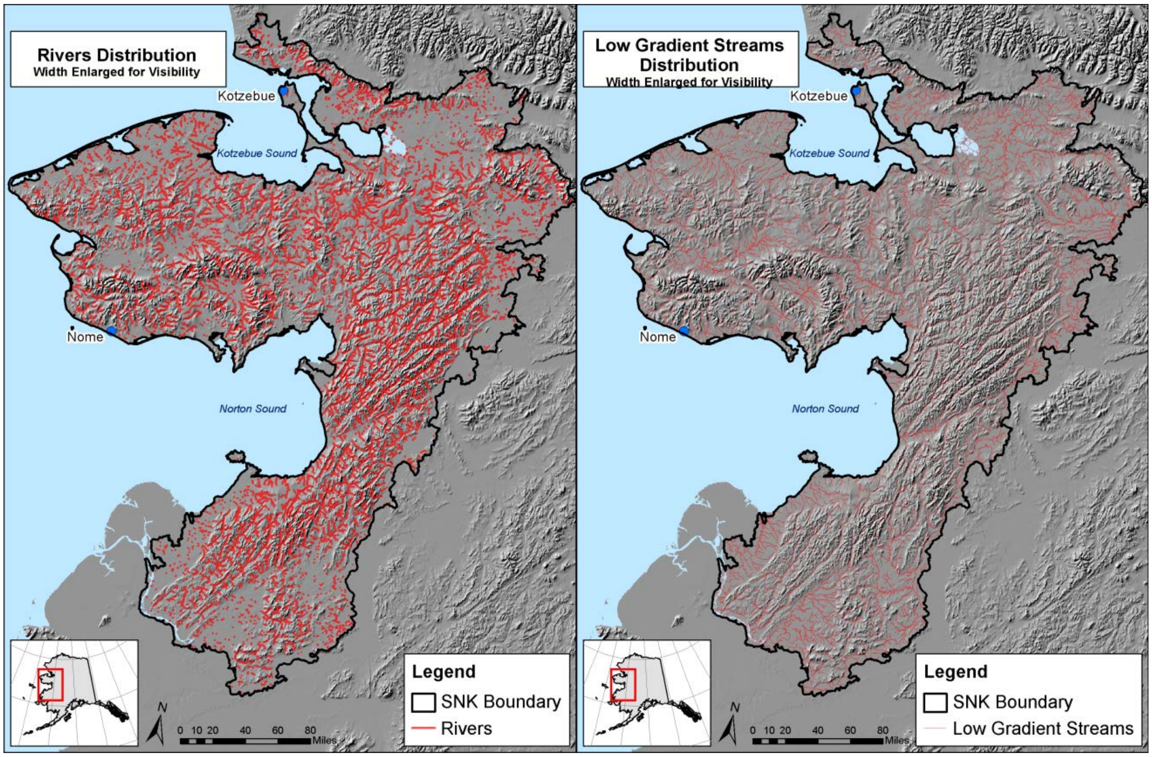
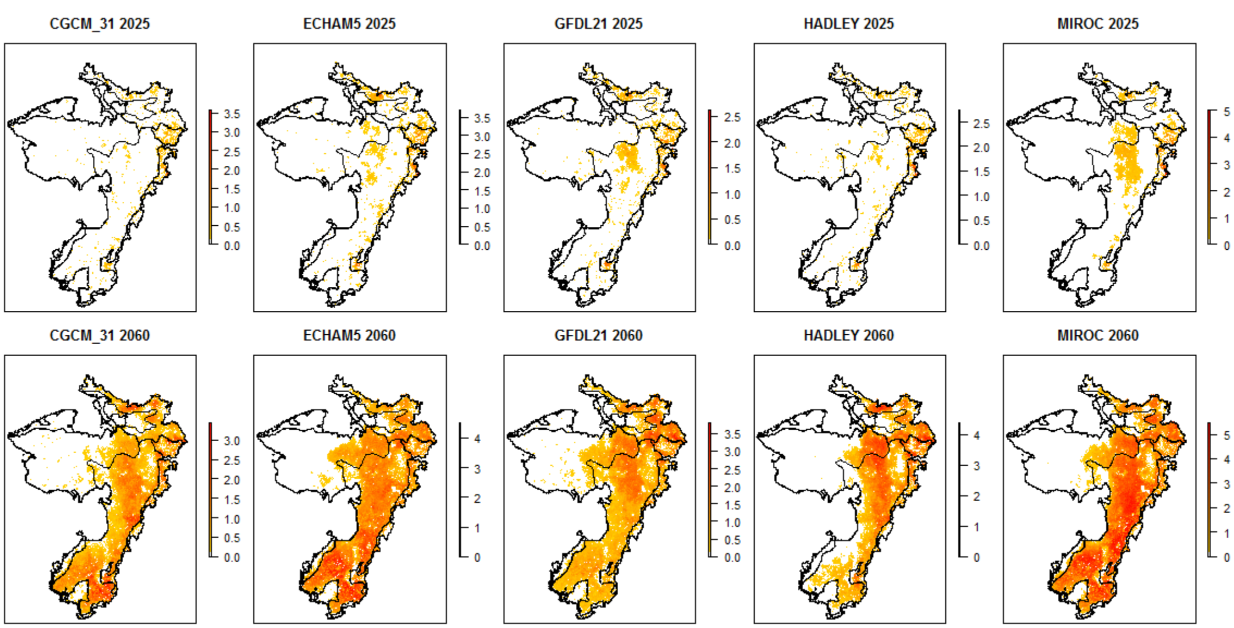



**Figure D-21. Projections of annual fire risk for two time periods (2025 and 2060) based on five different climate models. Annual fire risk is calculated as the % of times a pixel is projected to burn, averaged across 60 ALFRESCO replicates and over a 15-year time period prior (i.e., 2010 to 2025, and 2045 to 2060). The legend scale to the right of each graphic refers to % annual fire risk.**



# D-6 Development CAs and CEs

This section provides both detailed information on methods used to address the following management questions, as well as the detailed results and interpretation. The results and interpretation are also included in condensed form in the corresponding sections in the Current and Future Conditions chapters. This section addresses the management questions specifically in relation to the development change agent.

> **62**: Where do current CE distributions overlap with CAs?
>
> **64**: Where are CEs whose habitats are systematically threatened by CAs (other than climate change)?

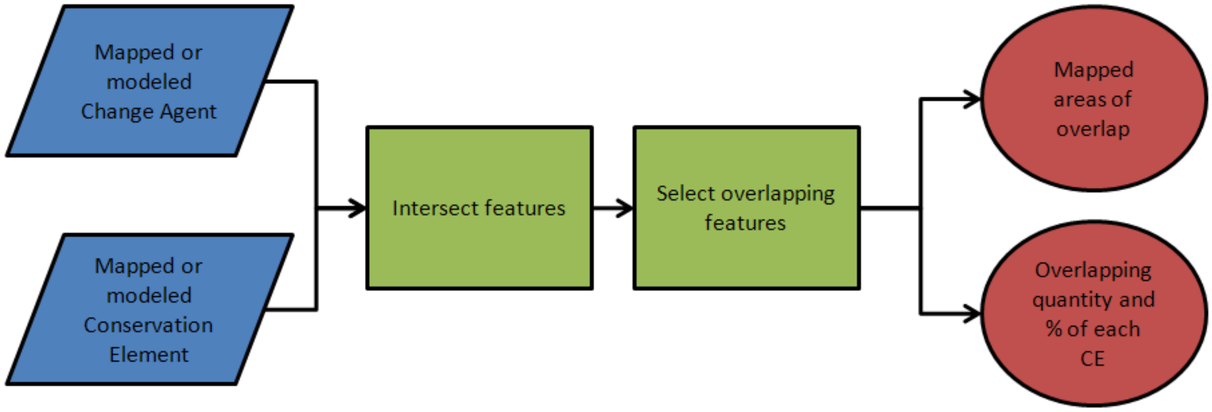
## D-6.1 Development CA Overlap with CEs: Current and Future

### D-6.1.1 Data and Methods

Many MQs can be summarized as "Where will X coincide with Y?" seeking to identify areas where CEs will be coincident with CAs that may cause impacts (but without attempting to model the impact). These types of MQs can be answered by a simple intersection of the mapped or modeled distribution of a CE with a mapped or modeled distribution of a CA. Areas or portions of overlap between the CE and development CA can then be displayed as a map and accompanied by summary statistics, as shown in Figure D-22.

To provide a coherent summary of the intersection of CEs with development CAs for the SNK REA, CE distributions that were mapped or modeled for the SNK ecoregion were intersected with an aggregated spatial layer incorporating all of the development features summarized in the **Development** section in Appendix A (Table D-16 and Table D-17). Given the large number of CEs in the SNK REA, conducting intersections of individual CEs with individual development CA layers was not feasible; 60-plus CEs intersected with 10 current development CA layers = 600+ maps and tables and 60-plus CEs x 11 future development CA layers = 660+ maps/tables), for a total of over 1,200 maps and tables. Therefore, the development CAs were compiled into a pair of aggregated layers, one reflecting the aggregation of all current development footprints and one reflecting the aggregation of all future development footprints. The individual CEs were intersected with each of these aggregated layers, to obtain a summary of the degree to which development change agents overlap with CEs under current and future conditions. In most cases, different categories of development did not overlap each other; all pixels where development footprints overlapped each other were accounted for in the "Multiple Development Change Agent" category (e.g., where roads and community footprints overlap they are summarized within the "Multiple Development Change Agent" category). Ports and renewable energy fund footprints were derived from community footprints and therefore completely overlap with community footprints. Consequently, they are reflected within the "Multiple Development Change Agent" category.

**Figure D-22. Basic model for assessing overlap of development CAs with CEs.**




### D-6.1.2 Results and Interpretation

In general, there is very little overlap between CEs and current development change agent footprints in the SNK ecoregion, with most CEs having 2% or less of their extent overlapping with development. Where there is overlap, it is typically between community footprints and CEs. This may be in part because the community footprint polygons are more extensive than the actual extent of the community. Trails and the military area were other commonly overlapped change agents. Seabird colonies were the CE having the highest proportion (8.4%) of their total estimated extent overlapped by development footprints. This is due to the fact that communities are predominantly located along the coast where seabird colonies are also located, and the community footprints (which were obtained from Tiger census data and therefore are larger than the actual extent of the communities) were not removed from the mapped distribution of seabird colonies. (If they had been removed, it would have underestimated the actual extent of seabird colonies.). Overlap results are summarized in Table D-16.

The same trends generally hold true when future proposed development projects are added to the overall development change agent footprint. There is still very little overlap, and where there is overlap, communities and trails are two of the most significant sources of overlap. The addition of proposed recreation areas adds another significant source of overlap for a number of CEs. Arctic char has 100% overlap with the estimated future development footprint, because this species is currently only identified within a small group of lakes within the Kigluaik Mountains, in an area proposed to become a future recreation area. However, the low intensity and diffuse nature of recreation in this ecoregion suggests it may have relatively little impact on most CEs, especially coarse-filter types. The future development change agent results show a decrease in the area of overlapping development footprint on seabird colonies due to the relocation of the community of Shishmaref. Overlap results for future development change agents are summarized in Table D-17.

Given such a low rate of overlap, across all CEs, there are no CEs that are *systematically* threatened by development, either currently or in the future. Development in this ecoregion, including proposed development projects, is highly localized and poses localized threats to CEs.

In general, limitations of these results stem from the accuracy of the mapped development footprints and the accuracy of the mapped CEs. (Discussions of accuracy of mapped CE extents are included with their methods summaries in Appendix B; discussions of mapped accuracy of development change footprints are include with the methods for mapping change agent distributions in Appendix A.) With improved map accuracy of these features, the areas of overlap are generally likely to be even lower. The other general limitation is that the results simply illustrate areas of overlap; they do not indicate how CEs respond to these overlaps with development features.

A particular limitation of the assessment of overlap with *future* development is the inclusion of *multiple* alternatives for proposed roads and other infrastructure. The portions of the three *proposed* road/railroad corridor alternatives that would support the Ambler mine and that would extend through the SNK ecoregion are included in the future development footprint map (the AMT decided that given the high uncertainty surrounding this proposed development it would be most appropriate to include ***all three*** proposed road/railroad alternatives rather than none or just one). Ultimately only one route will be selected; therefore, these footprints are over-represented in the aggregated future development change agent footprint. However, road/railroad corridors were mapped as 60 meter wide features on the landscape; thus, they do not encompass a significant portion of the total area of the ecoregion. Users should note that the percent overlap for CEs with roads and railroads shown in Table D-17 is somewhat inflated due to the inclusion of all three potential routes. However, at less than 0.2% overlap under both current and projected future conditions for each of the CEs, roads and railroads have among the smallest contribution to CA-CE overlap in the SNK.

**Table D-16. Percent of each CE's extent overlapped by current development CAs. Wherever current development footprints overlapped each other they were categorized and summarized as Multiple Development Change Agents (column five). Percent overlap was derived from an overlay of *raster* CE distribution data by *raster* development change agent footprints; therefore the total extent of CEs (even linear features) is summarized as total area (in acres). For ease of reading, the following formatting has been applied:**

- **Where development overlaps more than 2% of a CE's total extent, the total percentage of the CE having overlap with development (Total Development Footprint) and the corresponding percentage having no overlap with development (No Development Change Agent) are bolded.**
- **For each CE, the one to three development types having the greatest percent overlap are bolded.**

| Element Name | Total Area (Acres) | Total Development Change Agent Footprint | No Development Change Agent | Multiple Development Change Agents | Community | Trail | Military | Road | Active/Historic Mine | Landing Strip or Airport | Railroad | Open Contaminated Site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aquatic Coarse Filter** | | | | | | | | | | | | |
| Headwater Streams | 1,285,504 | 0.773% | 99.227% | 0.008% | **0.532%** | **0.141%** | 0.066% | 0.012% | 0.012% | - | 0.002% | - |
| Low-Gradient Streams | 371,777 | 0.916% | 99.084% | 0.012% | **0.528%** | **0.290%** | 0.046% | 0.027% | 0.012% | - | - | - |
| River | 91,989 | 0.785% | 99.215% | 0.009% | **0.408%** | **0.219%** | 0.024% | 0.083% | 0.040% | - | 0.001% | - |
| Estuary | 16,419 | **3.936%** | **96.064%** | 0.066% | **2.580%** | **1.258%** | - | 0.031% | - | - | - | - |
| Lakes: Large and Connected | 614,831 | 0.765% | 99.235% | 0.005% | **0.634%** | **0.126%** | - | - | - | - | - | - |
| Lakes: Large and Disconnected | 119,200 | 0.826% | 99.174% | 0.004% | **0.726%** | 0.096% | - | - | - | - | - | - |
| Lakes: Small and Connected | 78,124 | 0.937% | 99.063% | 0.004% | **0.805%** | **0.126%** | 0.002% | 0.001% | - | - | - | - |
| Lakes: Small and Disconnected | 271,994 | 1.419% | 98.581% | 0.012% | **1.259%** | **0.142%** | 0.004% | 0.001% | - | - | - | - |
| Hot Springs | 2 | - | 100.000% | - | - | - | - | - | - | - | - | - |
| **Aquatic Fine Filter** | | | | | | | | | | | | |
| Arctic Char | 451 | - | 100.000% | - | - | - | - | - | - | - | - | - |
| Alaska Blackfish | 408,411 | 1.122% | 98.878% | 0.013% | **0.855%** | **0.250%** | - | 0.002% | 0.001% | - | - | - |
| Chinook Salmon | 89,413 | 1.941% | 98.059% | 0.055% | **1.456%** | **0.419%** | - | 0.006% | 0.004% | 0.001% | - | - |

| Element Name | Total Area (Acres) | Total Development Change Agent Footprint | No Development Change Agent | Multiple Development Change Agents | Community | Trail | Military | Road | Active/Historic Mine | Landing Strip or Airport | Railroad | Open Contaminated Site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chum Salmon | 89,027 | **2.278%** | **97.722%** | 0.072% | **1.488%** | **0.521%** | 0.131% | 0.051% | 0.011% | - | 0.004% | - |
| Coho Salmon | 73,684 | 1.082% | 98.918% | 0.005% | **0.731%** | **0.199%** | 0.018% | 0.106% | 0.020% | - | 0.003% | - |
| Dolly Varden | 612,581 | 0.558% | 99.442% | 0.004% | **0.285%** | 0.097% | **0.129%** | 0.025% | 0.015% | - | 0.003% | - |
| Pink Salmon | 58,145 | **2.550%** | **97.450%** | 0.106% | **1.608%** | **0.724%** | - | 0.082% | 0.022% | - | 0.008% | - |
| Sheefish | 26,163 | **3.866%** | **96.134%** | 0.159% | **2.870%** | **0.837%** | - | - | - | - | - | - |
| Sockeye Salmon | 18,693 | **3.652%** | **96.348%** | 0.234% | **2.502%** | **0.795%** | - | 0.075% | 0.025% | 0.002% | 0.019% | - |
| **Terrestrial Coarse Filter - Ecological Systems** | | | | | | | | | | | | |
| Arctic Active Inland Dunes | 4,044 | - | 100.000% | - | - | - | - | - | - | - | - | - |
| Boreal Mesic Birch-Aspen Forest | 1,145,389 | 0.824% | 99.176% | 0.009% | **0.740%** | 0.074% | - | - | - | 0.002% | - | - |
| Boreal White or Black Spruce - Hardwood Forest | 1,148,553 | 1.597% | 98.403% | 0.006% | **1.546%** | 0.044% | - | - | - | - | - | - |
| Arctic Acidic Sparse Tundra | 585,060 | 0.256% | 99.744% | 0.003% | **0.146%** | 0.078% | 0.021% | - | 0.005% | 0.003% | - | - |
| Arctic Dwarf Shrubland | 1,907,555 | 1.049% | 98.951% | 0.007% | **0.466%** | 0.064% | 0.474% | 0.019% | 0.013% | 0.001% | 0.005% | - |
| Arctic Mesic-Wet Willow Shrubland | 1,274,262 | 1.158% | 98.842% | 0.012% | **0.742%** | **0.275%** | 0.083% | 0.035% | 0.007% | 0.004% | - | - |
| Arctic Scrub Birch-Ericaceous Shrubland | 6,118,469 | 0.476% | 99.524% | 0.006% | **0.193%** | **0.163%** | 0.062% | 0.030% | 0.013% | 0.001% | 0.007% | - |
| Arctic Mesic Alder | 2,464,508 | 0.642% | 99.358% | 0.009% | **0.520%** | 0.077% | 0.011% | 0.016% | 0.006% | - | 0.002% | - |
| Arctic Dwarf Shrub-Sphagnum Peatland | 1,123,465 | 1.848% | 98.152% | 0.011% | **1.749%** | 0.087% | - | - | - | - | - | - |

| Element Name | Total Area (Acres) | Total Development Change Agent Footprint | No Development Change Agent | Multiple Development Change Agents | Community | Trail | Military | Road | Active/Historic Mine | Landing Strip or Airport | Railroad | Open Contaminated Site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arctic Coastal Brackish and Tidal Marsh | 217,717 | **6.107%** | **93.893%** | 0.056% | **5.584%** | **0.441%** | - | 0.019% | - | 0.006% | - | - |
| Large River Floodplain | 307,652 | 1.115% | 98.885% | 0.020% | **0.964%** | **0.130%** | - | - | 0.001% | 0.001% | - | - |
| Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra | 3,204,507 | 0.364% | 99.636% | 0.001% | **0.145%** | 0.058% | **0.148%** | 0.008% | 0.001% | 0.001% | 0.001% | - |
| Arctic Shrub-Tussock Tundra | 6,065,470 | 0.392% | 99.608% | 0.003% | **0.239%** | 0.141% | - | 0.006% | 0.001% | - | 0.001% | - |
| Arctic Wet Sedge Tundra | 2,730,696 | 0.963% | 99.037% | 0.018% | **0.493%** | 0.168% | **0.243%** | 0.032% | 0.006% | 0.001% | 0.001% | - |
| Boreal Black or White Spruce Forest and Woodland | 5,481,044 | 0.634% | 99.366% | 0.004% | **0.560%** | 0.067% | - | 0.001% | 0.001% | - | - | - |
| **Landscape Species** | | | | | | | | | | | | |
| Alaskan Hare | 25,957,195 | 0.761% | 99.239% | 0.010% | **0.491%** | 0.133% | 0.099% | 0.018% | 0.007% | 0.001% | 0.003% | - |
| Arctic Peregrine Falcon | 14,241,623 | 0.764% | 99.236% | 0.010% | **0.616%** | 0.118% | 0.009% | 0.008% | 0.003% | 0.001% | 0.001% | - |
| Beaver | 34,495,847 | 0.712% | 99.288% | 0.008% | **0.482%** | 0.126% | 0.074% | 0.014% | 0.005% | 0.001% | 0.002% | - |
| Black Bear | 15,650,552 | 0.771% | 99.229% | 0.007% | **0.681%** | 0.082% | - | - | - | 0.001% | - | - |
| Black Scoter | 21,405,907 | 1.075% | 98.925% | 0.013% | **0.816%** | 0.177% | 0.041% | 0.017% | 0.006% | 0.001% | 0.003% | - |
| Brown Bear | 28,383,268 | 0.624% | 99.376% | 0.006% | **0.426%** | 0.116% | 0.059% | 0.011% | 0.004% | 0.001% | 0.001% | - |
| Bristle-thighed Curlew | 15,766,516 | 0.665% | 99.335% | 0.009% | **0.308%** | 0.155% | 0.150% | 0.028% | 0.010% | 0.001% | 0.004% | - |
| Bar-tailed Godwit | 24,460,712 | 0.758% | 99.242% | 0.009% | **0.477%** | 0.137% | 0.105% | 0.019% | 0.007% | 0.001% | 0.003% | - |
| Caribou | 19,939,569 | 0.410% | 99.590% | 0.003% | **0.171%** | 0.101% | 0.119% | 0.010% | 0.004% | 0.001% | 0.001% | - |

| Element Name | Total Area (Acres) | Total Development Change Agent Footprint | No Development Change Agent | Multiple Development Change Agents | Community | Trail | Military | Road | Active/Historic Mine | Landing Strip or Airport | Railroad | Open Contaminated Site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cackling Goose | 10,043,921 | 1.300% | 98.700% | 0.014% | **1.089%** | 0.182% | - | 0.011% | 0.003% | 0.001% | 0.001% | - |
| Common Eider | 3,681,542 | 1.251% | 98.749% | 0.038% | **0.934%** | 0.225% | 0.002% | 0.037% | 0.012% | 0.002% | 0.002% | - |
| King Eider | 11,620,079 | 0.634% | 99.366% | 0.011% | **0.184%** | **0.202%** | 0.175% | 0.041% | 0.014% | 0.002% | 0.006% | - |
| Moose | 25,704,851 | 0.655% | 99.345% | 0.006% | **0.384%** | 0.142% | 0.098% | 0.016% | 0.006% | 0.001% | 0.003% | - |
| Muskox | 19,655,035 | 0.400% | 99.600% | 0.003% | 0.108% | **0.123%** | 0.131% | 0.022% | 0.008% | 0.001% | 0.004% | - |
| Yellow-billed Loon | 4,675,498 | 0.450% | 99.550% | 0.005% | **0.242%** | **0.184%** | - | 0.009% | 0.007% | 0.001% | 0.001% | - |
| **Local Species** | | | | | | | | | | | | |
| Emperor Goose | 1,594,157 | 1.075% | 98.925% | 0.055% | **0.625%** | 0.236% | - | 0.114% | 0.032% | 0.002% | 0.010% | - |
| Hudsonian Godwit | 25,140,903 | 0.765% | 99.235% | 0.007% | **0.658%** | 0.099% | - | - | 0.001% | - | - | - |
| Kittlitz's Murrelet | 6,148,100 | 0.891% | 99.109% | 0.009% | 0.131% | 0.234% | **0.419%** | 0.064% | 0.022% | 0.002% | 0.010% | - |
| McKay's Bunting | 12,224,764 | 1.123% | 98.877% | 0.015% | **0.777%** | 0.121% | **0.161%** | 0.032% | 0.010% | 0.001% | 0.006% | - |
| Red Knot | 6,499,270 | 0.962% | 99.038% | 0.018% | **0.261%** | 0.211% | **0.382%** | 0.057% | 0.021% | 0.002% | 0.011% | - |
| Spectacled Eider | 11,684,447 | 1.058% | 98.942% | 0.017% | **0.690%** | **0.237%** | 0.065% | 0.033% | 0.011% | 0.002% | 0.003% | - |
| **Species Assemblages** | | | | | | | | | | | | |
| Marine Mammal Haul-out Sites | 40,491 | 1.112% | 98.888% | 0.023% | **0.533%** | **0.547%** | - | - | - | 0.009% | - | 0.001% |
| Seabird Colonies | 374,130 | **8.374%** | **91.626%** | 0.155% | **7.425%** | **0.669%** | 0.055% | 0.051% | 0.013% | 0.007% | - | - |
| Waterfowl Concentration Areas | 10,411,365 | 1.198% | 98.802% | 0.018% | **0.979%** | 0.175% | 0.014% | 0.009% | 0.002% | 0.001% | 0.001% | - |
| **Reindeer** | | | | | | | | | | | | |
| Reindeer Grazing Allotments | 14,017,033 | 0.746% | 99.254% | 0.012% | **0.294%** | **0.201%** | 0.184% | 0.036% | 0.012% | 0.002% | 0.005% | - |
| **Caribou** | | | | | | | | | | | | |
| WAH Caribou: Migratory Range | 3,085,591 | 0.795% | 99.205% | 0.009% | **0.588%** | 0.197% | - | - | - | - | - | - |
| WAH Caribou: Winter Range | 14,201,019 | 0.175% | 99.825% | 0.002% | 0.077% | **0.093%** | - | - | 0.002% | 0.001% | - | - |

**Table D-17. Percent of each CE's extent overlapped by future (current and proposed footprints) development CAs. Wherever future development footprints overlapped each other they were categorized and summarized as Multiple Development Change Agents (column five). Percent overlap was derived from an overlay of *raster* CE distribution data by *raster* development change agent footprints; therefore the total extent of CEs (even linear features) is summarized as total area (in acres). For ease of reading, the following formatting has been applied:**

- **Where development overlaps more than 2% of a CE's total extent, the total percentage of the CE having overlap with development (Total Development Footprint) and the corresponding percentage having no overlap with development (No Development Change Agent) are bolded.**
- **For each CE, the one to three development types having the greatest percent overlap are bolded.**

| Element Name | Total Area (Acres) | Total Development Footprint | No Development Change Agents | Multiple Development Change Agents | Community | Trail | Military | Road | Mine | Landing Strip or Airport | Railroad | Open Contaminated Site | Proposed Recreation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aquatic Coarse Filter** | | | | | | | | | | | | | |
| Headwater Streams | 1,285,504 | 1.481% | 98.519% | 0.013% | **0.533%** | **0.141%** | 0.066% | 0.036% | 0.012% | - | 0.018% | - | **0.662%** |
| Low-Gradient Streams | 371,778 | 1.189% | 98.811% | 0.014% | **0.528%** | **0.290%** | 0.046% | 0.044% | 0.012% | - | 0.011% | - | 0.243% |
| River | 91,989 | 1.377% | 98.623% | 0.011% | **0.407%** | 0.220% | 0.024% | 0.102% | 0.040% | - | 0.009% | - | **0.565%** |
| Estuary | 16,419 | **3.943%** | **96.057%** | 0.068% | **2.565%** | **1.258%** | - | 0.041% | - | - | 0.011% | - | - |
| Lakes: Large and Connected | 614,831 | 1.207% | 98.793% | 0.005% | **0.637%** | 0.126% | - | 0.001% | - | - | - | - | **0.437%** |
| Lakes: Large and Disconnected | 119,200 | 0.829% | 99.171% | 0.004% | **0.725%** | 0.096% | - | 0.003% | - | - | - | - | - |
| Lakes: Small and Connected | 78,124 | 1.514% | 98.486% | 0.008% | **0.805%** | 0.126% | 0.002% | 0.017% | - | - | 0.016% | - | **0.541%** |
| Lakes: Small and Disconnected | 271,994 | 1.531% | 98.469% | 0.013% | **1.271%** | 0.142% | 0.004% | 0.008% | - | - | 0.004% | - | 0.088% |
| Hot Springs | 2 | - | 100% | - | - | - | - | - | - | - | - | - | - |
| **Aquatic Fine Filter** | | | | | | | | | | | | | |
| Arctic Char | 451 | **100%** | **-** | - | - | - | - | - | - | - | - | - | **100%** |
| Alaska Blackfish | 408,411 | 1.149% | 98.851% | 0.015% | **0.863%** | 0.250% | - | 0.011% | 0.001% | - | 0.006% | - | 0.003% |
| Chinook Salmon | 89,413 | 1.980% | 98.020% | 0.059% | **1.454%** | **0.417%** | - | 0.035% | 0.004% | 0.001% | 0.007% | - | 0.004% |
| Chum Salmon | 89,027 | **2.307%** | **97.693%** | 0.076% | **1.491%** | **0.519%** | 0.131% | 0.063% | 0.011% | - | 0.009% | - | 0.007% |

| Element Name | Total Area (Acres) | Total Development Footprint | No Development Change Agents | Multiple Development Change Agents | Community | Trail | Military | Road | Mine | Landing Strip or Airport | Railroad | Open Contaminated Site | Proposed Recreation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coho Salmon | 73,684 | **2.143%** | **97.857%** | 0.007% | **0.728%** | 0.199% | 0.018% | 0.130% | 0.020% | - | 0.010% | - | **1.031%** |
| Dolly Varden | 612,582 | **2.146%** | **97.854%** | 0.007% | **0.284%** | 0.097% | 0.129% | 0.043% | 0.014% | - | 0.010% | - | **1.561%** |
| Pink Salmon | 58,145 | **2.749%** | **97.251%** | 0.110% | **1.609%** | **0.721%** | - | 0.094% | 0.022% | - | 0.013% | - | 0.180% |
| Sheefish | 26,163 | **3.875%** | **96.125%** | 0.167% | **2.877%** | **0.829%** | - | 0.002% | - | - | 0.001% | - | - |
| Sockeye Salmon | 18,693 | **4.032%** | **95.968%** | 0.236% | **2.533%** | **0.797%** | - | 0.075% | 0.025% | 0.002% | 0.019% | - | 0.345% |
| **Terrestrial Coarse Filter - Ecological System** | | | | | | | | | | | | | |
| Arctic Active Inland Dunes | 4,044 | - | 100% | - | - | - | - | - | - | - | - | - | - |
| Boreal Mesic Birch-Aspen Forest | 1,145,389 | 0.837% | 99.163% | 0.010% | **0.740%** | 0.074% | - | 0.008% | - | 0.002% | 0.003% | - | - |
| Boreal White or Black Spruce - Hardwood Forest | 1,148,553 | 1.607% | 98.393% | 0.007% | **1.541%** | 0.044% | - | 0.015% | - | - | - | - | - |
| Arctic Acidic Sparse Tundra | 585,060 | **11.522%** | **88.478%** | 0.004% | 0.151% | 0.077% | 0.021% | 0.001% | 0.005% | 0.003% | 0.001% | - | **11.260%** |
| Arctic Dwarf Shrubland | 1,907,556 | **3.067%** | **96.933%** | 0.010% | **0.467%** | 0.064% | 0.474% | 0.033% | 0.013% | 0.001% | 0.009% | - | **1.996%** |
| Arctic Mesic-Wet Willow Shrubland | 1,274,263 | 1.473% | 98.527% | 0.018% | **0.742%** | **0.275%** | 0.083% | 0.057% | 0.007% | 0.004% | 0.019% | - | **0.268%** |
| Arctic Scrub Birch-Ericaceous Shrubland | 6,118,469 | 0.952% | 99.048% | 0.011% | 0.193% | 0.163% | 0.062% | 0.057% | 0.013% | 0.001% | 0.024% | - | **0.427%** |
| Arctic Mesic Alder | 2,464,508 | 1.325% | 98.675% | 0.013% | **0.520%** | 0.077% | 0.011% | 0.034% | 0.006% | - | 0.014% | - | **0.650%** |
| Arctic Dwarf Shrub-Sphagnum Peatland | 1,123,465 | 1.886% | 98.114% | 0.015% | **1.752%** | 0.087% | - | 0.017% | - | - | 0.014% | - | - |
| Arctic Coastal Brackish and Tidal Marsh | 217,717 | **6.123%** | **93.877%** | 0.057% | **5.592%** | **0.441%** | - | 0.023% | - | 0.006% | 0.003% | - | - |
| Large River Floodplain | 307,652 | 1.124% | 98.876% | 0.020% | **0.969%** | 0.130% | - | 0.003% | 0.001% | 0.001% | 0.002% | - | - |

| Element Name | Total Area (Acres) | Total Development Footprint | No Development Change Agents | Multiple Development Change Agents | Community | Trail | Military | Road | Mine | Landing Strip or Airport | Railroad | Open Contaminated Site | Proposed Recreation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra | 3,204,509 | **3.218%** | **96.782%** | 0.003% | 0.146% | 0.058% | 0.148% | 0.014% | 0.001% | 0.001% | 0.005% | - | **2.841%** |
| Arctic Shrub-Tussock Tundra | 6,065,470 | 0.503% | 99.497% | 0.014% | **0.245%** | 0.141% | - | 0.052% | 0.001% | - | 0.039% | - | 0.010% |
| Arctic Wet Sedge Tundra | 2,730,696 | 1.213% | 98.787% | 0.026% | **0.493%** | 0.169% | 0.243% | 0.060% | 0.006% | 0.001% | 0.023% | - | 0.191% |
| Boreal Black or White Spruce Forest and Woodland | 5,481,044 | 0.681% | 99.319% | 0.008% | **0.556%** | 0.067% | - | 0.039% | 0.001% | - | 0.010% | - | - |
| **Landscape Species** | | | | | | | | | | | | | |
| Alaskan Hare | 25,957,200 | 1.761% | 98.239% | 0.013% | **0.493%** | 0.133% | 0.099% | 0.041% | 0.007% | 0.001% | 0.014% | - | **0.961%** |
| Arctic Peregrine Falcon | 14,241,626 | 0.820% | 99.180% | 0.016% | **0.608%** | 0.118% | 0.009% | 0.042% | 0.003% | 0.001% | 0.021% | - | 0.004% |
| Beaver | 34,495,854 | 1.485% | 98.515% | 0.013% | **0.480%** | 0.126% | 0.074% | 0.043% | 0.005% | 0.001% | 0.019% | - | **0.724**% |
| Black Bear | 15,650,552 | 0.799% | 99.201% | 0.008% | **0.681%** | 0.082% | - | 0.022% | - | - | 0.005% | - | - |
| Black Scoter | 21,405,911 | 1.248% | 98.752% | 0.020% | **0.818%** | 0.177% | 0.041% | 0.051% | 0.006% | 0.001% | 0.025% | - | 0.108% |
| Brown Bear | 28,383,274 | 1.439% | 98.561% | 0.011% | **0.422%** | 0.116% | 0.059% | 0.041% | 0.004% | 0.001% | 0.017% | - | **0.767%** |
| Bristle-thighed Curlew | 15,766,519 | **2.041%** | **97.959%** | 0.011% | **0.309%** | 0.155% | 0.150% | 0.041% | 0.010% | 0.001% | 0.010% | - | **1.353%** |
| Bar-tailed Godwit | 24,460,717 | 1.627% | 98.373% | 0.015% | **0.478%** | 0.137% | 0.105% | 0.046% | 0.007% | 0.001% | 0.019% | - | **0.820%** |
| Caribou | 19,939,573 | 1.543% | 98.457% | 0.007% | **0.173%** | 0.101% | 0.119% | 0.033% | 0.004% | 0.001% | 0.017% | - | **1.088%** |
| Cackling Goose | 10,043,923 | 1.356% | 98.644% | 0.020% | **1.090%** | 0.182% | - | 0.042% | 0.003% | 0.001% | 0.019% | - | 0.001% |
| Common Eider | 3,681,543 | 1.335% | 98.665% | 0.044% | **0.947%** | 0.226% | 0.002% | 0.068% | 0.012% | 0.002% | 0.025% | - | 0.009% |
| King Eider | 11,620,081 | 1.457% | 98.543% | 0.018% | 0.187% | **0.202%** | 0.175% | 0.075% | 0.014% | 0.002% | 0.024% | - | **0.761%** |
| Moose | 25,704,854 | 1.436% | 98.564% | 0.013% | **0.385%** | 0.142% | 0.098% | 0.053% | 0.005% | 0.001% | 0.025% | - | **0.713%** |
| Muskox | 19,655,039 | 1.739% | 98.261% | 0.012% | 0.109% | **0.123%** | 0.131% | 0.063% | 0.008% | 0.001% | 0.032% | - | **1.261%** |
| Yellow-billed Loon | 4,675,498 | 0.928% | 99.072% | 0.012% | **0.250%** | 0.185% | - | 0.034% | 0.007% | 0.002% | 0.025% | - | **0.413%** |

| Element Name | Total Area (Acres) | Total Development Footprint | No Development Change Agents | Multiple Development Change Agents | Community | Trail | Military | Road | Mine | Landing Strip or Airport | Railroad | Open Contaminated Site | Proposed Recreation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Local Species** | | | | | | | | | | | | | |
| Emperor Goose | 1,594,157 | 1.196% | 98.804% | 0.061% | **0.626%** | **0.236%** | - | 0.155% | 0.032% | 0.002% | 0.030% | - | 0.053% |
| Hudsonian Godwit | 25,140,906 | 0.823% | 99.177% | 0.012% | **0.658%** | 0.099% | - | 0.033% | 0.001% | - | 0.020% | - | - |
| Kittlitz's Murrelet | 6,148,101 | **4.964%** | **95.036%** | 0.014% | 0.132% | **0.234%** | **0.419%** | 0.074% | 0.022% | 0.002% | 0.016% | - | **4.051%** |
| McKay's Bunting | 12,224,766 | 1.677% | 98.323% | 0.021% | **0.778%** | 0.121% | 0.161% | 0.063% | 0.010% | 0.001% | 0.018% | - | **0.504%** |
| Red Knot | 6,499,273 | **2.198%** | **97.802%** | 0.028% | **0.261%** | 0.211% | 0.382% | 0.113% | 0.021% | 0.002% | 0.036% | - | **1.144%** |
| Spectacled Eider | 11,684,449 | 1.359% | 98.641% | 0.025% | **0.692%** | **0.237%** | 0.065% | 0.070% | 0.011% | 0.002% | 0.027% | - | 0.231% |
| **Species Assemblages** | | | | | | | | | | | | | |
| Marine Mammal Haul-out Sites | 40,491 | 1.193% | 98.807% | 0.059% | **0.384%** | **0.547%** | - | 0.096% | - | 0.009% | 0.096% | 0.001% | - |
| Seabird Colonies | 374,131 | **8.010%** | **91.990%** | 0.152% | **7.011%** | **0.686%** | 0.055% | 0.074% | 0.013% | 0.008% | 0.011% | - | - |
| Waterfowl Concentration Areas | 10,411,367 | 1.570% | 98.430% | 0.022% | **0.972%** | 0.176% | 0.014% | 0.027% | 0.002% | 0.001% | 0.014% | - | **0.342%** |
| **Reindeer** | | | | | | | | | | | | | |
| Reindeer Grazing Allotments | 14,016,390 | **2.601%** | **97.399%** | 0.020% | **0.295%** | 0.201% | 0.184% | 0.075% | 0.012% | 0.002% | 0.030% | - | **1.782%** |
| **Caribou** | | | | | | | | | | | | | |
| WAH Caribou: Migratory Range | 3,085,591 | 0.865% | 99.135% | 0.019% | **0.591%** | **0.197%** | - | 0.030% | - | - | 0.028% | - | - |
| WAH Caribou: Winter Range | 14,201,023 | 0.268% | 99.732% | 0.011% | 0.077% | **0.093%** | - | 0.052% | 0.002% | 0.001% | 0.033% | - | - |

## D-6.2 Identifying Potential Areas for Habitat Restoration

Habitat restoration or enhancement projects typically take place within relatively discrete areas that have been identified as high priorities for restoration or management. Climate change and changing fire regimes have impacted and will continue to have pervasive, system-wide impacts on habitats throughout this ecoregion, as summarized in other parts of this report.

The direct effects of climate change include impacts such as the 10-kilometer treeline shift that has already taken place on the Seward Peninsula between the 1880s and the present (Lloyd et al. 2002). However, modeling experiments conducted by the researchers suggested strongly non-linear vegetation responses to climate change at treeline. Being able to identify *discrete* areas that should be restored or enhanced as a result of climate change effects is problematic for several reasons. Based in part on model results from this REA, climate change impacts on vegetation composition and patterns and hydrology of aquatic systems (due to permafrost loss) are expected be relatively pervasive; site-specific changes on the scale at which habitat restoration might be prioritized cannot be predicted with available information and models. Secondly, there is the equally challenging question of what kind of land management response is practical in the face of wholesale ecosystem alterations. Taking the treeline shift that has occurred to date on the Seward Peninsula as an example, what would a land management agency's goal be in response to this change, and what management practices might feasibly be implemented to achieve this goal? Without some understanding of a land management agency's general direction for dealing with ecosystem change on the scale that is expected over time in the SNK, it is not possible to suggest particular areas for habitat restoration in relation to such changes.

Similarly, model results from this REA indicate substantial changes in fire regime in much of the ecoregion (see Fire section and fire risk figure in Future Conditions chapter). Again, these changes are expected to be relatively pervasive, and identifying areas that will undergo a particular degree *and* type of vegetation change – *with any certainty regarding locations that are sufficiently discrete in spatial extent to suggest areas for habitat restoration* – is not possible with the current resolution of data and knowledge regarding fire-mediated ecosystem change.

The areas documented to have invasive plant species (shown in the **Invasive Species** section of the Current Conditions chapter) can serve as a starting point for prioritizing restoration efforts, but with the recognition that there are likely other similarly impacted areas in the ecoregion that haven't yet been identified. As noted in the summary of invasive plant species locations, the surveys that have been conducted to date suggest approximately 63 acres have been impacted. It is at least somewhat likely that additional portions of the ecoregion have experienced small-scale invasions comparable to those documented in surveyed areas along the Iditarod Trail, the Unalakleet River, and others. Having a better understanding of how well current plant invasions are documented would be useful for determining how to use the existing data to inform and prioritize potential habitat restoration.

In addition to the option of using currently documented locations of invasive plants to inform habitat restoration, development is the other change agent with the potential to inform discrete areas that may be considered for habitat restoration. This section focuses on how the development data were used to characterize areas that may be used to inform restoration priorities in relation to the development change agent.

**79**: Given current and anticipated future locations of change agents, not including climate change, where will potential habitat enhancement/restoration locations likely occur?

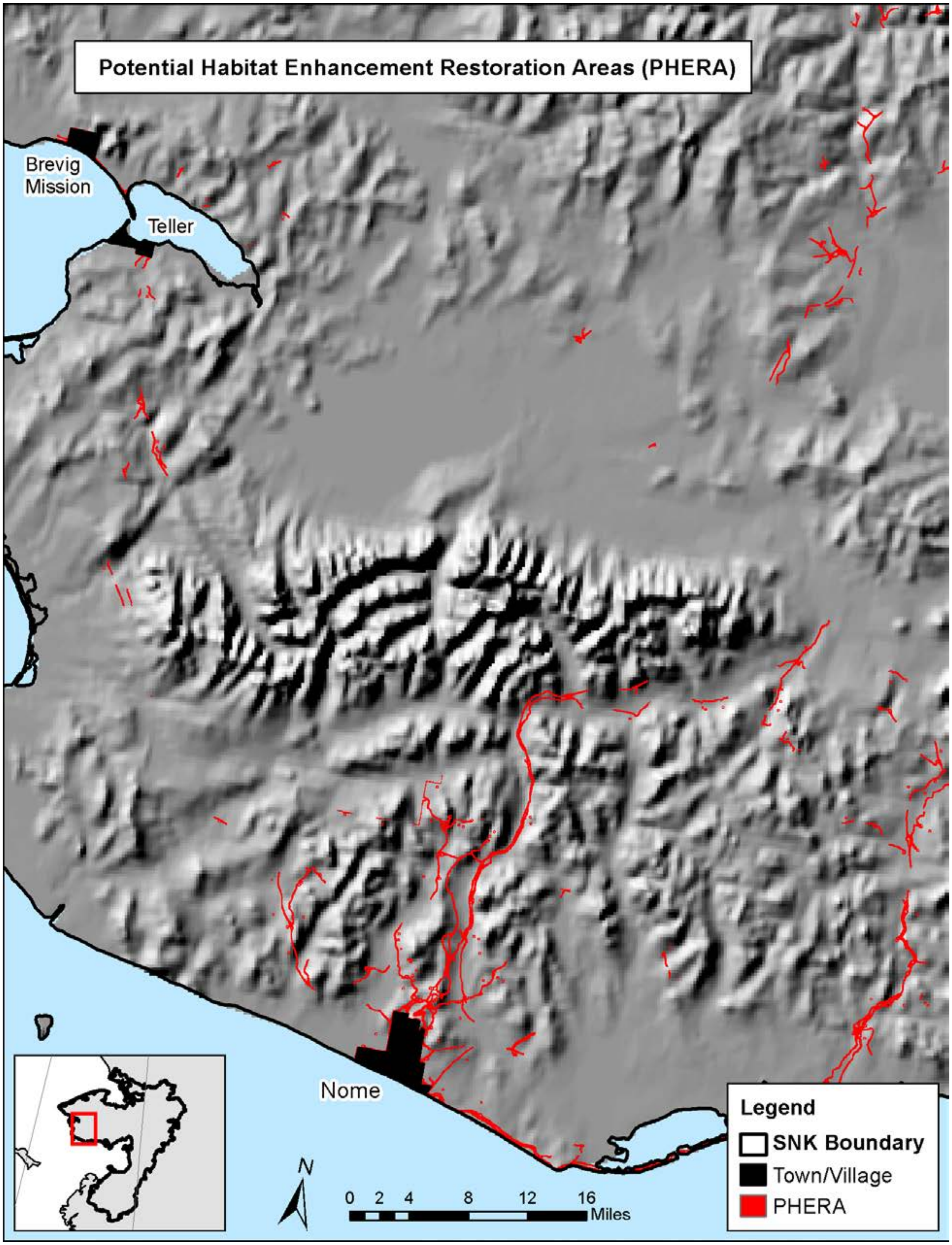
### D-6.2.1 Data and Methods

This Management Question was addressed in relation to development change agents. The SNK REA current Landscape Condition Model (LCM) layer was used to identify potential habitat enhancement/restoration areas (PHERA). The LCM ranges in value from 0 to 1, where 0 represents converted landscapes and 1 represents pristine landscapes. PHERA were identified as all LCM values from .5 to .75 (the third quartile), the landscape condition between extremely converted versus completely pristine. The **current** development change agent footprints used to produce the LCM (i.e. abandoned railroad, communities, open contaminated sites, landing strips/airports, military, active/historic mines, roads and trails) were then removed from the map to produce a final distribution of PHERA within the SNK REA (Figure D-23). Because the locations of future footprints will be determined by politically and economically driven decision-making at the state level (and some components potentially influenced by national politics), resulting in a high degree of uncertainty regarding the choice of alternatives and whether and when these projects may be constructed, future footprints were not considered for identifying PHERA.

### D-6.2.2 Results and Interpretation

Climate change and its synergistic effects on permafrost and the fire regime will have broad impacts on CEs throughout the ecoregion. In this relatively pristine ecoregion, with low population density, limited accessibility, and limited management resources, habitat enhancement or restoration on the scale at which those effects are being felt is assumed to be impractical. Development footprints, on the other hand, are discrete and localized in their spatial extent. The condition model developed for other components of this REA provides a relative indication of the effects of these features beyond their actual footprint. Therefore, it was used to provide an indication of potential enhancement or restoration areas in discrete locations in the SNK ecoregion. Because of the limitations of the footprint data used, and the limitations of the condition model, the areas identified would require further assessment, including site visits, to confirm the need for enhancement or restoration, and to prioritize those areas. Identifying a subset of species or coarse-filter CEs that are priorities for habitat restoration would also be important. (For example, given the importance of caribou, habitats supporting lichen forage might be prioritized for enhancement or management.) The total area identified with potential for restoration or enhancement is 46,202 acres, or approximately 0.12% of the SNK REA. Because the areas identified are such a small proportion of the ecoregion; they are not visible in an ecoregion-wide map; therefore, the area around Nome is used as an example to illustrate the results (Figure D-23).

**Figure D-23. Areas identified for potential habitat enhancement or restoration (PHERA) around Nome.**



**SEWARD PENINSULA – NULATO HILLS – KOTZEBUE LOWLANDS**
**RAPID ECOREGIONAL ASSESSMENT**
**FINAL REPORT II-3-c**

# Appendix E: Conceptual Models for Conservation Elements

**REA Draft Final Report for:**
Department of the Interior
Bureau of Land Management
Rapid Ecoregional Assessments

Version Date: 22 October 2012

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# E Appendix E: Conceptual Models for Conservation Elements

## E-1 Terrestrial Coarse-Filter CEs

### E-1.1 Introduction

Conceptual models developed for twenty terrestrial coarse-filter CEs in this REA include descriptive text and concept diagrams in order to clearly state our understanding of and assumptions made regarding the ecological composition, structure, environment, dynamic processes, and interactions of the CE with major CAs within the ecoregion. These conceptual models provide the information needed to identify measurable indicators that can be used to gauge the relative ecological status of each CE within the 2 x 2 km grid cell reporting units.

The descriptive material for terrestrial coarse-filter CEs is developed from two major sources: 1) the descriptive information for each land cover map class developed by the Alaska Natural Heritage Program (AKNHP) and 2) descriptions for the terrestrial ecological systems associated with the CE developed by NatureServe and collaborators and served on NatureServe's website. (See http://www.natureserve.org/explorer to search and download existing descriptions.) Relationships (crosswalks) of the CEs to the original AKNHP land cover map classes and related NatureServe ecological system types are included in the descriptions. Brief descriptions of ten land cover map classes (Landcover Types) that are not treated as CEs are included in section E-1.15.

Additional material was added for each coarse-filter CE, especially content describing succession and dynamics, as well as threats and stressors to the system. The information developed generally covers the full range of the CE's distribution, which can extend beyond the ecoregion, and does not specifically focus on the characteristics or dynamics as they occur within this ecoregion.

The descriptive text of the conceptual model includes geographic distribution and environmental setting, vegetation, succession and dynamics, and threats and stressors (change agents), with supporting literature cited. Literature in some cases pertains to portions of a CE's range outside of the ecoregion. These are not exhaustive literature surveys, but rather a brief accumulation of known references. Some documents may be listed that are not cited in the narrative text.

The descriptions include many names of plant species that are characteristic of the coarse-filter ecological system type. In the text sections these names are provided as scientific names. Vascular plant species nomenclature follows the nationally standardized list of Kartesz (1999), with very few exceptions. Nomenclature for nonvascular plants follows Anderson (1990) and Anderson et al. (1990) for mosses, Egan (1987, 1989, 1990, 1991) and Esslinger and Egan (1995) for lichens, and Stotler and Crandall-Stotler (1977) for liverworts/hornworts.

For context, the terrestrial CE conceptual models are grouped within the broader conceptual model established for the ecoregion. Each CE is placed within one of the three major model groups relevant to terrestrial coarse-filter CEs (upland, lowland, or coastal) and within one of the model subgroups within those (Table E-1).

**Table E-1. Terrestrial coarse-filter CEs in the SNK organized by conceptual model group and subgroup.**

| Model Component | | | | |
|---|---|---|---|---|
| Model Group | | Model Subgroup | | |
| Code | Name | Code | Name | Terrestrial Coarse-Filter CE |
| A | Uplands | A1 | Upland Forest and Woodland | Boreal Black or White Spruce Forest and Woodland |
| | | | | Boreal Spruce-Lichen Woodland |
| | | | | Boreal Mesic Birch-Aspen Forest |
| | | | | Boreal White or Black Spruce - Hardwood Forest |
| | | A2 | Scrub Birch and Ericaceous Shrublands | Arctic Scrub Birch-Ericaceous Shrubland |
| | | A3 | Dwarf Shrub and Scrub Birch Tundra with Lichens | Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra |
| | | | | Arctic Lichen Tundra |
| | | A4 | Dwarf Shrublands | Arctic Dwarf-Shrubland |
| | | A5 | Acidic Sparse Tundra | Arctic Acidic Sparse Tundra |
| | | A6 | Inland Dunes | Arctic Active Inland Dunes |
| | | A7 | Tall Deciduous Upland Shrublands | Arctic Mesic Alder |
| B | Lowlands | B1 | Tussock Tundra | Arctic Shrub-Tussock Tundra |
| | | B2 | Wet [Sedge] Tundra | Arctic Wet Sedge Tundra |
| | | B3 | Peatlands | Arctic Dwarf-Shrub-Sphagnum Peatland |
| | | | | Arctic Wet Sedge-Sphagnum Peatland |
| | | | | Boreal Black Spruce Dwarf-Tree Peatland |
| | | B4 | River Floodplains | Large River Floodplain |
| | | B5 | Wet Willow Shrublands | Arctic Mesic-Wet Willow Shrubland |
| C | Coastal | C1 | Coastal Marshes and Meadows | Arctic Coastal Brackish and Tidal Marsh |
| | | | | Arctic Marine Beach and Beach Meadow |

The conceptual model diagrams illustrate our understanding of how change agents may stress the terrestrial coarse-filter CEs and which of those individual stressors can be reflected in the indicators of ecological integrity. In addition to the understanding of a CE's composition, structure, processes, and response to stressors, data availability also shaped the set of indicators that could practically be used to evaluate terrestrial coarse-filter CEs. **Available data sets in the SNK ecoregion reflected ecosystem stressors**, rather than direct measures of ecological condition. The single indicator that could readily be assessed for individual terrestrial coarse-filter CEs *emphasizes development-related ecosystem stressors*; this indicator is the landscape condition model or index. A spatial modeling approach was previously developed to evaluate this indicator for the ecological status assessments of terrestrial coarse-filter CEs. The definition and justification for the indicator is provided in a simple Ecological Status Indicator table for each of the terrestrial CE conceptual models. The indicator is scored with values ranging from 0 to 1, with 1 indicating highest ecological status and 0 indicating lowest status (and presumably transitional to a wholly different ecological state).

## E-1.2 Model Group A1: Upland Forest and Woodland

### E-1.2.1 Boreal Black or White Spruce Forest and Woodland

**Crosswalks**

**AKNHP Map Class:**

- [White Spruce or Black Spruce (Open-Closed)]
- [White Spruce or Black Spruce (Woodland)] (in part; upland sloping portions only)

**NatureServe Ecological System Type:**

- Western North American Boreal Mesic Black Spruce Forest
- Western North American Boreal Black Spruce Wet-Mesic Slope Woodland

**Geographic Distribution and Environmental Setting:** These forests are widely distributed throughout the Nulato Hills with occurrences in the southeast Seward Peninsula. They occur on well-drained to moderately well-drained sites in the boreal transition region, including old alluvial fans, rolling hills, mountain side slopes, abandoned floodplains, and inactive terraces and is widespread on uplands (all aspects) and inactive alluvial surfaces in boreal Alaska. Soils are well-drained, gravelly, and feature shallow to moderately deep organic horizons. On most sites there is little to no peat development, but there may be an organic layer derived from non-sphagnum mosses. Permafrost is usually absent.

**Vegetation:** In mature stands, *Picea mariana* and *Picea glauca* are the dominant overstory species. Total tree cover in mature stands typically ranges from 25-70%. Early-successional stands may be dominated by *Betula papyrifera* or *Populus tremuloides*. *Populus tremuloides* replaces *Betula papyrifera* on drier sites (Foote 1983, Chapin et al. 2006). Common understory shrubs include *Betula nana, Ledum* spp., *Rosa acicularis, Vaccinium uliginosum, Vaccinium vitis-idaea*, *Empetrum nigrum, Betula nana*, and *Linnaea borealis*. Herbaceous species include *Calamagrostis canadensis, Geocaulon lividum, Pyrola* spp., *Equisetum sylvaticum, Equisetum arvense*, and *Mertensia paniculata*. Feathermosses (*Hylocomium splendens* and *Pleurozium schreberi*) are common in mature stands (Jorgenson et al. 2004). Lichens, such as *Cladina* spp., may be an important component in late-seral stages (Klein 1982).

**Succession and Dynamics:** In the boreal ecoregion, the disturbance regime in open to closed black spruce is characterized by large crown fires or ground fires of enough intensity to kill overstory trees. Mean fire-return interval estimates in boreal Alaska range from 25 to 130 years (Rowe et al.1974, Heinselman 1978, 1981, Viereck 1983, Yarie 1983). It is likely that the natural fire-return interval is longer than those estimated for boreal sites due to less frequent lightning strikes. A "best guess" for this system without human disturbance has been estimated at 170 years (FRCC experts pers. comm. 2004). Seasonality affects burn severity. An early-season burn can kill the overstory without affecting the ground layer, but a late-season burn can reduce the duff layer and kill the understory plants. The post-fire successional trajectory may be self-replacement, with black spruce following the early-seral herb-shrub stage. Alternatively, early-successional stands may be dominated by *Betula papyrifera* or *Populus tremuloides*. *Populus tremuloides* replaces *Betula papyrifera* on drier sites (Foote 1983, Chapin et al. 2006) before returning to black spruce (Chapin et al. 2006).

**Threats and Stressors:** Climate change and associated alterations in fire regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate and fire regimes (e.g., Lloyd et al. 2002, Johnstone et al. 2011, Higuera et al. 2008, Jandt et al. 2008). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregions (Figure E-1.)

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-2) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-1. Boreal Black or White Spruce Forest and Woodland Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

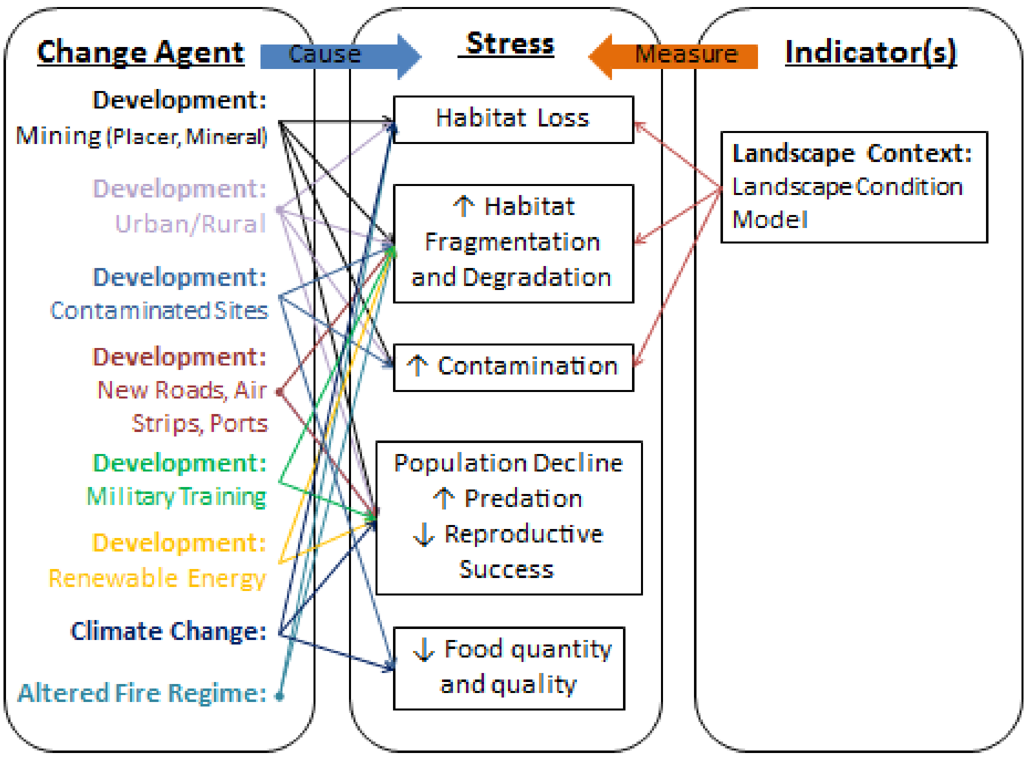


**Table E-2. Ecological status indicator for Boreal Black or White Spruce Forest and Woodland.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

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## E-1.2.2 Boreal Spruce-Lichen Woodland

**Crosswalks**

**AKNHP Map Class:**

- [White Spruce or Black Spruce/Lichen (Woodland-Open)]

**NatureServe Ecological System Type:**

- Western North American Boreal Spruce-Lichen Woodland

**Geographic Distribution and Environmental Setting:** This ecosystem is scattered throughout the central and southern Nulato Hills and southeastern Seward Peninsula. It is generally found along ridge tops or on riparian benches. These are cool dry sites on well-drained to excessively well-drained substrates. Soils are thin and develop on gravels, sandy loess deposits, or bedrock. Permafrost is not likely to be present or is discontinuous.

**Vegetation:** From 10-59% of the cover is trees, $\geq$75% of the trees are needleleaf, and $\geq$ 20% of the understory is lichen. The forest canopy is dominated by *Picea glauca* or *Picea mariana*. The shrub layer is open and typically features low and dwarf-shrubs including *Betula nana, Shepherdia canadensis, Arctostaphylos rubra, Arctostaphylos uva-ursi, Vaccinium uliginosum*, or *Empetrum nigrum*. Lichens (primarily *Cladina* spp.) are an important component of the understory in mature stands. Feathermosses are not as important as in other white spruce woodlands.

**Succession and Dynamics:** Woodland to open stands of white or black spruce with a lichen understory are probably climax. The recovery of the lichens following fire in white spruce or black spruce/lichen woodlands follows a general trend of initially low diversity, which peaks and then declines (Holt 2007 p 60), which resembles many other successional trajectories in the boreal forest (e.g. Kershaw 1978, Coxson and March 2001). Following fire disturbance, lichens such as *Placynthiella, Lecidia, Trapeliopsis* form dense crusts at the soil surface and reach maximum development within 20 years. 20 to 70 years after fire *Cladonia* spp. and mid-successional *Cladina* spp. (e.g. *Cladina mitis*, *Cladina rangiferina*) generally dominate. Sixty-five years after fire, *Cladina stellaris* increases in importance and corresponds to the development of mature lichen-spruce woodlands (Morneau and Payette 1989) where groundcover is nearly pure *Cladina stellaris*, with low cover of other lichens (Kershaw and Rouse 1971, Rencz and Auclair 1977). Late successional decline in lichen abundance and diversity has been attributed to canopy closure followed by lichen displacement by mosses (Fortin et al. 1999, Morneau and Payette 1989).

**Threats and Stressors:** Climate change and associated alterations in fire regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate and fire regimes (e.g., Lloyd et al. 2002, Johnstone et al. 2011, Higuera et al. 2008, Jandt et al. 2008). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregions (Figure E-2).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-3) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-2. Boreal Spruce-Lichen Woodland Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

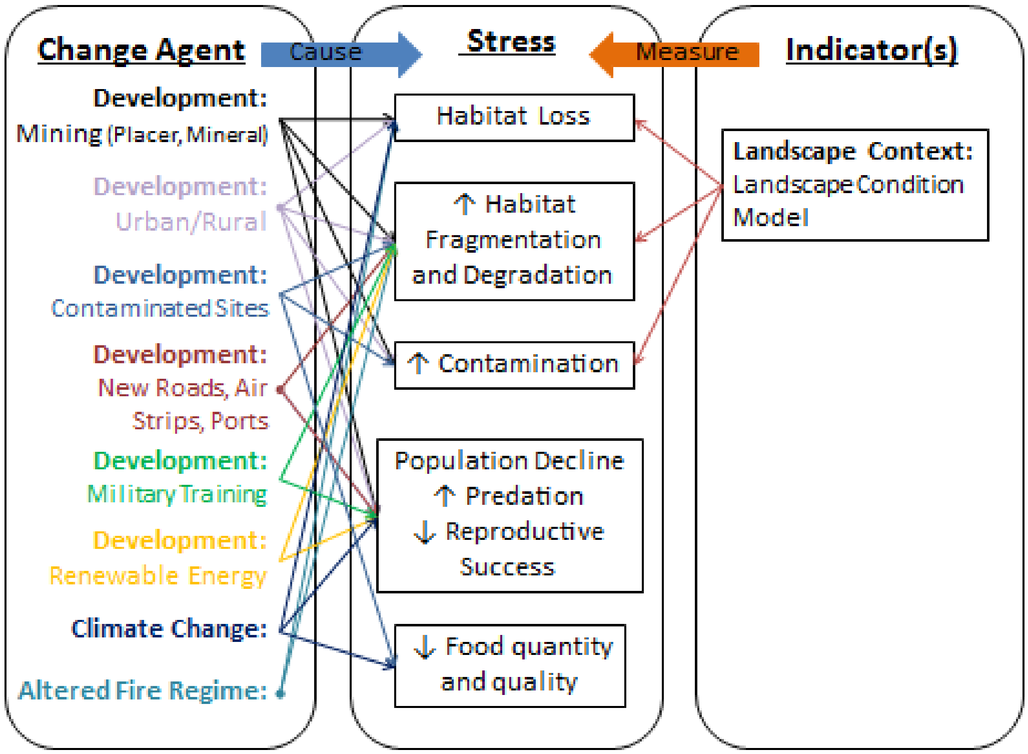


**Table E-3. Ecological status indicator for Boreal Spruce-Lichen Woodland.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

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### E-1.2.3 Boreal Mesic Birch-Aspen Forest

**Crosswalks**

**AKNHP Map Class:**

- [Deciduous Tree (Open-Closed)]

**NatureServe Ecological System Type:**

- Western North American Boreal Mesic Birch-Aspen Forest

**Geographic Distribution and Environmental Setting:** This ecosystem is distributed in the eastern Nulato Hills with scattered occurrences in the central and eastern Seward Peninsula. It occurs on rolling hills, valley bottoms, floodplains and mountain sideslopes on west, east, and south aspects up to 750 m elevation. Soils are well-drained and develop on residual material or retransported deposits including glacial till, loess, and colluvium. Permafrost is rare on most sites.

**Vegetation:** At least 25% of the cover is trees, and ≥75% of the trees are deciduous. There is generally a needleleaf component to this class though it is < 25% of the tree canopy. Dominant or codominant tree species include *Betula papyrifera*, *Populus balsamifera* and *Populus tremuloides*. *Populus balsamifera* can occur in the subalpine zone above the coniferous treeline. Common understory species include *Alnus viridis ssp. sinuata, Ledum* spp., *Vaccinium vitis-idaea, Betula nana, Rosa acicularis, Ribes triste, Linnaea borealis, Shepherdia canadensis*, and *Viburnum edule*. Common herbaceous species include *Calamagrostis canadensis, Chamerion angustifolium, Gymnocarpium dryopteris*, and *Cornus canadensis*. Feathermosses such as *Hylocomium splendens* and *Pleurozium schreberi* are common in the ground layer (Boggs and Sturdy 2005).

**Succession and Dynamics:** This class often acts as a firebreak and has a longer fire-return interval than white and black spruce sites. On drier sites, *Populus tremuloides* or *Betula papyrifera* can persist and be self-replacing. Fire regimes prevent spruce the opportunity of reoccupying a site. Since this class represents a long-term seral stage of sub-boreal white spruce-hardwood forests and sub-boreal white-Lutz spruce forests and woodlands, the disturbance regime is the same as those defined for these types.

**Threats and Stressors:** Climate change and associated alterations in fire regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate and fire regimes (e.g., Lloyd et al. 2002, Higuera et al. 2008, Jandt et al. 2008). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-3).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-4) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-3. Boreal Mesic Birch-Aspen Forest Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

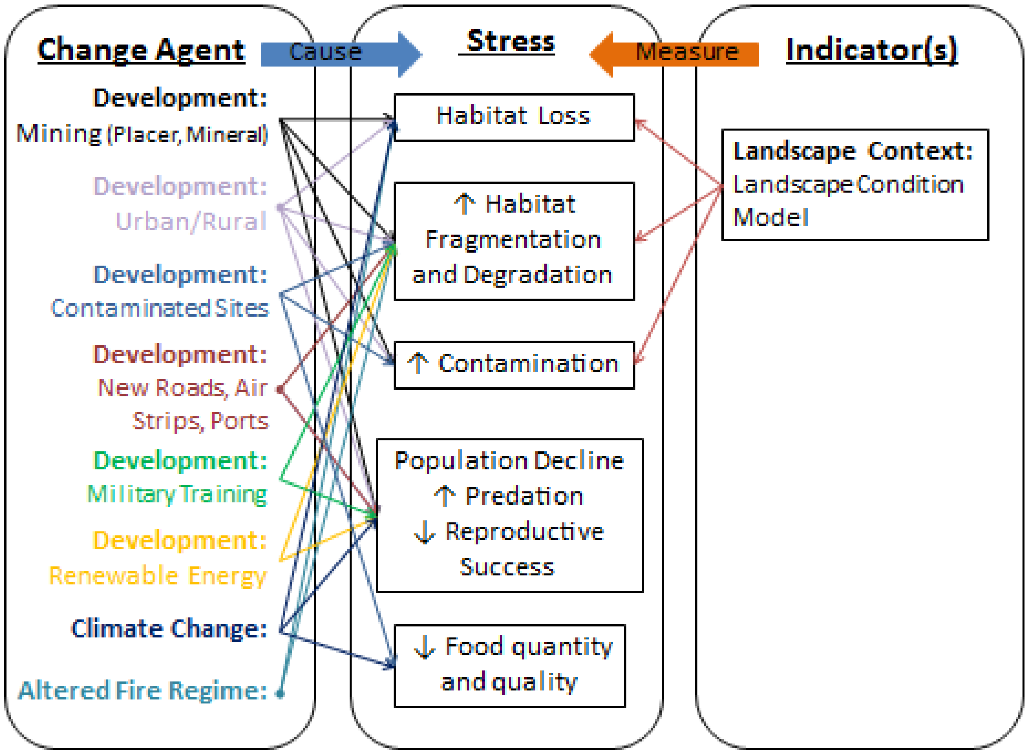


**Table E-4. Ecological status indicator for Boreal Mesic Birch-Aspen Forest.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

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### E-1.2.4 Boreal White or Black Spruce - Hardwood Forest

**Crosswalks**

**AKNHP Map Class:**

- [White spruce or Black spruce-Deciduous (Open-Closed)]

**NatureServe Ecological System Type:**

- Western North American Boreal White Spruce-Hardwood Forest

**Geographic Distribution and Environmental Setting:** These forests occur on rolling hills, inactive terraces, and mountain sideslopes up to 750 m elevation. Soils are typically well-drained and derived from glacial or other depositional processes and include moraines, drumlins, eskers, kettle-kame, colluvium, alluvial fan, floodplains, and loess deposits. This system is common on all aspects except north. Permafrost is rare on most sites; inclusions of wet mixed forest on loamy soils underlain by permafrost also occur (Jorgenson et al. 1999).

**Vegetation:** Canopy cover is dominated by *Picea glauca* and *Betula papyrifera* and typically ranges from 25% to 80%. *Populus tremuloides* or *Populus balsamifera* may be codominant in the hardwood component. The understory is open shrub or herbaceous. Common understory species include *Alnus* spp., *Ledum* spp., *Vaccinium vitis-idaea, Betula nana, Rosa acicularis, Shepherdia canadensis*, and *Viburnum edule*. Feathermosses such as *Hylocomium splendens* and *Pleurozium schreberi* are common in the ground layer (Boggs and Sturdy 2005). Common understory species on wet sites include *Calamagrostis canadensis* and *Equisetum* spp. (Jorgenson et al. 1999).

**Succession and Dynamics:** After fire, this system returns more quickly to mixed hardwood-spruce than the conifer-dominated systems.

**Threats and Stressors:** Climate change and associated alterations in fire regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate and fire regimes (e.g., Lloyd et al. 2002, Johnstone et al. 2011, Higuera et al. 2008, Jandt et al. 2008). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-4).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-5) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-4. Boreal White or Black Spruce - Hardwood Forest Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

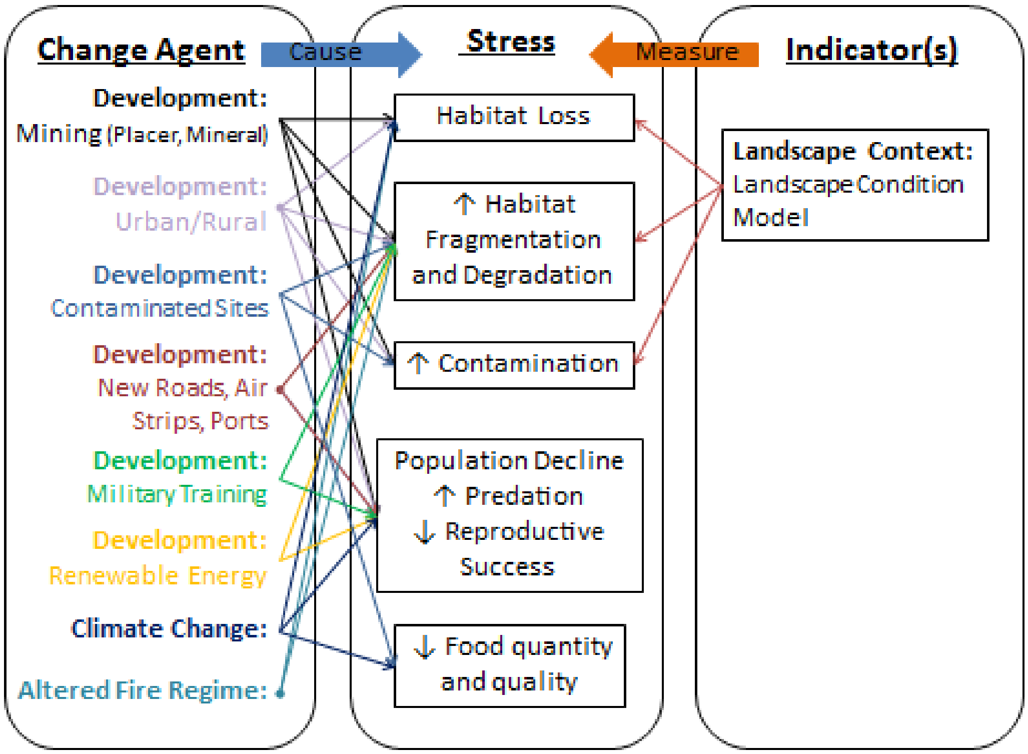


**Table E-5. Ecological status indicator for Boreal White or Black Spruce - Hardwood Forest.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

**REFERENCES**


Boggs, K., and M. Sturdy. 2005. Plant associations and post-fire vegetation succession in Yukon-Charley Rivers National Preserve. Prepared for National Park Service, Landcover Mapping Program, National Park Service-Alaska Support Office, Anchorage. Alaska Natural Heritage Program, Environment and Natural Resources Institute, University of Alaska Anchorage, Anchorage.

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## E-1.3 Model Group A2: Scrub Birch and Ericaceous Shrublands

### E-1.3.1 Arctic Scrub Birch-Ericaceous Shrubland

**Crosswalks**

**AKNHP Map Class:**

- [Low Shrub]

**NatureServe Ecological System Type:**

- Alaska Arctic Scrub Birch-Ericaceous Shrubland

**Geographic Distribution and Environmental Setting:** These shrublands are scattered throughout the study area with highest density in the central and western Seward Peninsula. The system is widespread and common on mesic to wet mountain slopes, hillslopes, flats, and adjacent to streams throughout arctic and subarctic Alaska. Patch size is small to large and often linear along small streams.

**Vegetation:** Shrubs make up 25-100% of the cover and either 25% of the site consisted of shrubs 0.2-1.3 m in height OR shrubs 0.2-1.3 m are the most common shrubs. This class includes low willow, low *Betula nana* and ericaceous shrubs, and low shrubs in peatlands. *Salix pulchra*, *S. glauca*, *S. niphoclada, S. chamissonis,* and *S. bebbiana* dominate or codominate with *Alnus viridis* ssp. *crispa, Betula nana, Vaccinium uliginosum*, and *Ledum palustre* ssp. *decumbens*. Dwarf-shrubs such as *Empetrum nigrum* and *Vaccinium vitis-idaea* may be common under the low-shrub layer. Herbaceous species are sparse, and feathermosses (*Hylocomium splendens* and *Pleurozium schreberi*) and lichens may be common.

**Succession and Dynamics:** This type represents a topoedaphic climax in some areas; in other cases it may be seral to shrub-tussock tundra over long time periods (Viereck et al. 1992). There is little information available about the fire history of shrub communities in Alaska. Birch and ericaceous shrub tundra tends to produce more severe burns than shrub tussock tundra (Racine 1979). After fire, shrubs resprout readily from underground propagules if they have not been burned, and a shrub community re-establishes on the site within 5 years. After severe fires that remove the organic layer and burn the propagules, herbaceous species that establish by seed may dominate the site for more than 5 years. Burned-over spruce woodlands near treeline may be converted to low shrub after fire (Pegau 1972) and may slowly regenerate a spruce overstory.

**Threats and Stressors:** Climate change and associated alterations in fire regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate and fire regimes (e.g., Lloyd et al. 2002, Higuera et al. 2008, Jandt et al. 2008). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-5).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-6) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-5. Arctic Scrub Birch-Ericaceous Shrubland Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

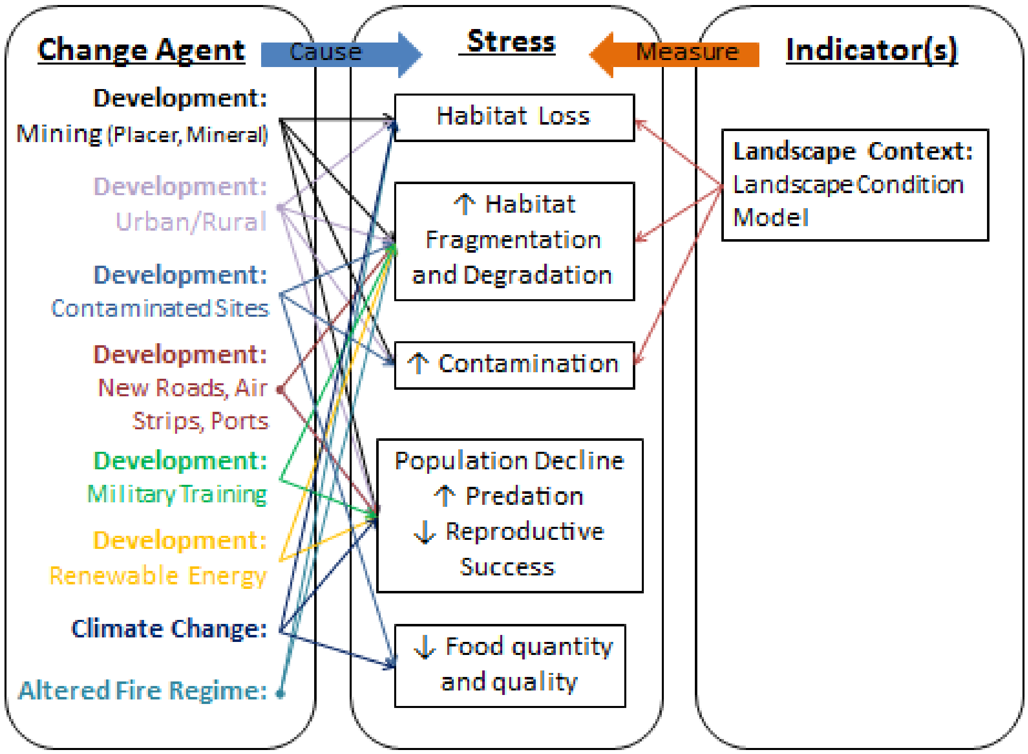


**Table E-6. Ecological status indicator for Arctic Scrub Birch-Ericaceous Shrubland.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

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Higuera, P.E., L.B. Brubaker, P.M. Anderson, T.A. Brown, A.T. Kennedy, and F.S. Hu. 2008. Frequent Fires in Ancient Shrub Tundra: Implications of Paleorecords for Arctic Environmental Change. PLoS ONE 3:e0001744.

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## E-1.4 Model Group A3: Dwarf Shrub and Scrub Birch Tundra with Lichens

### E-1.4.1 Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra

**Crosswalks**

**AKNHP Map Class:**

- [Low Shrub/Lichen]
- [Dwarf Shrub-Lichen]

**NatureServe Ecological System Type:**

- Alaska Arctic Acidic Dwarf-Shrub Lichen Tundra

**Geographic Distribution and Environmental Setting:** These dwarf- and low shrublands are distributed throughout the study area with its highest densities in the southern Nulato Hills and southern Seward Peninsula at mid-high elevations. Common slope positions include valleys, sideslopes, and summits and ridges. Sites are typically dry to mesic, exposed to the wind, and accumulate little winter snow (Viereck et al. 1992). Patch size is small to large.

**Vegetation:** Shrubs make up 25-100% of the cover, $\geq$20% of the cover is made up of lichen, and either 25% of the site consists of shrubs 0.25-1.3 m in height or shrubs 0.25-1.3 m are the most common shrubs. The low shrub species in this class is nearly always *Betula nana*. Common dwarf shrubs (<0.2 m tall) include *Dryas octopetala, Empetrum nigrum, Vaccinium uliginosum, Dryas integrifolia,* and *Salix phlebophylla.* Other species include *Antennaria alpina, Hierochloe alpina, Festuca altaica*, and *Carex microchaeta*. Mosses may be present but contribute little cover (Viereck et al. 1992). Some of the dominant lichens are *Cladina rangiferina* and/or *Cladina stellaris*.

**Succession and Dynamics:** These communities may be stable (Viereck et al. 1992). Others may develop on burned spruce forests near tree line (Pegau 1972) and may be seral to spruce forest. Lichen communities of this class include many early successional species (e.g. *Cladina mitis, C. arbuscula, Flavocetraria cucullata*) and ubiquitous species (e.g. *Cetraria laevigata, Cladina amaurocraea, C. stygia*). Post-disturbance recolonization is by lichens tolerant of high vascular plant competition or those able to establish in novel sites exposed by cryoturbation, fire, or grazing.

**Threats and Stressors:** Climate change and associated alterations in fire regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, permafrost, and distribution are expected with changing climate and fire regimes (e.g., Lloyd et al. 2002, Johnstone et al. 2011, Higuera et al. 2008, Jandt et al. 2008). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-6).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-7) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-6. Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

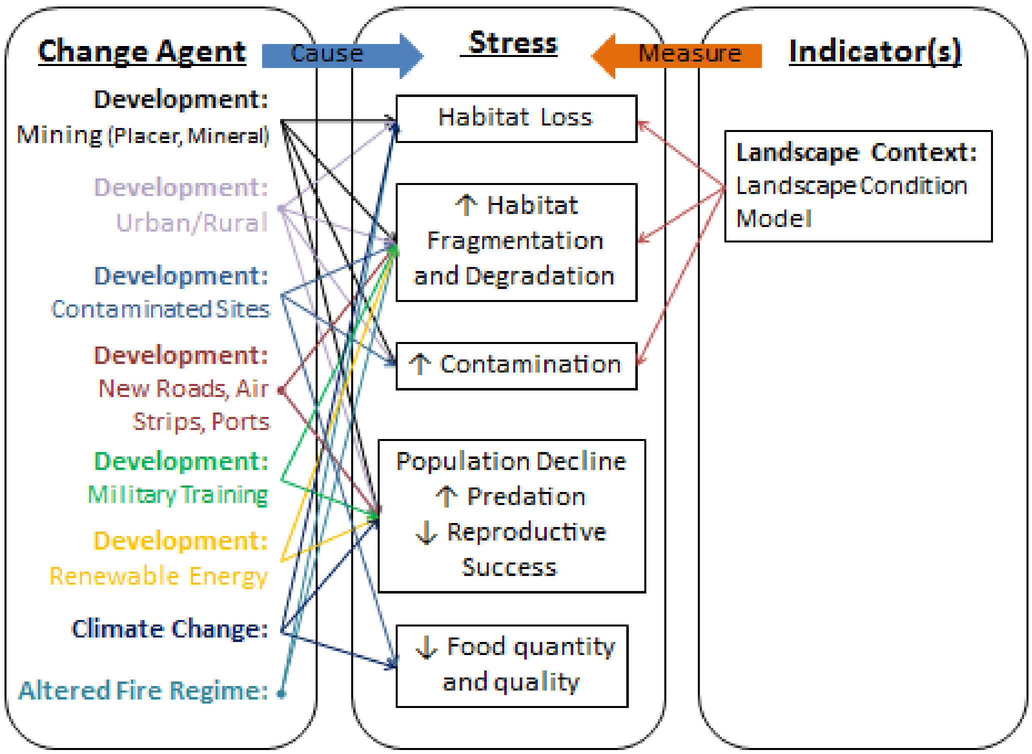


**Table E-7. Ecological status indicator for Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

**REFERENCES**

Higuera, P.E., L.B. Brubaker, P.M. Anderson, T.A. Brown, A.T. Kennedy, and F.S. Hu. 2008. Frequent Fires in Ancient Shrub Tundra: Implications of Paleorecords for Arctic Environmental Change. PLoS ONE 3:e0001744.

Jandt, R., K. Joly, C.R. Meyers, and C. Racine. 2008. Slow recovery of lichen on burned caribou winter range in Alaska tundra: Potential influences of climate warming and other disturbance factors. Arctic, Antarctic, and Alpine Research 40 (1): 89-95.

Lloyd, A.H., Rupp, T.S., Fastie, C.L., and Starfield, A.M. 2002.Patterns and dynamics of treeline advance on the SewardPeninsula, Alaska. J. Geophys. Res.–Atmos. 107. doi: 10.1029/2001JD000852,2003

Pegau, R. E. 1972. Caribou investigations-analysis of range. Pages 1-216 in: R. E. Pegau and J. E. Hemming, editors. Caribou report. Volume 12. Progress report. Federal Aid in Wildlife Restoration, Projects W-17-2 and W-17-3, Job 3.3R. Alaska Department of Fish and Game, Juneau, AK.

Viereck, L. A., C. T. Dyrness, A. R. Batten, and K. J. Wenzlick. 1992. The Alaska vegetation classification. General Technical Report PNW-GTR286. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. 278 pp.

Western Ecology Working Group of NatureServe. No date. International Ecological Classification Standard: International Vegetation Classification. Terrestrial Vegetation. NatureServe, Boulder, CO.

## E-1.4.2 Arctic Lichen Tundra

**Crosswalks**

**AKNHP Map Class:**

- [Lichen]

**NatureServe Ecological System Type:**

- Alaska Arctic Lichen Tundra

**Geographic Distribution and Environmental Setting:** This is an uncommon tundra type, and is centrally distributed in the central and western Seward Peninsula and some scattered locations throughout the Nulato Hills. Common slope positions include sideslopes, summits and ridges. Sites are typically acidic and mesic to dry. It is especially common on recent volcanic deposits with little soil development. Patch size is small to large.

**Vegetation:** Composed of <25% herbaceous species, ≤25% water, and ≥ 50% bryoid species of which ≥50% are lichen species. Foliose and fruticose lichens dominate and include *Umbilicaria* spp., *Rhizocarpon geographicum, Cladina stellaris (= Cladonia stellaris), Racomitrium lanuginosum, Flavocetraria* spp., and *Alectoria ochroleuca*. Common dwarf shrubs (<0.2 m tall) include *Loiseleuria procumbens, Betula nana, Ledum palustre* ssp. *decumbens, Empetrum nigrum*, and *Vaccinium uliginosum*.

**Succession and Dynamics:** Areas with high rock cover, thin soils and low competition from vascular plants tend to have greater lichen cover and species richness. The lichen class is likely to support species that dwell strictly on rocks (e.g. *Umbilicaria spp.*, *Arctoparmelia* spp.) or gravels (e.g. *Alectoria nigricans, Cetraria nigricans* and *Bryocaulon divergens*) as well as calciphiles (e.g. *Cetraria tilesii*), alectoroids and dry-associated lichens (e.g. *Asahinea chrysantha, Thamnolia subuliformis, Cetraria spp. and Dactylina* spp.). Because this cover class may be more resistant to fires and soil disturbance, late successional lichen species are better able to establish and become dominant.

**Threats and Stressors:** Climate change is an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate (e.g., Lloyd et al. 2002, Johnstone et al. 2011, Higuera et al. 2008, Jandt et al. 2008). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-7).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-8) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-7. Arctic Lichen Tundra Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

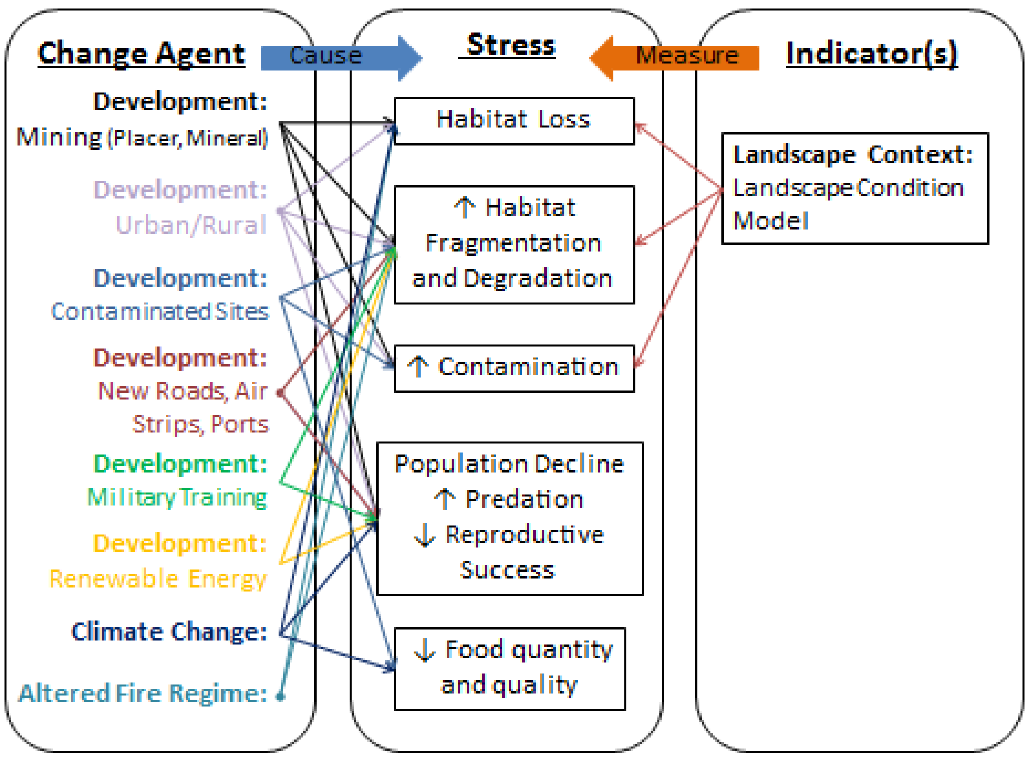

**Table E-8. Ecological status indicator for Arctic Lichen Tundra.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

**REFERENCES**


Higuera, P.E., L.B. Brubaker, P.M. Anderson, T.A. Brown, A.T. Kennedy, and F.S. Hu. 2008. Frequent Fires in Ancient Shrub Tundra: Implications of Paleorecords for Arctic Environmental Change. PLoS ONE 3:e0001744.

Jandt, R., K. Joly, C.R. Meyers, and C. Racine. 2008. Slow recovery of lichen on burned caribou winter

range in Alaska tundra: Potential influences of climate warming and other disturbance factors. Arctic, Antarctic, and Alpine Research 40 (1): 89-95.

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## E-1.5 Model Group A4: Dwarf Shrublands

### E-1.5.1 Arctic Dwarf-Shrubland

**Crosswalks**

**AKNHP Map Class:**

- [Dwarf Shrub]

**NatureServe Ecological System Type:**

- Alaska Arctic Dwarf Shrubland

**Geographic Distribution and Environmental Setting:** This map class found throughout the study area with the exception of Kotzebue Sound Lowlands with its highest density in the southern Seward Peninsula. Common slope positions include valleys, sideslopes (especially north-facing), late-lying snowbeds, and summits and ridges. Sites are typically dry to mesic. Patch size is small to large.

**Vegetation:** Shrubs made up >25% of the cover and either 25% of the site consisted of shrubs $\leq$ 0.2 m in height OR shrubs $\leq$ .2 m are the most common shrubs. Dwarf shrub species include *Dryas octopetala*, *Empetrum nigrum, Vaccinium uliginosum, Dryas integrifolia, Loiseleuria procumbens*, and *Salix phlebophylla*. Common herbaceous species include *Antennaria alpina, Hierochloe alpina, Minuartia* *obtusiloba, Carex scirpoidea, C. podocarpa, C. microchaeta*, and *Festuca altaica*. Mosses such as *Tortula ruralis* and *Polytrichum* spp. may be common.

**Succession and Dynamics:** Successional relationships are unknown.

**Threats and Stressors:** Climate change and associated alterations in fire regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate and fire regimes (e.g., Lloyd et al. 2002, Johnstone et al. 2011, Higuera et al. 2008, Jandt et al. 2008). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-8).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-9) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-8. Arctic Dwarf-Shrubland Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

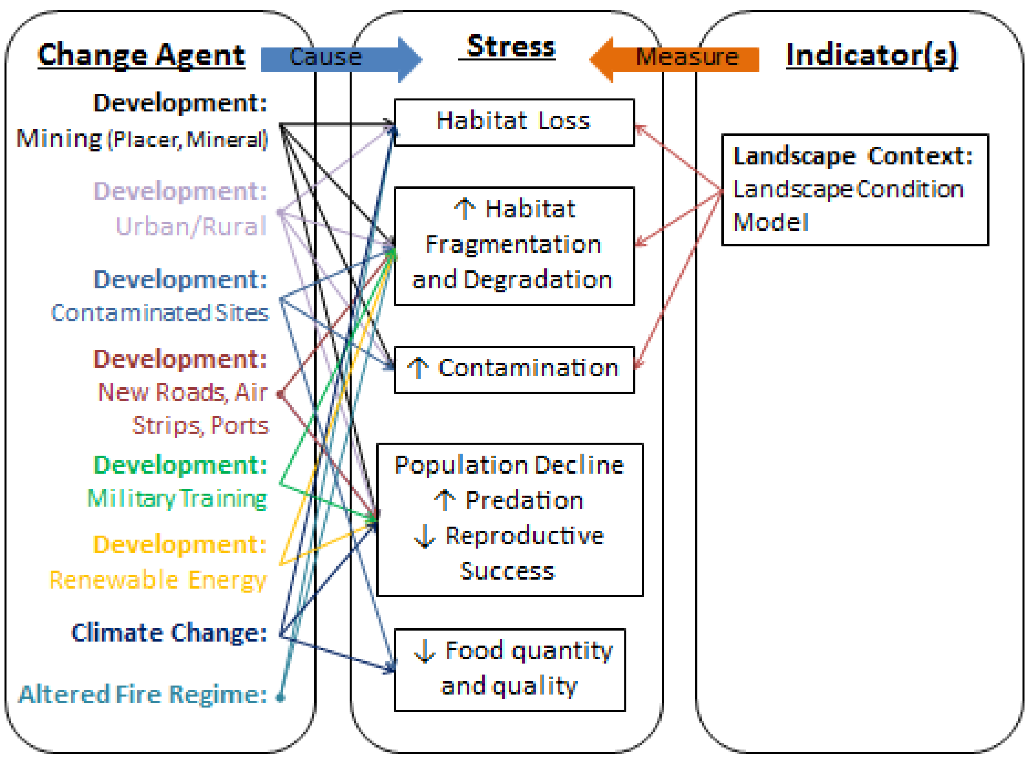

**Table E-9. Ecological status indicator for Arctic Dwarf-Shrubland.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

**REFERENCES**

Higuera, P.E., L.B. Brubaker, P.M. Anderson, T.A. Brown, A.T. Kennedy, and F.S. Hu. 2008. Frequent Fires in Ancient Shrub Tundra: Implications of Paleorecords for Arctic Environmental Change. PLoS ONE 3:e0001744.

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Lloyd, A.H., Rupp, T.S., Fastie, C.L., and Starfield, A.M. 2002.Patterns and dynamics of treeline advance on the SewardPeninsula, Alaska. J. Geophys. Res.–Atmos. 107. doi: 10.1029/2001JD000852,2003

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## E-1.6 Model Group A5: Acidic Sparse Tundra

### E-1.6.1 Arctic Acidic Sparse Tundra

**Crosswalks**

**AKNHP Map Class:**

- [Sparse Vegetation]

**NatureServe Ecological System Type:**

- Alaska Arctic Acidic Sparse Tundra

**Geographic Distribution and Environmental Setting:** This sparse tundra ecosystem is uncommon within the study area and distributed mostly in the south-central and western Seward Peninsula. It occurs on acidic substrates (pH typically <6). Common slope positions include valleys, sideslopes, and summits and ridges. The canopy is sparse due to extreme exposure, exposed bedrock or unstable substrates. Sites are typically dry to mesic and occur on acidic substrates. Soils are typically thin, stony, and well-drained. Patch size is small to matrix-forming.

**Vegetation:** At least 50% of the area is barren, but vegetation makes up ≥20% of the cover, and lichen cover is <25%. Common dwarf shrub species include *Dryas octopetala, Empetrum nigrum, Vaccinium uliginosum, Dryas integrifolia, Loiseleuria procumbens*, and *Salix phlebophylla*. Herbaceous species may include *Antennaria alpina, Hierochloe alpina, Minuartia obtusiloba, Carex scirpoidea, C. podocarpa, C. microchaeta*, and *Festuca altaica*. Lichens include *Cladina* spp., *Sphaerophorus globosus, Nephroma arcticum, Flavocetraria* spp., and *Alectoria ochroleuca.*

**Succession and Dynamics:** Successional relationships are unknown.

**Threats and Stressors:** Climate change and associated alterations in permafrost distribution are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate and loss of permafrost (e.g., Lloyd et al. 2002). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-9).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-10) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells.  The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-9. Arctic Acidic Sparse Tundra Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

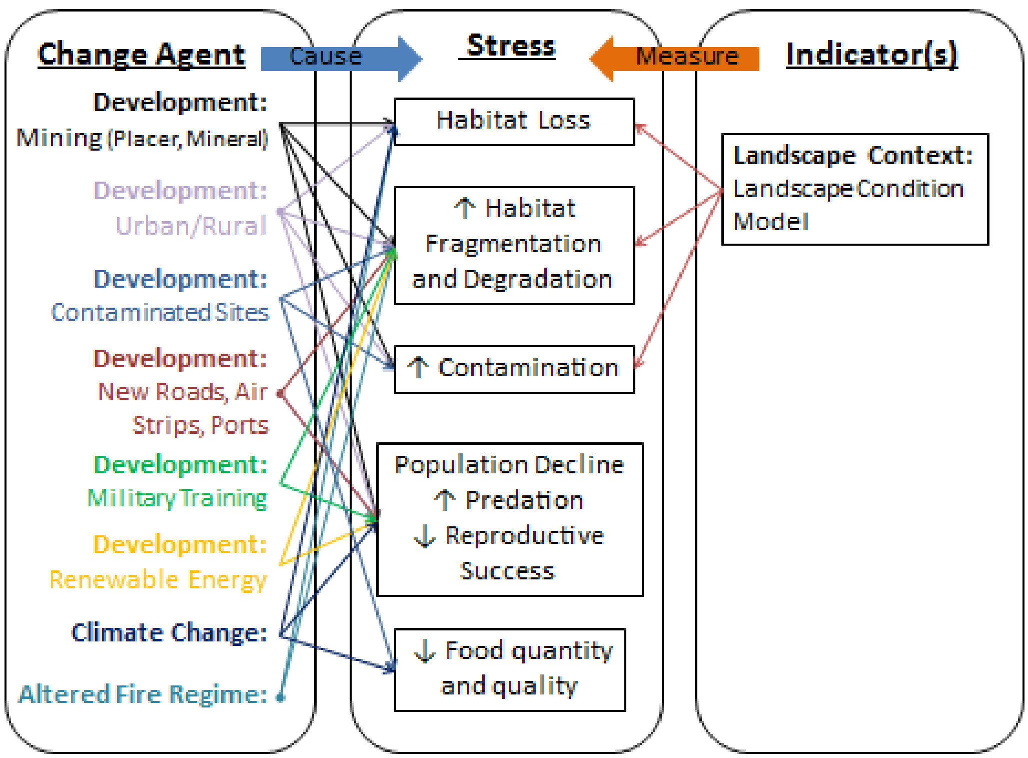

**Table E-10. Ecological status indicator for Arctic Acidic Sparse Tundra.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

**REFERENCES**

Viereck, L. A., C. T. Dyrness, A. R. Batten, and K. J. Wenzlick. 1992. The Alaska vegetation classification. General Technical Report PNW-GTR286. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. 278 pp.

## E-1.7 Model Group A6: Inland Dunes

### E-1.7.1 Arctic Active Inland Dunes

**Crosswalks**

**AKNHP Map Class:**

- [no match with AKNHP map]

**NatureServe Ecological System Type:**

- Alaska Arctic Active Inland Dune

**Geographic Distribution and Environmental Setting:** Inland dunes are unusual; this ecosystem is only known from 2 locations in the northern Nulato Hills. Common landforms include transverse and longitudinal dunes, sandsheets, desert pavements, blowouts, and interdune slacks. The dunes or blowouts are dry to mesic sand deposits, and the slacks may be wet silts and sands. Tundra vegetation has stabilized most of these sand deposits, but small blowouts and areas of active transport and deposition still exist. This system's patch size is small.

**Vegetation:** Some common vegetation types include those dominated by low and tall willows, mesic herbaceous meadows, and wet sedge meadows. Low- and tall-willow communities are dominated by *Salix glauca, Salix alaxensis*, and *Salix niphoclada (= Salix brachycarpa ssp. niphoclada)*, along with *Bromus inermis var. pumpellianus (= Bromus pumpellianus)*. The mesic herbaceous meadows include *Leymus mollis, Bromus inermis var. pumpellianus*, and *Chamerion latifolium (= Epilobium latifolium)*. Additional herbaceous species include *Carex obtusata, Carex lachenalii, Festuca rubra, Festuca brachyphylla, Astragalus alpinus*, and others. Ponds and wet depressions may occur in the slacks and support wet herbaceous communities dominated by *Carex aquatilis* and *Arctophila fulva*.

**Succession and Dynamics:** Active inland dunes occur as remnants of a larger system of dunes and sandsheets that developed under the climatic conditions of the late Pleistocene. Strong storm winds carried glacio-fluvial silts and sands across vast areas of northwestern North America. Most of these sand deposits have been stabilized by forest and tundra vegetation, but areas of active transport and deposition still exist. Dunes are also common where rivers have cut through sandsheets, and new dunes are still forming along rivers with high sediment loads and outwash deposits. These active dunes share many floristic elements and geomorphic processes (Parker and Mann 2000). The main disturbance process is the transport and deposition of sand.

**Threats and Stressors:** Climate change and associated alterations in permafrost distribution are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate and loss of permafrost (e.g., Lloyd et al. 2002). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregions (Figure E-10).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-11) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-10. Arctic Active Inland Dunes Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

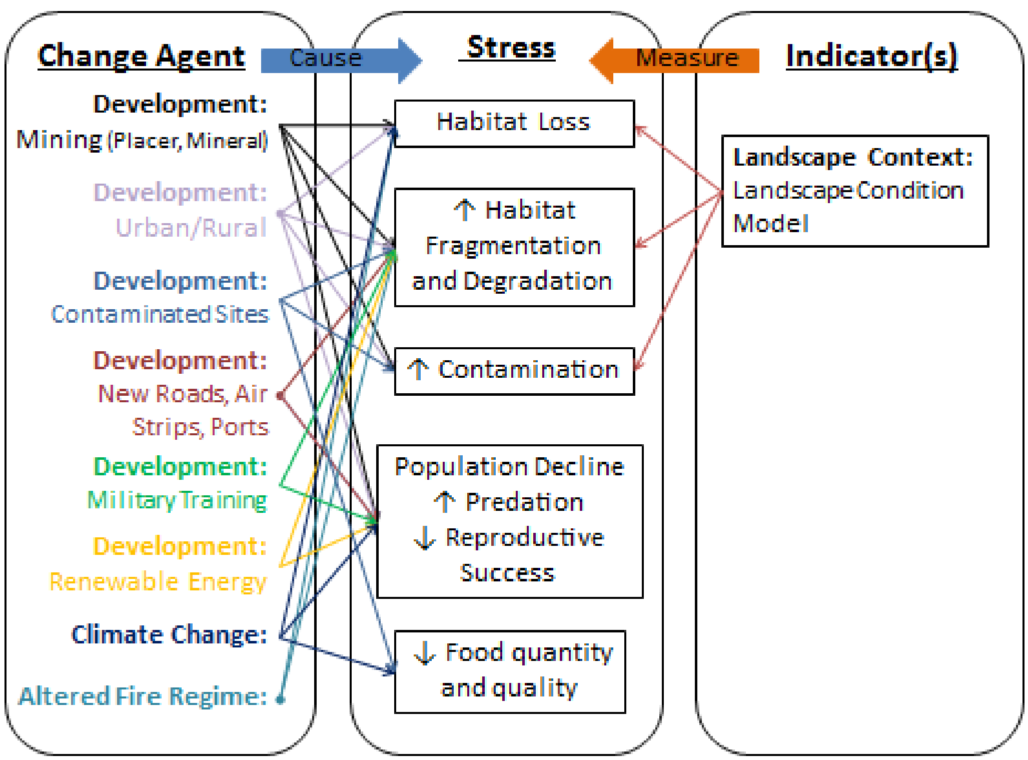

**Table E-11. Ecological status indicator for Arctic Active Inland Dunes.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |


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Parker, C. L., and D. H. Mann. 2000. Floristics and vegetation of active sand dunes in the Kobuk River Valley, northwestern Arctic Alaska. American Association for the Advancement of Science & Yukon Science Institute. [Abstract available: http://www.taiga.net/arctic2000/abstracts/parker.html]

Western Ecology Working Group of NatureServe. No date. International Ecological Classification Standard: International Vegetation Classification. Terrestrial Vegetation. NatureServe, Boulder, CO.


## E-1.8 Model Group A7: Tall Deciduous Upland Shrublands

### E-1.8.1 Arctic Mesic Alder

**Crosswalks**

**AKNHP Map Class:**

- [Tall Shrub (Open-Closed)]

**NatureServe Ecological System Type:**

- Alaska Arctic Mesic Alder Shrubland

**Geographic Distribution and Environmental Setting:** These shrublands are widepsread thoughout the entire study area, but are most common throughout the southern Nulato Hills. They are found on mountain slopes, hillslopes and small steep streams throughout arctic Alaska. Patch size is typically small. Soils are mesic but sometimes wet if found adjacent to a small stream.

**Vegetation:** Total shrub cover is >25% and dominated by alders. *Alnus viridis ssp. crispa* is the dominant shrub species but may codominate with *Salix glauca* and *Salix pulchra*. Additional species include *Vaccinium uliginosum, Vaccinium vitis-idaea, Betula nana, Ledum palustre ssp. decumbens, Empetrum nigrum, Equisetum* spp., *Spiraea stevenii (= Spiraea beauverdiana), Dryas* spp., and *Cassiope tetragona*. Mosses include *Hylocomium splendens* and *Dicranum* spp. Low-shrub tundra and dwarf-shrubs are common in the gaps between alder patches.

**Succession and Dynamics:** This system may or may not be controlled by avalanche activity and unstable slopes. Alder will resprout following fire, but no studies exist on fire effects in this type. The fire-return interval is likely long. Burns are more common on the Seward Peninsula and other parts of western

Alaska near the spruce forest boundary. Early-season fire prior to green-up would be more likely to carry than late-season fire. Insect defoliators and canker also affect alder. Alder invades disturbed sites but also spreads into undisturbed sites adjacent to existing patches. After establishing in the uplands, it may be stable for long periods. Alder appears to be increasing in cover in the Arctic.

Numerous authors consider alder above treeline to be stable over long time periods in southern Alaska (Griggs 1936). It is also an important seral species in Alaska, colonizing floodplain sandbars (Klingensmith and Van Cleve 1993), avalanche chutes (Viereck et al. 1992), and is a major early to mid-successional species in boreal forests. Extensive alder (*Alnus* spp.) mortality from pathogens, insects, and other factors has occurred in Alaska from 2000 to 2006. Three sub-species of alder are affected, *Alnus incana* ssp. *tenuifolia*, *Alnus viridis* ssp. *sinuata*, and *Alnus viridis* ssp. *crispa*. Symptoms range from dead leaves to entire genet (clump) death. The causal agents are often a complex of both biotic and abiotic influences, and include native canker fungi (Trummer and Kruse 2006), and a native generalist hardwood defoliator *Sunira verberata*. After death, alder patches shift from shrubland to what is growing adjacent to the patch including low shrubs (0.2-1.5 m tall) and herbaceous meadows.

**Threats and Stressors:** Climate change and associated alterations in permafrost distribution and hydrologic regimes, as well as fire regimes, are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate, permafrost, hydrology, and fire (e.g., Lloyd et al. 2002, Jorgenson 2005, 2010, Johnstone et al. 2011). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-11).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-12) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells.  The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-11. Arctic Mesic Alder Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

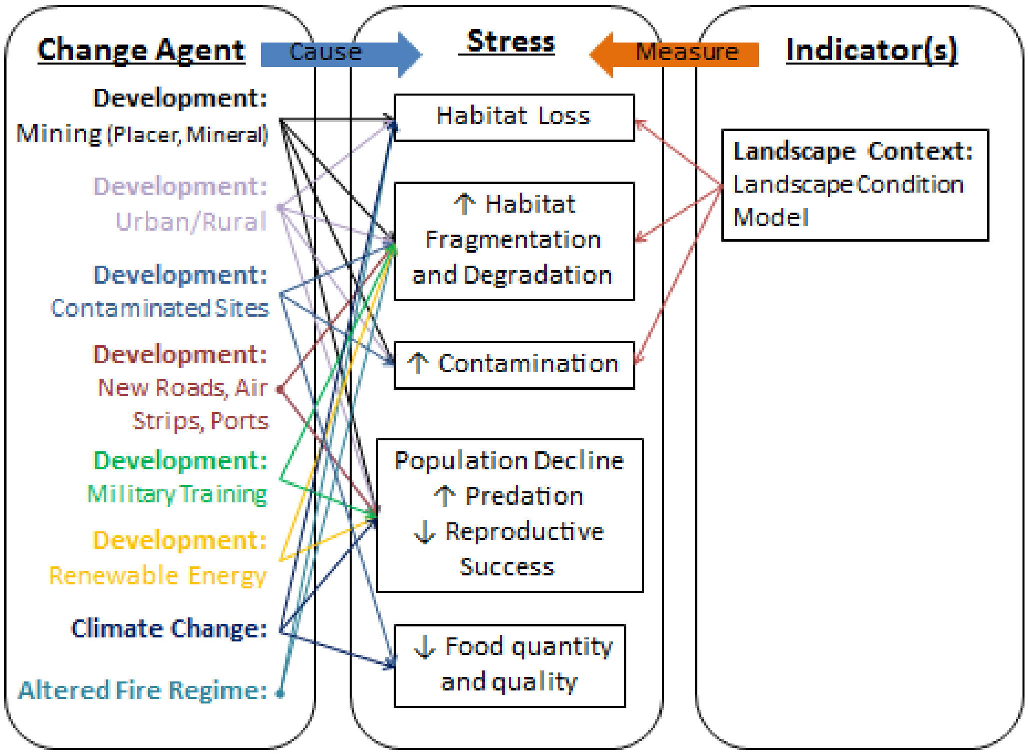


**Table E-12. Ecological status indicator for Arctic Mesic Alder.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

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## E-1.9 Model Group B1: Tussock Tundra

### E-1.9.1 Arctic Shrub-Tussock Tundra

**Crosswalks**

**AKNHP Map Class:**

- [Tussock Tundra (Herbaceous or Low Shrub Dominated)]

**NatureServe Ecological System Type:**

- Alaska Arctic Tussock Tundra, Alaska Arctic Shrub-Tussock Tundra

**Geographic Distribution and Environmental Setting:** This map class is common and widespread the northern Nulato Hills and thoughout most of the Seward Penninsula and Kotzebue Sound Lowlands. Tussock tundra is common in valleys and slopes throughout arctic Alaska. These sites are cold, poorly drained, and underlain by mesic, silty mineral soils with a shallow surface organic layer surrounding the tussocks (Viereck et al. 1992). Permafrost is present. Patch size is small, large or matrix forming.

**Vegetation:** Tussock tundra has >35% cover of sedges in a tussock growth form with or without dwarf- and low shrubs. *Eriophorum vaginatum* is the primary tussock-former in most stands, but *Carex bigelowii* may dominate some sites. *Calamagrostis canadensis, Arctagrostis latifolia*, and *Chamerion latifolium (= Epilobium latifolium)* may be common. When shrubs are present, *Betula nana* and *Salix pulchra* dominate the low-shrub layer. Other species include *Ledum palustre ssp. decumbens, Vaccinium vitis-idaea, Vaccinium uliginosum,* and *Empetrum nigrum*. Mosses (*Sphagnum* spp., *Polytrichum strictum*, and *Hylocomium splendens*) may form a nearly continuous mat between tussocks. There are also distinctions between acidic and non-acidic tussock tundra. Acidic sites have more ericaceous shrubs and *Sphagnum* and less *Eriophorum* spp., *Betula nana*, and *Carex bigelowii*. Acidic sites also have more organic matter buildup and the tussocks tend to be larger.

**Succession and Dynamics:** The fuel layer in low shrub dominated tussock tundra is dense and continuous and leads to large, fast-spreading fires (Racine et al. 87). Differences in topography, moisture, vegetation composition, and organic matter depth cause variations in burn severity and lead to a patchy burn pattern (Racine 1979). Fire severity however, tends to be light because of the wet soil profile. Burns in this type usually consume all aerial woody and herbaceous plant material and litter. A study on the Seward Peninsula reported that less than one half of accumulated organic soil layer is removed by fire (Racine 1979). Thaw depths increased to reach into the mineral soil, but were not greatly increased except where organics were removed. Subsidence and thermal erosion following fire are usually minimal in tundra ecosystems (Walker 1996).

Woody shrubs and graminoids typically resprout vigorously after fire, and their cover, production and biomass can recover to pre-fire levels within 10 years (Wein and Bliss, 1973). The recovery sequence of lichens is characterized by an immediate reduction in cover soon after the fire, followed by slow accumulation and subsequent decline with time. Wildfires reduce the abundance of lichens, especially the late-successional fruticose lichens that are the primary caribou forage lichens, for decades in tundra ecosystems (Jandt et al. 2008). Lichens have few perennating structures and these are often destroyed by burning. For the first 15 years following fire, crustose lichens and *Cladonia* squamules are reported to occur with high frequency, but at low (≤1%) cover (Jandt et al. 2008); 30-35 years post-fire, lichen cover in burned tundra was less than 5% at (Holt et al. 2007, Jandt et al. 2008); 50-100 years after fire, *Cladina mitis, Cladina arbuscula* and other *Cladonia spp*. may reach peak abundance but are eventually replaced by late-successional species such as *Cladina stellaris* and *Cladina rangiferina* (Swanson 1996). Overal cover is low.

**Threats and Stressors:** Climate change and associated alterations in permafrost distribution and hydrologic regimes, as well as fire regimes, are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate, permafrost, hydrology, and fire (e.g., Lloyd et al. 2002, Jorgenson 2005, 2010, Johnstone et al. 2011). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-12).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-13) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-12. Arctic Shrub-Tussock Tundra Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

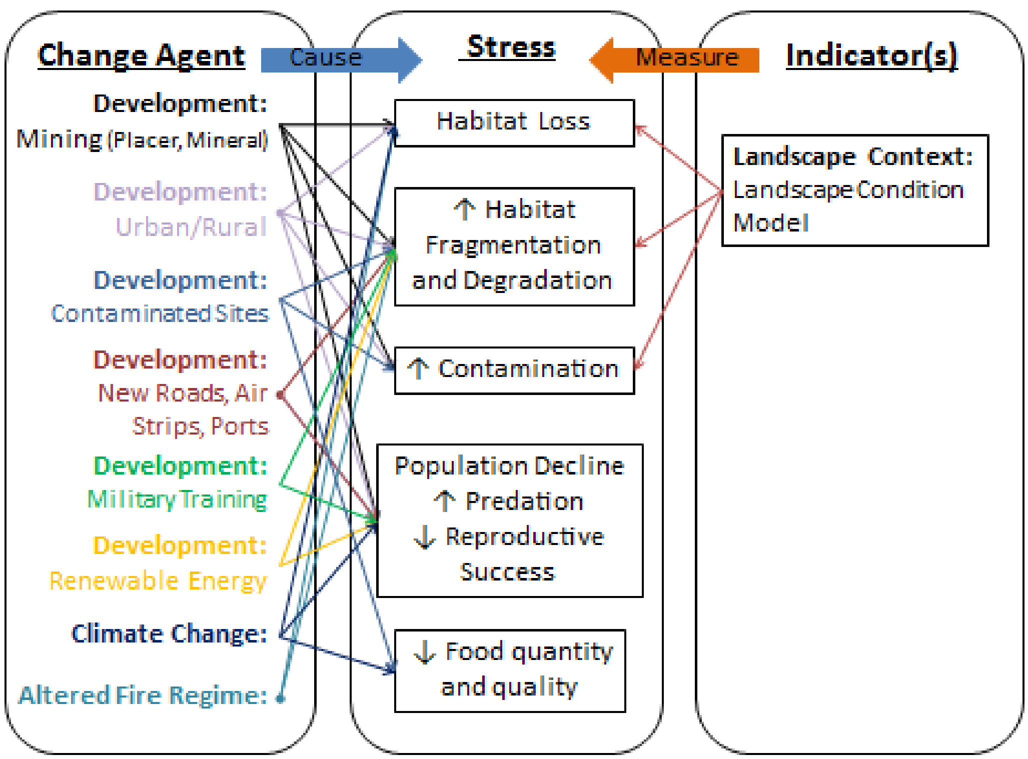

**Table E-13. Ecological status indicator for Arctic Shrub-Tussock Tundra.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

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Holt E.A., B. McCune and P. Neitlich. 2007a. Reindeer grazing and fire impacts on macrolichen communities of the Seward Peninsula, Alaska. In prep.

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## E-1.10 Model Group B2: Wet [Sedge] Tundra

### E-1.10.1 Arctic Wet Sedge Tundra

**Crosswalks**

**AKNHP Map Class:**

- [Herbaceous (Wet)]

**NatureServe Ecological System Type:**

- Alaska Arctic Wet Sedge Meadow
- Alaska Arctic Polygonal Ground Wet Sedge Tundra

**Geographic Distribution and Environmental Setting:** This map unit is found throughout the study area, but is most prevalent in the in the far western coastal areas of the Seward Peninsula and Kotzebue Sound Lowlands. Sites are flat to sloping in valley bottoms, basins, water tracks, ice-wedge polygons and adjacent to streams. It also includes patterned wetlands such as ribbed fens. Soils range from acidic to non-acidic, saturated during the summer, and have an organic horizon over silt with permafrost. Soils range from acidic to non-acidic, are saturated during the summer, and have an organic horizon over silt with permafrost, although on floodplains, permafrost is absent. Patch size is small to moderate and may be linear.

**Vegetation:** Composed of ≥40% herbaceous species, 5-25% water or ≥20% *Carex aquatilis*, and where ≥50% of the herbaceous cover is graminoid. Sites are typically dominated by *Carex aquatilis* and *Eriophorum angustifolium* but may also be dominated or codominated by *Carex glareosa, C. rotundata, C. rariflora, C. chordorrhiza, C. rostrata, C. saxatilis, C. utriculata, Eriophorum russeolum*, and *Eriophorum scheuchzeri*. *Dupontia fisheri* may also occur. Dwarf shrubs (<0.2 m tall) such as *Salix fuscescens, S. pulchra, Andromeda polifolia, Betula nana, Empetrum nigrum, Ledum palustre* ssp. *decumbens*, and *Vaccinium uliginosum* may be common but make up <25% cover. Moss species include *Drepanocladus* spp. and *Sphagnum* spp.

**Succession and Dynamics:** This class occurs within a variety of successional processes, including thaw lakes, polygonal ground, ice-wedge polygons, oriented lakes, water tracks and adjacent to streams. Seral stages and the rate of succession in this system are unclear. An alternate wetland pathway is mesic sites supporting low or tall willows moving to wet low-tall shrub to wet sedge to tussocks, but this last stage is no longer part of floodplain dynamics. Paludification may lead to wet sedge (possibly persisting for 1000-2000 years), and permafrost formation may lead to tussock tundra, but this last stage is no longer part of the floodplain dynamics.

Ice-wedge polygons are formed by large ice wedges which grow in thermal contraction cracks in permafrost. Low-center polygons indicate that ice wedges are actually growing and that sediments are being actively upturned. High-center polygons indicate that erosion, deposition, or thawing are more prevalent than the up-pushing of the sediments along the sides of the wedge. Ice-wedge polygons are typically part of a spatially coarser thaw-lake cycle.

**Threats and Stressors:** Climate change and associated alterations in permafrost distribution and hydrologic regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate, permafrost, and hydrologic regimes (e.g., Lloyd et al. 2002). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregions (Figure E-13).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-14) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-13. Arctic Wet Sedge Tundra Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

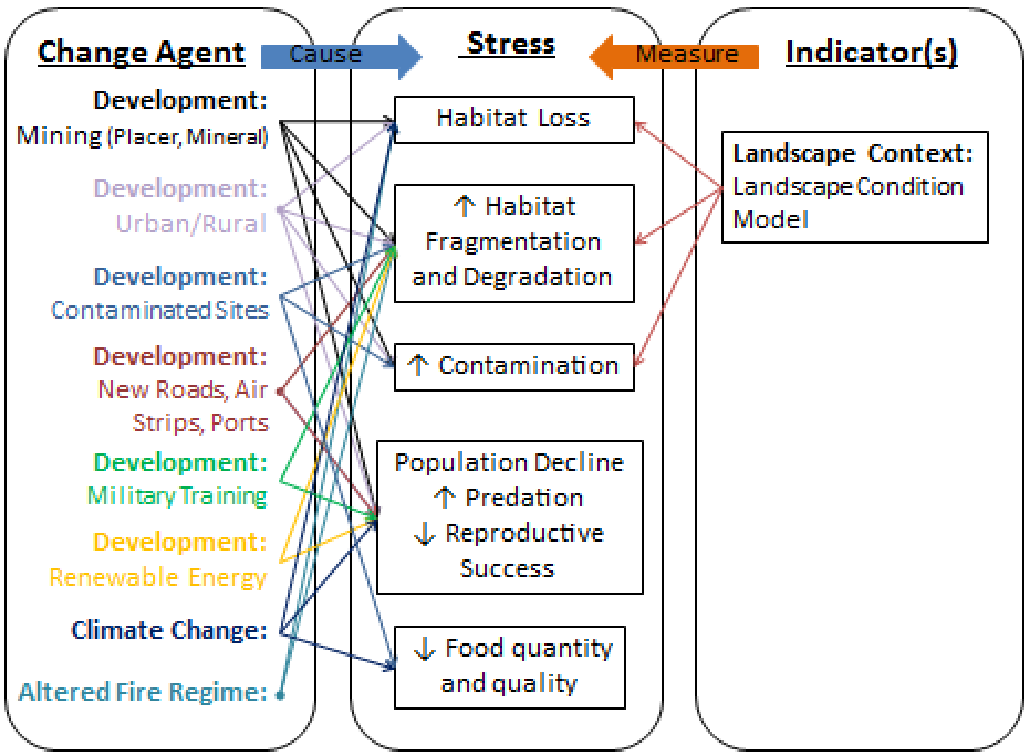


**Table E-14. Ecological status indicator for Arctic Wet Sedge Tundra.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

**REFERENCES**

Lloyd, A.H., Rupp, T.S., Fastie, C.L., and Starfield, A.M. 2002.Patterns and dynamics of treeline advance on the SewardPeninsula, Alaska. J. Geophys. Res.–Atmos. 107. doi: 10.1029/2001JD000852,2003

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Western Ecology Working Group of NatureServe. No date. International Ecological Classification Standard: International Vegetation Classification. Terrestrial Vegetation. NatureServe, Boulder, CO.

## E-1.11 Model Group B3: Peatlands

AKNHP did not attempt to map any peatland ecosystems in the SNK land cover map. NatureServe chose to include 3 different peatland classes in our map and conceptual models, because peatlands are important ecosystems throughout arctic and boreal Alaska. Descriptions are provided below for each of the three classes; the Arctic Dwarf Shrub-Sphagnum Peatland is the CE assessed for status.

### E-1.11.1 Arctic Dwarf-Shrub-Sphagnum Peatland

**Crosswalks**

**AKNHP Map Class:**

- [no match to AKNHP land cover map]

**NatureServe Ecological System Type:**

- Alaska Arctic Dwarf-shrub-Sphagnum Peatland

**Geographic Distribution and Environmental Setting:** This map class is primarily found in the Kotzebue Sound Lowlands with scattered occurrences in the northern and southern Nulato Hills. It is common in abandoned floodplains, wet depressions and old lake basins. Soils are poorly drained and acidic, typically with a well-developed peat layer. Permafrost may be present. Patch size is small to large.

**Vegetation:** *Sphagnum* cover is >25% (usually continuous), and herbaceous species (primarily sedges) cover is >25%. Shrubs and dwarf trees may dominate the shrub layer. The dominant dwarf-shrubs and trees are *Picea mariana, Betula nana* and *Ledum palustre ssp. decumbens*. Other species include *Empetrum nigrum, Chamaedaphne calyculata, Vaccinium uliginosum, Salix pulchra, Spiraea stevenii(= Spiraea beauverdiana), Vaccinium vitis-idaea,* and *Arctostaphylos* spp. The dominant sedges are *Eriophorum* spp. and *Carex utriculata*. Other common species include *Betula nana, Comarum palustre (= Potentilla palustris)*, and *Equisetum fluviatile*.

**Succession and Dynamics:** Shrub-dominated occurrences represent a late-seral stage created by permafrost uplift within the thaw-pond cycle and on raised bogs due to organic matter buildup, but could also develop due to permafrost uplift outside the thaw-pond cycle. It likely persists for more than 100 years. Thaw pond succession starts with the collapse of a permafrost plateau, resulting in a wet depression often with open water. This is colonized by marsh species or *Sphagnum* spp. or a combination of both.

In boreal wetlands dominated by *Picea mariana,* the general successional trend is from marsh to fen to treed bog; however, succession is not necessarily directional, and environmental conditions, such as nutrient content and abundance of groundwater, may prevent fens from developing into bogs (Zoltai et al. 1988). Succession begins in shallow ponds or low-lying wetlands formed by processes such as glacial recession and floodplain dynamics (oxbows) or thermokarst. An organic root mat typically develops and is either anchored to the mineral soil or floating on water such as a pond's edge. Over time, peat-forming mosses and sedges may fill in the basin. As the peat layer develops, low and/or dwarf-shrubs become established. Dwarf-trees may establish on the well-developed peat and also around the margin of the peatland. Many peatlands on the Kenai Lowland formed in kettles after remnant glacial ice melted. In this region, there is a trend toward peatlands drying and ponds shrinking and filling in (Klein et al. 2005). Permafrost degradation leading to collapse scars and thaw ponds is common in boreal Alaska, and studies from the Tanana Flats show areas of widespread degradation (Racine et al. 1998, Jorgenson et al. 2001a, 2001b, 2003). Thaw ponds form when ice-rich permafrost degrades and collapses forming a basin. Aquatic plants rapidly colonize the pond. Over time, marsh plants and sphagnum moss invade creating peatland conditions. This trend is leading to widespread ecosystem conversion in the Tanana Flats (Jorgenson et al. 2001b). If a collapse scar is isolated, succession follows a bog development model, whereas in an open hydrologic setting, succession follows a fen development model. Pond systems may become connected as adjacent permafrost thaws. Succession to peatlands can also occur through paludification of previously forested landscapes. Restricted drainage from permafrost development (on inactive alluvial terraces, for example) can lead to the establishment of *Sphagnum* spp. or other peat-forming mosses or sedges, and over time, peatland plants dominate the site.

**Threats and Stressors:** Climate change and associated alterations in permafrost distribution and hydrologic regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate, permafrost, and hydrologic regimes (e.g., Lloyd et al. 2002). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-14).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-15) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells.  The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-14. Arctic Dwarf-Shrub-Sphagnum Peatland Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

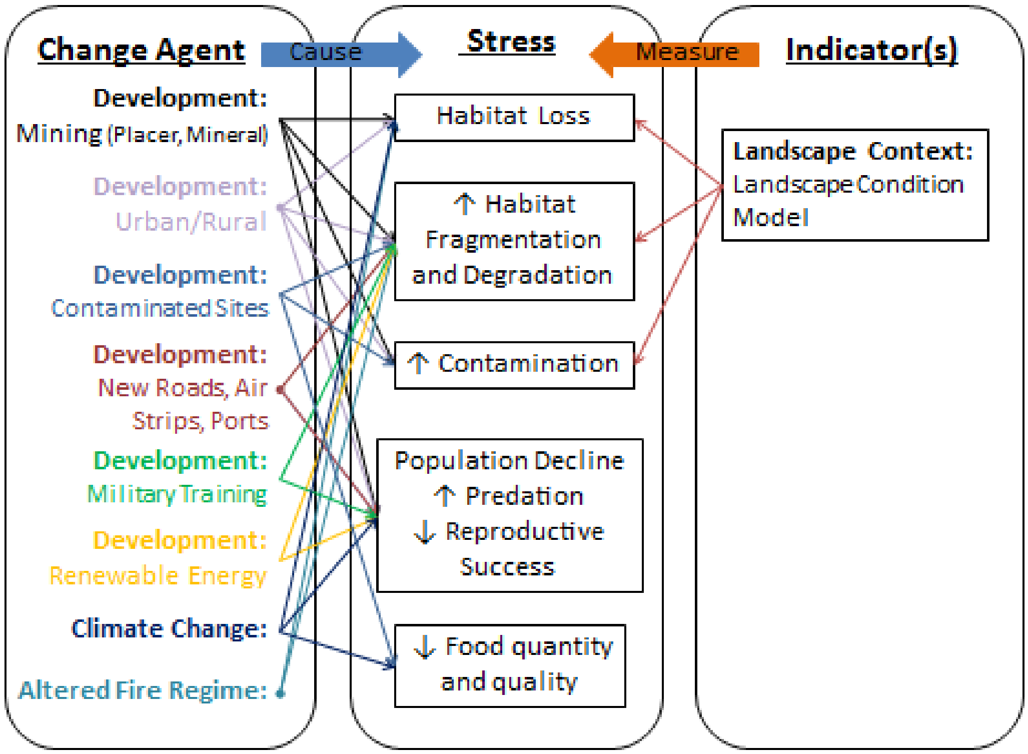


**Table E-15. Ecological status indicator for Arctic Dwarf Shrub-Sphagnum Peatland.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

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Shiflet, T. N., editor. 1994. Rangeland cover types of the United States. Society for Range Management. Denver, CO. 152 pp.

Western Ecology Working Group of NatureServe. No date. International Ecological Classification Standard: International Vegetation Classification. Terrestrial Vegetation. NatureServe, Boulder, CO.

### E-1.11.2 Arctic Wet Sedge-Sphagnum Peatland

**Crosswalks**

**AKNHP Map Class:**

- [no match to AKNHP land cover map]

**NatureServe Ecological System Type:**

- Alaska Arctic Wet Sedge-Sphagnum Peatland

**Geographic Distribution and Environmental Setting:** This map class is primarily found in the Kotzebue Sound Lowlands. It is common in wet depressions and old lake basins. Soils are poorly drained and acidic, typically with a well-developed peat layer. Permafrost may be present. Patch size is small to large.

**Vegetation:** *Sphagnum* cover is >25% (usually continuous), and herbaceous species (primarily sedges) cover is >25%. The dominant sedges are *Eriophorum* spp. and *Carex utriculata*. Other common species include *Betula nana, Comarum palustre (= Potentilla palustris)*, and *Equisetum fluviatile*.

**Succession and Dynamics:** Herbaceous-dominated occurrences represent an early-seral stage in the thaw-pond cycle. It starts with the collapse of a permafrost plateau resulting in a wet depression often with open water. This is colonized by marsh species or *Sphagnum* spp. or a combination of both. Sedges eventually invade, and this wet sedge-*Sphagnum* system develops. If organic matter buildup or permafrost uplift the surface, then this type may be seral to the Arctic Dwarf Shrub-Sphagnum Peatland. However, the seral sequence may not be unidirectional, and the timeframe is unclear, possibly taking hundreds of years.

**Threats and Stressors:** Climate change and associated alterations in permafrost distribution and hydrologic regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate, permafrost, and hydrologic regimes (Lloyd et al. 2002). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-15).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-16) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-15. Arctic Wet Sedge-Sphagnum Peatland Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

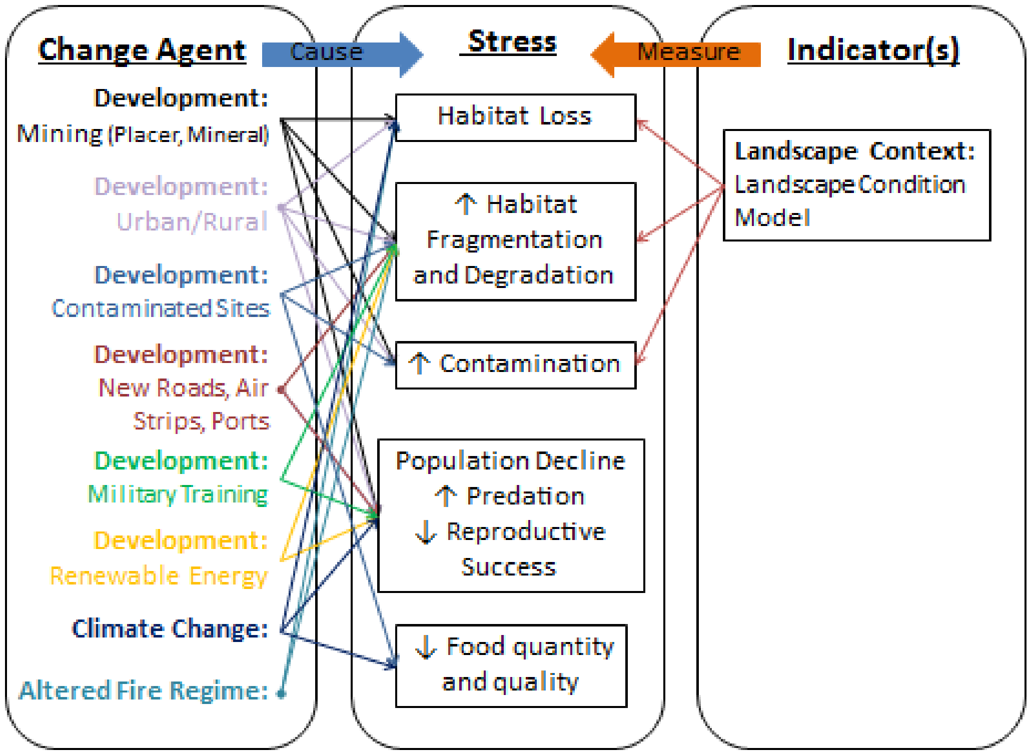


**Table E-16. Ecological status indicator for Arctic Wet Sedge-Sphagnum Peatland.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

**REFERENCES**


Lloyd, A.H., Rupp, T.S., Fastie, C.L., and Starfield, A.M. 2002.Patterns and dynamics of treeline advance on the SewardPeninsula, Alaska. J. Geophys. Res.–Atmos. 107. doi: 10.1029/2001JD000852,2003

### E-1.11.3 Boreal Black Spruce Dwarf-Tree Peatland

**Crosswalks**

**AKNHP Map Class:**

- [White Spruce or Black Spruce (Woodland)] (in part; modeled to split low and flat slopes into spruce peatland)

**NatureServe Ecological System Type:**

- Western North American Boreal Black Spruce Dwarf-Tree Peatland

**Geographic Distribution and Environmental Setting:** Occurs on north-facing slopes, valley bottoms and on abandoned floodplains and includes treed bogs (and poor fens). Soils are poorly drained and acidic, often with a well-developed peat layer. Permafrost is generally present.

**Vegetation:** The forest canopy is typically open to woodland and trees are generally stunted with the canopy dominated by *Picea mariana*. Common *Ledum palustre ssp. decumbens, Ledum groenlandicum, Andromeda polifolia, Betula nana, Empetrum nigrum, Vaccinium vitis-idaea, Vaccinium uliginosum, Chamaedaphne calyculata, Carex pluriflora, Carex* spp., *Eriophorum angustifolium, Calamagrostis canadensis*, and *Sphagnum* spp. (DeVelice et al. 1999).

**Succession and Dynamics:** In black spruce tussock tundra, following fires of moderate burn intensity where few tussocks burned, the peat layer survives (Boggs and Sturdy 2005). *Picea mariana* quickly invade or are already present and grow rapidly. *Picea glauca* and *Betula papyrifera* also occur in early succession—up to 15 years post-fire for *Betula papyrifera*—suggesting that drier conditions occurred briefly. *Alnus* species, *Ledum groenlandicum* and *Betula nana* increased following fire, but eventually die out in late succession. *Ledum palustre* ssp. *decumbens* recovers quickly and maintains itself through the late seral stages. *Vaccinium uliginosum* also recovers rapidly but appears to decrease in late succession. The thatch associated with sedge tussocks are usually consumed in light to moderate fires, leaving the lower portions alive and able to resprout. They appear to recover rapidly, showing no decrease in cover following fire. *Carex bigelowii* appears to be stimulated by fire but eventually dies out, whereas *Eriophorum vaginatum* recovers quickly and its cover remains relatively stable throughout succession.

**Threats and Stressors:** Climate change and associated alterations in permafrost distribution and hydrologic regimes, as well as fire regimes, are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate, permafrost, hydrology, and fire (Lloyd et al. 2002). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-16).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-17) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-16. Boreal Black Spruce Dwarf-Tree Peatland Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

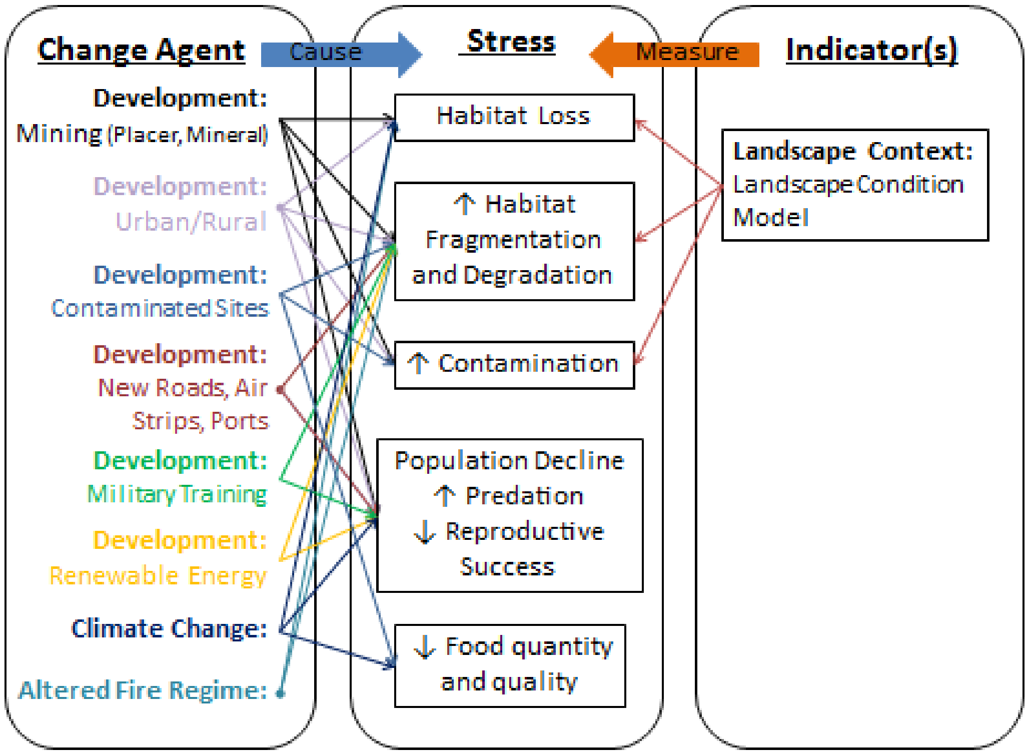


**Table E-17. Ecological status indicator for Boreal Black Spruce Dwarf Tree Peatland.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

**REFERENCES**


DeVelice, R. L. , C. J. Hubbard, K. Boggs, S. Boudreau, M. Potkin, T. Boucher, and C. Wertheim. 1999. Plant community types of the Chugach National Forest: South-central Alaska. USDA Forest Service, Chugach National Forest, Alaska Region. Technical Publication R10-TP-76. November 1999. 375 pp.

Lloyd, A.H., Rupp, T.S., Fastie, C.L., and Starfield, A.M. 2002.Patterns and dynamics of treeline advance on the SewardPeninsula, Alaska. J. Geophys. Res.–Atmos. 107. doi: 10.1029/2001JD000852,2003

Western Ecology Working Group of NatureServe. No date. International Ecological Classification Standard: International Vegetation Classification. Terrestrial Vegetation. NatureServe, Boulder, CO.

## E-1.12 Model Group B4: River Floodplains

### E-1.12.1 Large River Floodplain

**Crosswalks**

**AKNHP Map Class:**

- [no match to AKNHP land cover map]

**NatureServe Ecological System Type:**

- Alaska Arctic Large River Floodplain
- Western North American Boreal Lowland Large River Floodplain Forest and Shrubland

**Geographic Distribution and Environmental Setting:** This map class is infrequent and occurs primarily on the Yukon River with scattered locations inland. It includes active (flooded frequently) and inactive floodplains (flooded infrequently) and is mosaiced with the various floodplain wetland ecological systems. The flooding regime is characterized by large spring floods at ice break-up. The active flooding zone is often several kilometers wide. Permafrost is usually absent. Patch size is matrix-forming and linear, following the river courses.

**Vegetation:** Primary succession on floodplains begins when new alluvial surfaces are colonized by tree, shrub, and herbaceous species. Common woody species include *Populus balsamifera, Picea glauca, Alnus viridis ssp. sinuata, Alnus incana ssp. tenuifolia, Salix barclayi*, and *Salix alaxensis* (Viereck 1966, Scott 1974, Thilenius 1990, Shephard 1995, Boggs 2000). Common early-seral herbaceous species may include *Lupinus* spp., *Hedysarum* spp., and *Equisetum* spp. The next seral stage includes communities dominated by *Populus balsamifera* and/or *Picea glauca* with an understory of *Alnus viridis ssp. sinuata, Salix* spp., and bryophytes. The tall-shrub component of the early-successional stages diminishes rapidly, probably because of decreased light from the dense tree overstory. *Populus balsamifera* does not regenerate in the understory, and consequently, *Picea glauca* gains dominance in the overstory within 150 years. On older surfaces common shrubs include *Rosa acicularis, Viburnum edule*, and *Linnaea borealis*, and common herbs include *Pyrola* ssp. and *Cornus canadensis*. Feathermosses and lichens such as *Peltigera* spp occur on older surfaces.

**Succession and Dynamics:** Flooding can be caused by snowmelt, precipitation, ice jams and glacial runoff. Different rivers or portions of rivers may be more prone to certain types of flooding. Frequent flooding and channel migration create a pattern of gravel bars and early-successional stages across the valley bottom. Sediment deposition raises the surface of the floodplain over time. As the terrace becomes farther removed from the channel, flooding becomes less frequent. Water availability on terraces plays a major role in community structure and composition. Water inputs are from overbank flow (flooding), groundwater, and precipitation. Fine sediments are trapped when the floodwaters recede; this ongoing sediment input maintains high productivity.

**Threats and Stressors:** Climate change and associated alterations in hydrologic regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate, permafrost, and hydrologic regimes (e.g., Lloyd et al. 2002, Jorgenson 2005, 2010). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-17).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-18) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-17. Large River Floodplain Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

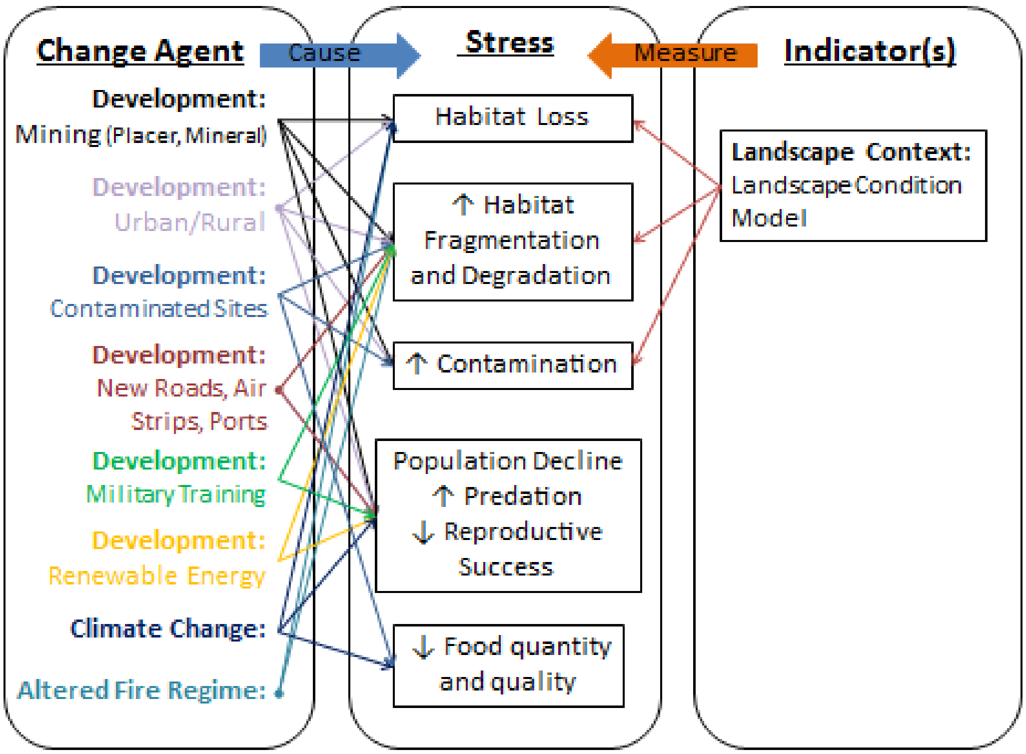


**Table E-18. Ecological status indicator for Large River Floodplain.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

**REFERENCES**

Boggs, K. 2000. Classification of community types, successional sequences and landscapes of the Copper River Delta, Alaska. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-469. Portland, OR. March 2000. 244 pp.

Scott, R. W. 1974. Successional patterns on moraines and outwash of the Frederika Glacier, Alaska. Pages 319-329 in: V. C. Bushnell and M. G. Marcus, editors. Icefield ranges research project scientific results. Volume 4. American Geographical Society, New York.

Shephard, M. E. 1995. Plant community ecology and classification of the Yakutat Foreland, Alaska. R10-TP-56. USDA Forest Service, Alaska Region. 213 pp. plus appendices.

Thilenius, J. F. 1990. Woody plant succession on earthquake-uplifted coastal wetlands of the Copper River Delta, Alaska. Forest Ecology and Management 33/34:439-462

Viereck, L. A. 1966. Plant succession and soil development on gravel outwash on the Muldrow Glacier, Alaska. Ecological Monographs 36(3):181-199.

## E-1.13 Model Group B5: Wet Willow Shrublands

### E-1.13.1 Arctic Mesic-Wet Willow Shrubland

**Crosswalks**

**AKNHP Map Class:**

- [Tall Shrub (open-closed)]

**NatureServe Ecological System Type:**

- Alaska Arctic Mesic Wet Willow Shrubland

**Geographic Distribution and Environmental Setting:** The low-tall willow map class is widespread and common on mesic to wet mountain slopes, hillslopes, flats, and adjacent to streams throughout the study area. Soils are mesic to wet, including wet sites with subsurface waterflow, water tracks, adjacent to narrow constrained streams, and on snow accumulation areas with late snowmelt.

**Vegetation:** Shrubs make up 25-100% of the cover and either $\geq$25% of the site consisted of shrubs $\geq$1.3 m in height OR shrubs $\geq$1.3 m are the most common shrubs. This typically does not include floodplain or tussock-dominated (>35% tussocks) sites. *Salix alaxensis, Salix pulchra*, and *Salix glauca* are the dominant species. Other shrubs may codominate, such as *Salix niphoclada, Salix chamissonis, Salix bebbiana, Salix planifolia, Salix richardsonii, Alnus viridis ssp. crispa, Betula nana, Vaccinium uliginosum*, and *Ledum palustre ssp. decumbens*. Dwarf-shrubs such as *Empetrum nigrum* and *Vaccinium vitis-idaea* may be common under the low-shrub layer. Herbaceous species are sparse but sedges are sometimes common. Feathermosses (*Hylocomium splendens* and *Pleurozium schreberi*) and lichens may be common.

**Succession and Dynamics:** Expert review indicates that this system is not controlled by avalanche activity, although avalanches may occur. The fire-return interval is likely long. The willow canopy shades the understory vegetation, possibly making the fine-fuel layer moist and less able to carry fire. Insects and diseases also affect willows. Shrub stringers that occur next to small streams or water tracks appear to be stable. Seasonal overbank flooding may occur, but generally it does not result in shifting channels or gravel bar formation. Subsurface flow may be common, and the soils are often stony.

**Threats and Stressors:** Climate change and associated alterations in fire regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate and fire regimes (Lloyd et al. 2002, Higuera et al. 2008, Jandt et al. 2008). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-18).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-19) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-18. Arctic Mesic-Wet Willow Shrubland Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

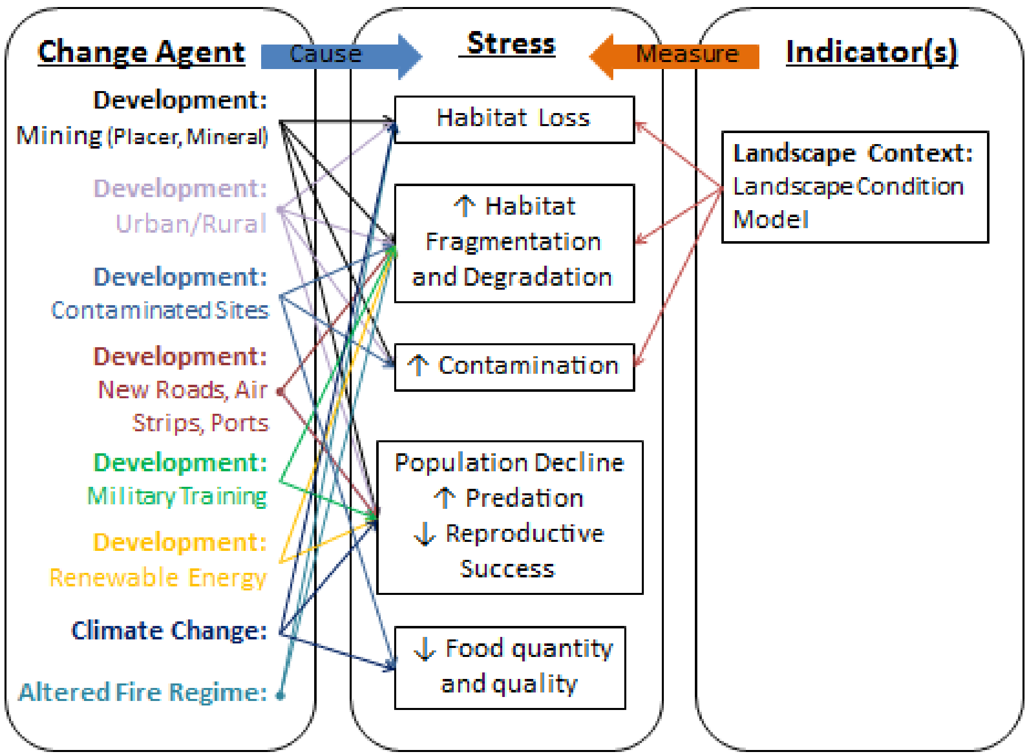

**Table E-19. Ecological status indicator for Arctic Mesic-Wet Willow Shrubland.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

**REFERENCES**


Higuera, P.E., L.B. Brubaker, P.M. Anderson, T.A. Brown, A.T. Kennedy, and F.S. Hu. 2008. Frequent Fires in Ancient Shrub Tundra: Implications of Paleorecords for Arctic Environmental Change. PLoS ONE 3:e0001744.

Jandt, R., K. Joly, C.R. Meyers, and C. Racine. 2008. Slow recovery of lichen on burned caribou winter range in Alaska tundra: Potential influences of climate warming and other disturbance factors. Arctic, Antarctic, and Alpine Research 40 (1): 89-95.

Lloyd, A.H., Rupp, T.S., Fastie, C.L., and Starfield, A.M. 2002.Patterns and dynamics of treeline advance on the SewardPeninsula, Alaska. J. Geophys. Res.–Atmos. 107. doi: 10.1029/2001JD000852,2003

Viereck, L. A., C. T. Dyrness, A. R. Batten, and K. J. Wenzlick. 1992. The Alaska vegetation classification. General Technical Report PNW-GTR286. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. 278 pp.


## E-1.14 Model Group C1: Coastal Marshes and Meadows

### E-1.14.1 Arctic Coastal Brackish and Tidal Marsh

**Crosswalks**

**AKNHP Map Class:**

- [Tidal Marsh]

**NatureServe Ecological System Type:**

- Alaska Arctic Coastal Brackish Meadow
- Alaska Arctic Tidal Marsh

**Geographic Distribution and Environmental Setting:** These are coastal marshes restricted to the coastal portions of the study area. These sites are tidally inundated during storm tides and extreme high tides and, consequently, are brackish. They are primarily salt or brackish, but some are primarily freshwater that are infrequently flooded during storm surges or extreme high tides. Classes moving inland include low tidal marsh (*Puccinellia* spp.), then mid tidal marsh (*Carex*), then high tidal marsh (herbaceous), and then high tidal marsh (herbaceous-dwarf shrub). The soils typically lack organics, and permafrost is uncommon. Patch size is small to moderate and often linear.

**Vegetation:** These are predominantly herbaceous marshes with >10% vascular species cover that are subject to regular to infrequent tidal inundation. Sedges, forbs or dwarf shrubs can be dominant in different areas of the marsh. Two different types of tidal marshes are included in this system: tidal sedge marshes and tidal herbaceous (non-sedge) marshes. *Carex ramenskii, Carex rariflora*, *Calamagrostis deschampsioides* or *Carex subspathacea* dominate the tidal sedge marshes and meadows. *Carex lyngbyei* may dominate on portions of the Yukon-Kuskokwim Delta and is often found more inland or adjacent to tidal creeks. *Dupontia fisheri* and *Puccinellia* spp. dominate the tidal herbaceous marshes.

Coastal brackish meadows typically occur immediately above tidal marshes in arctic Alaska. The main indicators on the Yukon-Kuskokwim Delta and the Kotzebue Sound lowlands ecoregions are *Carex rariflora* (>10%), *Calamagrostis deschampsioides*, and *Dendranthema arcticum (= Chrysanthemum arcticum)*. Other common species include *Eriophorum russeolum, Carex ramenskii* (usually present but not dominant), and *Salix ovalifolia*.

**Succession and Dynamics:** Tidal marshes often form an ecotone with freshwater non-tidal wetlands, especially on the Yukon-Kuskokwim Delta. On this delta, the first system moving inland is tidal marsh (*Puccinellia* spp. then *Carex ramenskii* or *Carex subspathacea*), then the coastal brackish meadows (*Carex rariflora, Calamagrostis deschampsioides*, and *Dendranthema arcticum (= Chrysanthemum arcticum)*), then coastal sedge-Dwarf-shrubland (*Empetrum nigrum, Salix fuscescens, Salix ovalifolia, Carex rariflora, Calamagrostis deschampsioides, Deschampsia caespitosa*), and then raised bogs or permafrost plateaus supporting Alaska Arctic Dwarf-Shrub-Sphagnum Peatland or Alaska Arctic Permafrost Plateau Dwarf-Shrub Lichen Tundra.

**Threats and Stressors:** Climate change and associated alterations in permafrost distribution and hydrologic regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate, permafrost, and hydrologic regimes (Lloyd et al. 2002). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-19).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-20) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-19. Arctic Coastal Brackish and Tidal Marsh Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

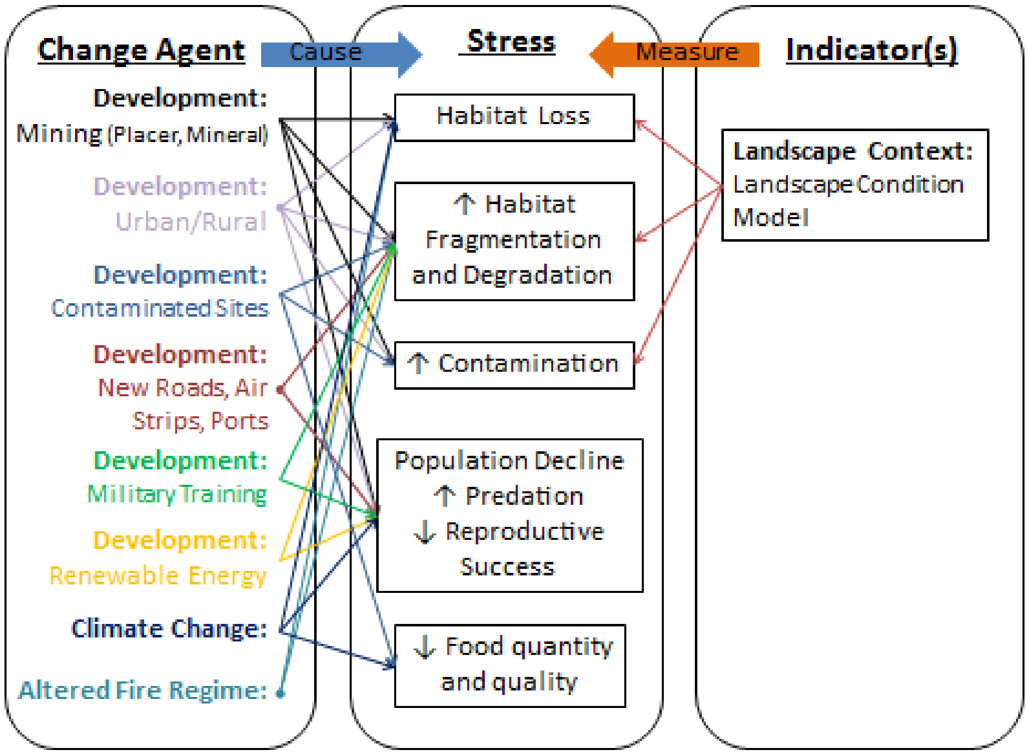


**Table E-20. Ecological status indicator for Arctic Coastal Brackish and Tidal Marsh.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

**REFERENCES**


Lloyd, A.H., Rupp, T.S., Fastie, C.L., and Starfield, A.M. 2002.Patterns and dynamics of treeline advance on the SewardPeninsula, Alaska. J. Geophys. Res.–Atmos. 107. doi: 10.1029/2001JD000852,2003

Western Ecology Working Group of NatureServe. No date. International Ecological Classification Standard: International Vegetation Classification. Terrestrial Vegetation. NatureServe, Boulder, CO.

### E-1.14.1 Arctic Marine Beach and Beach Meadow

**Crosswalks**

**AKNHP Map Class:**

- [Barren] (in part)
- [Herbaceous (Mesic, Dry)] (in part)

**NatureServe Ecological System Type:**

- Alaska Arctic Marine Beach and Beach Meadow

**Geographic Distribution and Environmental Setting:** These are coastal beaches, beach dunes, and vegetation having stabilized sand or cobble deposits. They occur along the Alaska arctic coastline, from the Bristol Bay lowlands in southwestern Alaska to the North Slope on the Arctic Ocean. Soils are dry to mesic (occasionally tidally inundated) and typically sandy. Patch size is small to moderate and often linear.

**Vegetation:** Two different physiognomic structures are found in the system: *Leymus mollis* grasslands and dwarf-shrublands; bare sand or cobble are also common. Salt-tolerant forb communities occur just above mean high tide and are dominated or codominated by *Cochlearia groenlandica, Achillea millefolium var. borealis, Honckenya peploides*, and/or *Mertensia maritima*. As dune height and distance from the ocean increase, sites are dominated by *Leymus mollis* communities that may include near-monocultures of *Leymus mollis* to more species-rich associations including *Leymus mollis, Lathyrus japonicus var. maritimus (= Lathyrus maritimus)*, and *Poa eminens*. Older dunes support dwarf-shrubs (primarily *Empetrum nigrum*) mixed with herbaceous species which often grow in narrow stringers on the older beach ridges behind the *Leymus mollis* zone. *Lathyrus japonicus var. maritimus, Conioselinum chinense*, and *Cnidium cnidiifolium* are uncommon east of Cape Lisburne. The *Leymus mollis* and *Empetrum nigrum* zones are above the high tide line but still experience storm surges, high winds and salt spray.

**Succession and Dynamics:** Coastal processes that define this system include sand deposition, wind erosion, long-shore transport, dune formation, and water erosion such as overwash from storm surges. Herbaceous species stabilize the sand deposits (dunes, beaches), and the older deposits support dwarf-shrubs mixed with herbaceous species.

**Threats and Stressors:** Climate change and associated alterations in fire regimes are an overarching threat for this and other CEs in the SNK ecoregion. Significant changes in vegetation structure, composition, and distribution are expected with changing climate and fire regimes (Lloyd et al. 2002, Higuera et al. 2008, Jandt et al. 2008). Localized stressors include placer and mineral mining. In limited portions of the ecoregion, existing or proposed roads, ports, and railroads, or other types of human development or infrastructure may threaten the CE. Oil and gas exploration is not occurring within the ecoregion, and there are no near-term plans to explore oil and gas reserves within the ecoregion (Figure E-20).

**Indicators of Ecological Status:** The stressor-based indicator identified for this CE (Table E-21) provide a link between the ecological requirements of the CE and CA effects on the CE; it serves as an indication of the ecological status based on the effects of CAs on the CE. The indicator is assessed through spatial modeling to provide a measure of status. For terrestrial conservation elements, the reporting unit is 2 x 2 km grid cells. The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-20. Arctic Marine Beach and Beach Meadow Conceptual Model/Diagram The diagram illustrates how change agents produce stress in the CE and what indicators can be measured to evaluate the level of stress and the ecological status of the CE.**

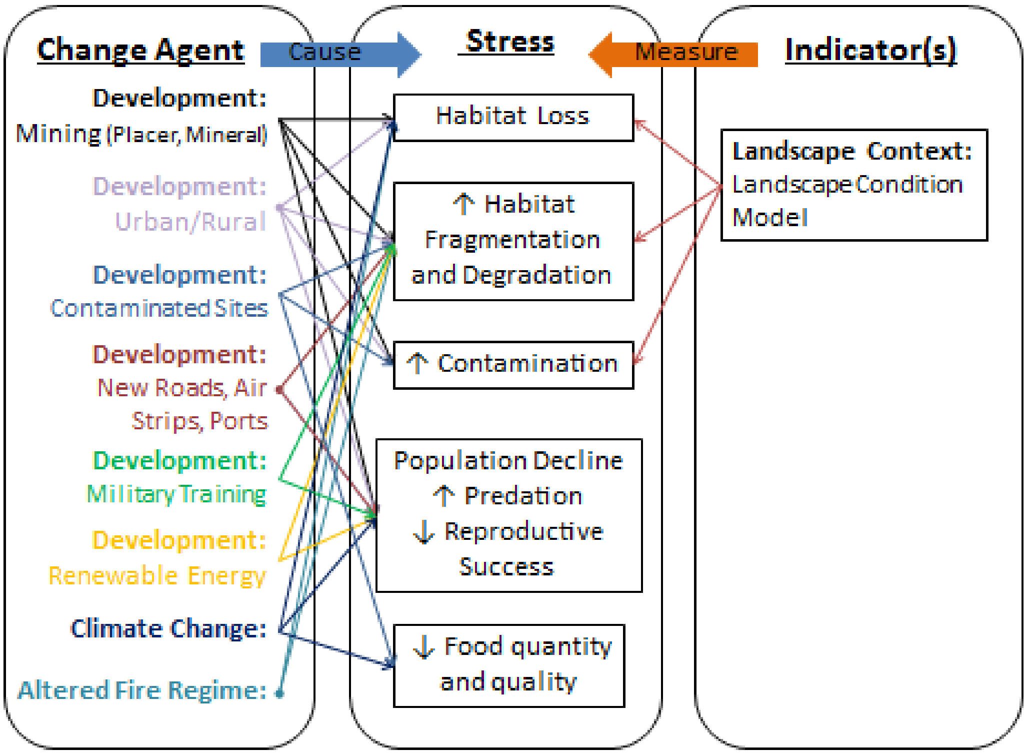


**Table E-21. Ecological status indicator for Arctic Marine Beach and Beach Meadow.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

**REFERENCES**

Higuera, P.E., L.B. Brubaker, P.M. Anderson, T.A. Brown, A.T. Kennedy, and F.S. Hu. 2008. Frequent Fires in Ancient Shrub Tundra: Implications of Paleorecords for Arctic Environmental Change. PLoS ONE 3:e0001744.

Jandt, R., K. Joly, C.R. Meyers, and C. Racine. 2008. Slow recovery of lichen on burned caribou winter range in Alaska tundra: Potential influences of climate warming and other disturbance factors. Arctic, Antarctic, and Alpine Research 40 (1): 89-95.

Lloyd, A.H., Rupp, T.S., Fastie, C.L., and Starfield, A.M. 2002.Patterns and dynamics of treeline advance on the SewardPeninsula, Alaska. J. Geophys. Res.–Atmos. 107. doi: 10.1029/2001JD000852,2003

## E-1.15 Additional Landcover Types

Below are descriptions for the additional land cover classes provided in the final land cover map. These descriptions were provided by Alaska Natural Heritage Program; NatureServe has not updated or edited them.

### E-1.15.1 LANDCOVER: Arctic Mesic Tundra

**AKNHP Map Class Name:** [Herbaceous (Mesic-Dry)]

**Description:** This class occurs on dry to mesic sites with >25% cover of herbaceous species. Dwarf shrubs (<0.2 m tall) may exceed 25% under the herbaceous layer. It includes sedge-*Dryas* (mesic), sedge-willow (mesic), herbaceous (mesic), and herbaceous dunegrass.

Species include *Carex aquatilis, Epilobium angustifolium Carex microchaeta* ssp. *Nesophila*, *Eriophorum angustifolium*, and *Carex microchaeta* and *Leymus mollis.* The dominant shrubs are *Salix pulchra, S. richardsonii*, and *Betula nana.*

This class is common on mountain slopes, hillslopes, drained lake basins, stabilized dunes, and snowbeds throughout arctic Alaska. Patch size is small to matrix-forming. Permafrost is present, and the soil surface is mesic but may be saturated below 15 cm.

### E-1.15.2 LANDCOVER: Herbaceous (Aquatic)

**Description:** Aquatic vegetation made up ≥20% of the cover, and ≥20% of the aquatic vegetation is composed of plants with floating leaves. Vegetation: A variety of rooted or floating aquatic herbaceous species may dominate, including *Nuphar lutea* ssp. *polysepala, Potamogeton* spp., *Lemna minor, Sparganium* spp., and *Ranunculus* spp. Other common species include *Myriophyllum* spp., *Hippuris vulgaris, Isoetes tenella*, and *Callitriche* spp. This class occurs as small patches formed in shallow water in ponds and lake margins including kettles, oxbow lakes, and thaw ponds. In large bodies of water, it is usually restricted to the littoral region where penetration of light is the limiting factor for growth.

### E-1.15.3 LANDCOVER: Arctic Freshwater Marsh

**AKNHP Map Class Name:** [Herbaceous (Marsh)]

**Description:** Fresh water aquatic vegetation made up ≥20% of the cover, and ≥20% of the aquatic vegetation is composed of emergent species other than pond lilies. In the arctic, it is often dominated by monocultures of *Arctophylla fulva, Carex aquatilis* or *Eriophorum angustifolium*. Other emergent species may occur, including *Comarum palustre, Hippuris vulgaris, Carex utriculata, Menyanthes trifoliata, Lysimachia thyrsiflora*, and *Equisetum fluviatile*. Species diversity is low. In the arctic, freshwater marshes occur as small to large patches, typically on the margins of ponds, lakes and beaded streams. They are semi-permanently flooded, but some have seasonal flooding, and the water depth typically exceeds 10 cm.

### E-1.15.4 LANDCOVER: Snow and Ice

**Description:** Composed of ≥50% snow or ice.

### E-1.15.5 LANDCOVER: Freshwater

**Description:** Composed of ≥80% water.

### E-1.15.6 LANDCOVER: Urban

**Description:** At least 50% of the area is agriculture, urban and/or roads.

### E-1.15.7 LANDCOVER: Unclassified

**Description:** Unclassified included clouds, cloud shadow, forest fire smoke, and terrain shadows. On the interior boreal map it also included sites that did not fall into any of the other defined land cover types. For example, sites containing 25%-80% water, <25% shrub and <20% aquatic vegetation are classed as Unclassified. It also included areas of vegetative litter, such as downed wood.

### E-1.15.8 LANDCOVER: Salt Water

**Description:** The breakpoint between saltwater and freshwater at river mouths is “photo interpreted” by the image processor.

### E-1.15.9 LANDCOVER: Bedrock Cliff, Talus, and Block Fields

**AKNHP Map Class Name:** [Bareground]

**Description:** Bareground included sand along the major rivers, high-elevation rock/gravel areas, cliffs, tidal mud flats (note: mapped into Arctic Tidal Marsh, or Arctic Marine Beach and Beach Meadow), unvegetated sand dunes (note: mapped into Arctic Active Inland dunes), and large piles of driftwood found on the west coast in the Innoko (Unalakleet) area.

### E-1.15.10 LANDCOVER: Fire Scar

**Description:** Burned areas dominated by snags or burned vegetation. These areas are typically too difficult to spectrally label; had poor field data (difficult/dangerous to fly in areas with numerous snags); or had changed significantly between the time of burn, the image acquisition date, and/or the date of field work. **Note: In the final NatureServe land cover map, most of these areas were remapped into one of the above vegetation types.**

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# E-2 Aquatic Coarse-Filter CEs

## E-2.1 Introduction

Conceptual models developed for the nine aquatic coarse-filter CEs in this REA include descriptive text and concept diagrams in order to clearly state our understanding of and assumptions made regarding the hydrology, geomorphology, other processes, and interactions of the CE with major CAs within the ecoregion. These conceptual models provide the information needed to identify measurable indicators that can be used to gauge the relative ecological status of each CE within 5$^{th}$ level watersheds.

All of the aquatic coarse-filter CEs (Table E-22) fit into the aquatic model group within the overall conceptual model established for the ecoregion.

**Table E-22. Aquatic coarse-filter CEs for the SNK ecoregion.**

| Aquatic Coarse-Filter CEs |
|---|
| Headwater Streams |
| Low-gradient Streams |
| High-gradient Rivers (Rivers) |
| Estuaries |
| Large Connected Lakes |
| Small Connected Lakes |
| Large Disconnected Lakes |
| Small Disconnected Lakes |
| Hot Springs |

The descriptive material for aquatic coarse-filter CEs is developed from two sources: 1) the descriptive information for each CE developed by AKNHP and 2) additional literature review conducted by NatureServe on stressors to the CEs. Descriptions include a summary description, distribution and abundance, ecological importance, and threats/stressors, with supporting literature cited. Literature is listed that is relevant to the classification, distribution, ecological processes, threats, stressors, or management of the CE. These are not exhaustive literature surveys, but rather a brief accumulation of known references. Some documents may be listed that are not cited in the narrative text.

The conceptual model diagrams illustrate our understanding of how change agents may stress the aquatic CEs and which of those individual stressors can be reflected in the indicators of ecological integrity. In addition to the understanding of a CE's composition, structure, processes, and response to stressors, data availability also shaped the set of indicators that could practically be used to evaluate aquatic CEs. **Available data sets in the SNK ecoregion reflected ecosystem stressors**, rather than direct measures of ecological condition. The five indicators that could readily be assessed for individual aquatic CEs *emphasize development-related ecosystem stressors*. Various spatial modeling approaches were developed to evaluate these indicators for the ecological status assessments of aquatic CEs. The definition and justification for each of the indicators *relevant to the individual aquatic CE* is provided in a simple Ecological Status Indicator table for each of the aquatic CE conceptual models. The indicators are scored with values ranging from 0 to 1, with 1 indicating highest ecological status and 0 indicating lowest status (and presumably transitional to a wholly different ecological state).

## E-2.2 Headwater Streams

**DESCRIPTION**

Headwater streams make up a large portion of the stream network and, on the Seward Peninsula, 1st order streams constitute 40% of the total river length (NHD 2011). They contribute substantially to sustaining water quantity and water quality (55% of volume and 40% of nitrogen) in fourth and higher order streams (Alexander 2007). They provide an important link between terrestrial and aquatic ecosystems by providing subsidies of organic material to downstream organisms (Wipfli 2007). Headwater streams include all perennial first-order streams, which occur across the landscape in high elevation mountain ranges and in coastal or interior lowlands. Fish communities and their habitats are described for headwater streams based on two ADF&G studies: in 2004, 118 first through third order streams on the Seward Peninsula were sampled for fish (Weidmer 2011); a 2008 fish inventory of tributaries of the lower Yukon River summarized fish and environmental data by small, medium and large stream sizes defined by their catchment areas ( <100, 100-500, and >500 $km^2$) (Buckwalter et al. 2010).

**HYDROLOGY**

Hydrologic regime and water chemistry of headwater streams are variable and depend upon the watershed slope, elevation, precipitation, snowpack, vegetation, and underlying geology and soils. Several studies have shown that physical and chemical attributes and associated fish communities of low order streams are strongly related to stream gradient and elevation (Bryant et al. 2004, Walker et al. 2007). Headwater streams draining areas of higher relief have higher discharge, colder temperatures, higher dissolved oxygen, and higher pH than streams draining low-relief areas. Headwater streams draining low relief areas have warmer temperatures due to longer flow paths, lower dissolved oxygen, and lower pH. Streams of low relief usually have more wetland area in the surrounding riparian zone leading to higher dissolved organic carbon concentrations and lower pH.

**ECOLOGICAL IMPORTANCE**

Headwater streams provide important spawning and rearing habitat for several of the resident and anadromous fish conservation elements: coho salmon, Chinook salmon, Dolly Varden, Arctic grayling, and Alaska blackfish. In tributaries of the lower Yukon River, Alaska blackfish occupied small streams in low relief areas with smaller catchment sizes, warmer summertime temperatures, and higher turbidity. The habitat characteristics preferred by Alaska blackfish were found to preclude other fish species (Buckwalter et al. 2010, Weidmer 2011). Coho salmon and Dolly Varden tend to occupy headwater streams draining high relief areas with relatively higher discharge than headwater streams where they are not present (Buckwalter et al. 2010). In low-order streams of the Seward Peninsula, coho salmon were found in habitats downstream of Dolly Varden (Weidmer 2011), which corresponds to other Alaskan studies indicating that Dolly Varden prefer the uppermost limit of high gradient fish habitats (Bryant et al. 2004, Walker et al. 200 7). Chinook salmon were not found in low order streams of the Seward Peninsula (Weidmer 2011) and were found infrequently in small streams of the lower Yukon River in habitats similar to those preferred by coho salmon (Buckwalter et al. 2010). Arctic grayling were observed in low gradient small streams of both the Seward Peninsula and the lower Yukon River (Buckwalter et al. 2010, Weidmer 2011). Adult grayling tend to be more abundant in headwaters than younger fish (Hughes 1999).

**THREATS/STRESSORS**

The conceptual model diagram for this CE (Figure E-21) includes threats/stressors (change agents) and an illustration of how they produce stress on streams.

**Vulnerability to climate change***:* Headwater streams are dependent on perennial stream flow. Climate change is likely to change, in complex ways, the hydrology of headwater streams. The predicted changes of climate in the REA study area include increased precipitation, increased day time maximum and night time minimum temperatures, decreases in the winter snowpack, earlier spring snowmelt, longer growing season, increased evapotranspiration, decreased permafrost extent, increased soil active layer thickness, and earlier ice breakup and later freeze-up (Loya 2011, Schindler and Rogers 2009). Climate change may increase the flow within streams in the study area as precipitation increases in the wintertime, although increased temperatures will increase evapotranspiration in the summertime so overall effects on discharge are difficult to predict (B. Bolton, pers. comm.). Due to thawing permafrost and increased active layer thickness, base flows will increase and peak flows will decrease due to a higher water holding capacity in soils across the watershed (B. Bolton, pers. comm.).

**Increased human infrastructure**: Stream ecosystems may be more vulnerable to human development than other aquatic habitats due to their high density across the landscape. Increased development is often associated with increased density of roads and road crossings of streams. Road culverts cause more problems for aquatic habitat and species compared to bridges for road crossings. Culverts have a higher likelihood of blocking passage for fish, water flow, sediments and other materials (Sheer and Steel 2006). A survey of culverts on the Nome road system found that 72% of the road crossings (76 culverts) were impassable for juvenile coho salmon (ADF&G 2011). A study on the Nome River found that juvenile coho salmon were able to migrate upstream on all seven of their streams with beaver dams, but did not find coho salmon above the one stream with a perched culvert (Nemeth et al. 2009).

**Historic and current placer mining**: In addition to roads, mining can also negatively affect stream ecosystems. The discovery of gold near Nome in 1898 led to extensive placer mining activity in streams along the southern Seward Peninsula and 377 mines occur within the REA study area, 25 of which are currently active (USGS 2008). Un-remediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability of stream substrates with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. Tailings left within the active channel are often re-worked by next year's ice scour and flooding events. However, tailings piled beyond active floodplains last longer and may cause some acid drainage runoff during storm events.

**Flow regimes** may be altered in streams, rivers, and connected lakes as a result of dams, road culverts, or other blockages. Where stream bed morphology has been significantly altered (i.e., incised and unstable) from historical, unremediated placer mines (Densmore and Karle 2009) within the stream network, this may also have altered flow regimes. As noted above, complex interactions of changes in climate (precipitation quantity, timing, type, etc.) and permafrost are also expected to significantly alter hydrologic regimes.

**Wildfire:** The results of the SNK REA indicate that the frequency of fire is likely to increase in some parts of the ecoregion (see discussion of fire in Future Conditions chapter of the SNK report). Wildfire can impact aquatic systems (whether hydrologically connected or disconnected) through a variety of complex interactions, such as increasing sedimentation due to vegetation removal and increasing peak flows due to lower evapotranspiration from loss of vegetation (Rieman and Clayton 1997). Wildfires also have the potential to increase permafrost melting by removing insulating vegetation, thereby increasing active layer depths post-fire (Yoshikawa et al. 2002), which can result in increased sediment inputs due to thermokarsting (Jorgensen and Osterkamp 2005). A large thaw slump on the Selawik River was observed in 2004 has increased sedimentation and may affect spawning sheefish habitat (Hander et al. 2008).

**Invasive species**: The impacts of invasive species on aquatic systems, such as streams, include displacement of native aquatic fauna and alteration of stream food webs (McClory and Gotthardt 2008). Non-native, invasive aquatic species have not been documented in this ecoregion as of this assessment. Aquatic invasive taxa currently known from Alaska as a whole (see McClory and Gotthardt 2008) include two invasive crayfish, *Procambarus clarkia* (red swamp crayfish; known from the Kenai Peninsula) and *Pacifastacus leniusculus* (signal crayfish; known from Kodiak Island), *Myxobolus cerebralis* (the whirling disease parasite; documented from the Anchorage Bowl) (McClory and Gotthardt 2008), *Gambusia affinis* (western mosquito fish; documented in Alaska, specific location unknown), and pondweed *Elodea canadensis* (documented from Fairbanks; Larson et al. 2010). A brief summary of potential impacts and modes of spread of the five species documented to date in Alaska is included in the non-native species section of the Future Conditions chapter of the SNK REA report.

**INDICATORS OF ECOLOGICAL STATUS**

The stressor-based indicators identified for this CE (Table E-23) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling (e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5$^{th}$-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-21. Streams & Rivers Conceptual Model/Diagram illustrating how change agents produce stress on streams, and what indicators can be measured to evaluate the level of stress and the ecological integrity of streams.**

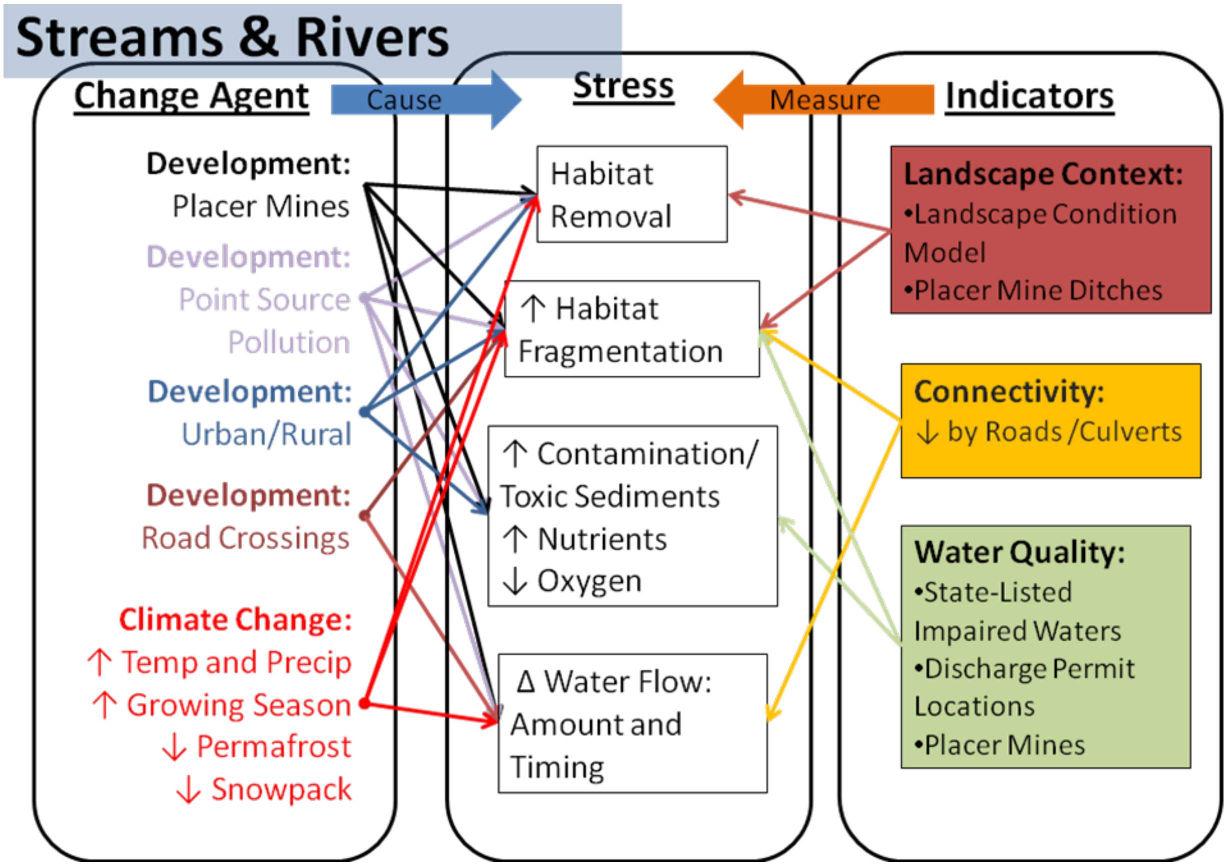


**Table E-23. Ecological status indicators for Headwater Streams.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Key Ecological Attribute: Connectivity** | | |
| Index of Fish Passage (culverts) | This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

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## E-2.3 Low-Gradient Streams

**DESCRIPTION**

Low-gradient streams include streams of 3rd order or higher with gradients less than 2%. In the REA study area, surface water inputs to streams peak during spring snowmelt and winter baseflows may be very limited in streams on the northern Seward Peninsula and other streams whose headwaters originate in flat, coastal areas (BLM 2006). Groundwater is unable to maintain adequate baseflows in many streams due to the prevalence of permafrost in the REA study area, which restricts infiltration. Streams with depths greater than two meters remain unfrozen in the winter and may provide important winter refuge for aquatic organisms (BLM 2006).

**ECOLOGICAL IMPORTANCE**

Low-gradient streams provide important habitat for northern pike, many of the whitefish species, Alaska blackfish, and anadromous fishes that utilize them during migration. Low-gradient streams and associated wetland habitats may provide important feeding areas for aquatic organisms due to earlier breakup and higher temperatures in the spring (BLM 2006).

**THREATS/STRESSORS**

The conceptual model diagram for this CE (Figure E-22) includes threats/stressors (change agents) and an illustration of how they produce stress on streams.

**Vulnerability to climate change***:* Low-gradient streams are dependent on perennial stream flow. Climate change is likely to change, in complex ways, the hydrology of low-gradient streams. The predicted changes of climate in the REA study area include increased precipitation, increased day time maximum and night time minimum temperatures, decreases in the winter snowpack, earlier spring snowmelt, longer growing season, increased evapotranspiration, decreased permafrost extent, increased soil active layer thickness, and earlier ice breakup and later freeze-up (Loya 2011, Schindler and Rogers 2009). Climate change may increase the flow within streams in the study area as precipitation increases in the wintertime, although increased temperatures will increase evapotranspiration in the summertime so overall effects on discharge are difficult to predict (B. Bolton, pers. comm.). Due to thawing permafrost and increased active layer thickness, base flows will increase and peak flows will decrease due to a higher water holding capacity in soils across the watershed (B. Bolton, pers. comm.).

**Increased human infrastructure**: Stream ecosystems may be more vulnerable to human development than other aquatic habitats due to their high density across the landscape. Increased development is often associated with increased density of roads and road crossings of streams. Road culverts cause more problems for aquatic habitat and species compared to bridges for road crossings. Culverts have a higher likelihood of blocking passage for fish, water flow, sediments and other materials (Sheer and Steel 2006). A survey of culverts on the Nome road system found that 72% of the road crossings (76 culverts) were impassable for juvenile coho salmon (ADF&G 2011). A study on the Nome River found that juvenile coho salmon were able to migrate upstream on all seven of their streams with beaver dams, but did not find coho salmon above the one stream with a perched culvert (Nemeth et al. 2009).

**Historic and current placer mining**: In addition to roads, mining can also negatively affect stream ecosystems. The discovery of gold near Nome in 1898 led to extensive placer mining activity in streams along the southern Seward Peninsula and 377 mines occur within the REA study area, 25 of which are currently active (USGS 2008). Un-remediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability of stream substrates with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. Tailings left within the active channel are often re-worked by next year's ice scour and flooding events. However tailings piled beyond active floodplains last longer and may cause some acid drainage runoff during storm events.

**Flow regimes** may be altered in streams, rivers, and connected lakes as a result of dams, road culverts, or other blockages. Where stream bed morphology has been significantly altered (i.e., incised and unstable) from historical, unremediated placer mines (Densmore and Karle 2009) within the stream network, this may also have altered flow regimes. As noted above, complex interactions of changes in climate (precipitation quantity, timing, type, etc.) and permafrost are also expected to significantly alter hydrologic regimes.

**Wildfire:** The results of the SNK REA indicate that the frequency of fire is likely to increase in some parts of the ecoregion (see discussion of fire in Future Conditions chapter of the SNK report). Wildfire can impact aquatic systems (whether hydrologically connected or disconnected) through a variety of complex interactions, such as increasing sedimentation due to vegetation removal and increasing peak flows due to lower evapotranspiration from loss of vegetation (Rieman and Clayton 1997). Wildfires also have the potential to increase permafrost melting by removing insulating vegetation, thereby increasing active layer depths post-fire (Yoshikawa et al. 2002), which can result in increased sediment inputs due to thermokarsting (Jorgensen and Osterkamp 2005). A large thaw slump on the Selawik River was observed in 2004 has increased sedimentation and may affect spawning sheefish habitat (Hander et al. 2008).

**Invasive species**: The impacts of invasive species on aquatic systems, such as streams, include displacement of native aquatic fauna and alteration of stream food webs (McClory and Gotthardt 2008). Non-native, invasive aquatic species have not been documented in this ecoregion as of this assessment. Aquatic invasive taxa currently known from Alaska as a whole (see McClory and Gotthardt 2008) include two invasive crayfish, *Procambarus clarkia* (red swamp crayfish; known from the Kenai Peninsula) and *Pacifastacus leniusculus* (signal crayfish; known from Kodiak Island), *Myxobolus cerebralis* (the whirling disease parasite; documented from the Anchorage Bowl) (McClory and Gotthardt 2008), *Gambusia affinis* (western mosquito fish; documented in Alaska, specific location unknown), and pondweed *Elodea canadensis* (documented from Fairbanks; Larson et al. 2010). A brief summary of potential impacts and modes of spread of the five species documented to date in Alaska is included in the non-native species section of the Future Conditions chapter of the SNK REA report.

### INDICATORS OF ECOLOGICAL STATUS

The stressor-based indicators identified for this CE (Table E-24) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling (e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5th-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-22. Streams & Rivers Conceptual Model/Diagram illustrating how change agents produce stress on streams, and what indicators can be measured to evaluate the level of stress and the ecological integrity of streams.**

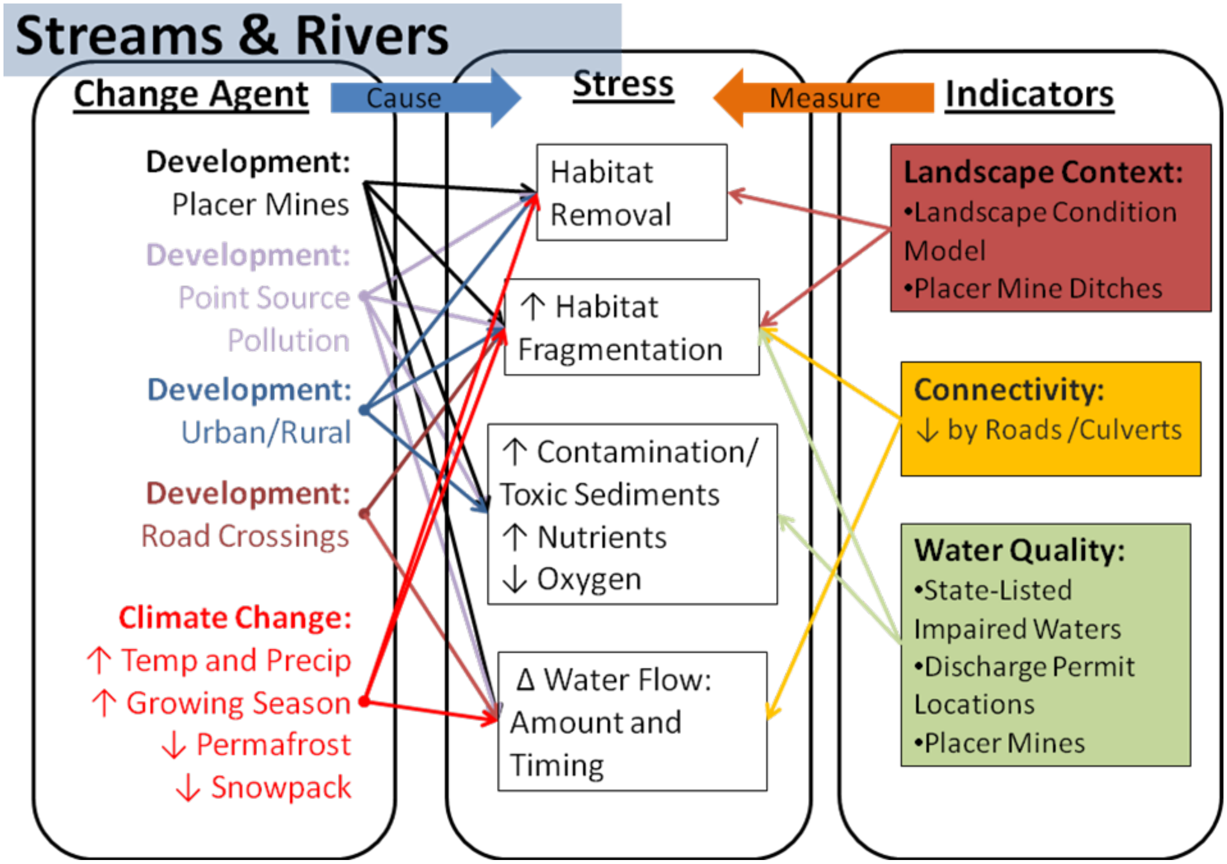


**Table E-24. Ecological status indicators for Low-Gradient Streams.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |
| **Key Ecological Attribute: Connectivity** | | |
| Index of Fish Passage (culverts) | This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

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## E-2.4 High-Gradient Rivers

### DESCRIPTION

High-gradient rivers include 3rd order and higher rivers that have slopes greater than 2%. They occur in mountainous parts of the REA study area such as the Nulato Hills and mountains on the Seward Peninsula. A hydrograph peak occurs during spring snowmelt in the REA study area, and a second large peak may occur during fall rains in high-gradient rivers that originate in areas of higher relief. These systems are underlain by discontinuous permafrost due to the well-drained nature of the surrounding topography (BLM 2006), which may increase the availability of groundwater to support winter baseflows.

### ECOLOGICAL IMPORTANCE

Fish species that utilize high-gradient river habitat include coho salmon and Dolly Varden, as well as other salmon species and Arctic grayling.

### THREATS/STRESSORS

The conceptual model diagram for this CE (Figure E-23) includes threats/stressors (change agents) and an illustration of how they produce stress on rivers.

**Vulnerability to climate change**: High-gradient rivers are dependent on perennial stream flow. Climate change is likely to change, in complex ways, the hydrology of high-gradient rivers. The predicted changes of climate in the REA study area include increased precipitation, increased day time maximum and night time minimum temperatures, decreases in the winter snowpack, earlier spring snowmelt, longer growing season, increased evapotranspiration, decreased permafrost extent, increased soil active layer thickness, and earlier ice breakup and later freeze-up (Loya 2011, Schindler and Rogers 2009). Climate change may increase the flow within streams in the study area as precipitation increases in the wintertime, although increased temperatures will increase evapotranspiration in the summertime so overall effects on discharge are difficult to predict (B. Bolton, pers. comm.). Due to thawing permafrost and increased active layer thickness, base flows will increase and peak flows will decrease due to a higher water holding capacity in soils across the watershed (B. Bolton, pers. comm.).

**Increased human infrastructure**: Stream ecosystems may be more vulnerable to human development than other aquatic habitats due to their high density across the landscape. Increased development is often associated with increased density of roads and road crossings of streams. Road culverts cause more problems for aquatic habitat and species compared to bridges for road crossings. Culverts have a higher likelihood of blocking passage for fish, water flow, sediments and other materials (Sheer and Steel 2006). A survey of culverts on the Nome road system found that 72% of the road crossings (76 culverts) were impassable for juvenile coho salmon (ADF&G 2011). A study on the Nome River found that juvenile coho salmon were able to migrate upstream on all seven of their streams with beaver dams, but did not find coho salmon above the one stream with a perched culvert (Nemeth et al. 2009).

**Historic and current placer mining**: In addition to roads, mining can also negatively affect stream ecosystems. The discovery of gold near Nome in 1898 led to extensive placer mining activity in streams along the southern Seward Peninsula and 377 mines occur within the REA study area, 25 of which are currently active (USGS 2008). Un-remediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability of stream substrates with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. Tailings left within the active channel are often re-worked by next year's ice scour and flooding events. However tailings piled beyond active floodplains last longer and may cause some acid drainage runoff during storm events.

**Flow regimes** may be altered in streams, rivers, and connected lakes as a result of dams, road culverts, or other blockages. Where stream bed morphology has been significantly altered (i.e., incised and unstable) from historical, unremediated placer mines (Densmore and Karle 2009) within the stream network, this may also have altered flow regimes. As noted above, complex interactions of changes in climate (precipitation quantity, timing, type, etc.) and permafrost are also expected to significantly alter hydrologic regimes.

**Wildfire:** The results of the SNK REA indicate that the frequency of fire is likely to increase in some parts of the ecoregion (see discussion of fire in Future Conditions chapter of the SNK report). Wildfire can impact aquatic systems (whether hydrologically connected or disconnected) through a variety of complex interactions, such as increasing sedimentation due to vegetation removal and increasing peak flows due to lower evapotranspiration from loss of vegetation (Rieman and Clayton 1997). Wildfires also have the potential to increase permafrost melting by removing insulating vegetation, thereby increasing active layer depths post-fire (Yoshikawa et al. 2002), which can result in increased sediment inputs due to thermokarsting (Jorgensen and Osterkamp 2005). A large thaw slump on the Selawik River was observed in 2004 has increased sedimentation and may affect spawning sheefish habitat (Hander et al. 2008).

**Invasive species**: The impacts of invasive species on aquatic systems, such as streams, include displacement of native aquatic fauna and alteration of stream food webs (McClory and Gotthardt 2008). Non-native, invasive aquatic species have not been documented in this ecoregion as of this assessment. Aquatic invasive taxa currently known from Alaska as a whole (see McClory and Gotthardt 2008) include two invasive crayfish, *Procambarus clarkia* (red swamp crayfish; known from the Kenai Peninsula) and *Pacifastacus leniusculus* (signal crayfish; known from Kodiak Island), *Myxobolus cerebralis* (the whirling disease parasite; documented from the Anchorage Bowl) (McClory and Gotthardt 2008), *Gambusia affinis* (western mosquito fish; documented in Alaska, specific location unknown), and pondweed *Elodea canadensis* (documented from Fairbanks; Larson et al. 2010). A brief summary of potential impacts and modes of spread of the five species documented to date in Alaska is included in the non-native species section of the Future Conditions chapter of the SNK REA report.

**INDICATORS OF ECOLOGICAL STATUS**

The stressor-based indicators identified for this CE (Table E-25) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling

(e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5$^{th}$-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-23. Streams & Rivers Conceptual Model/Diagram illustrating how change agents produce stress on rivers, and what indicators can be measured to evaluate the level of stress and the ecological integrity of rivers.**

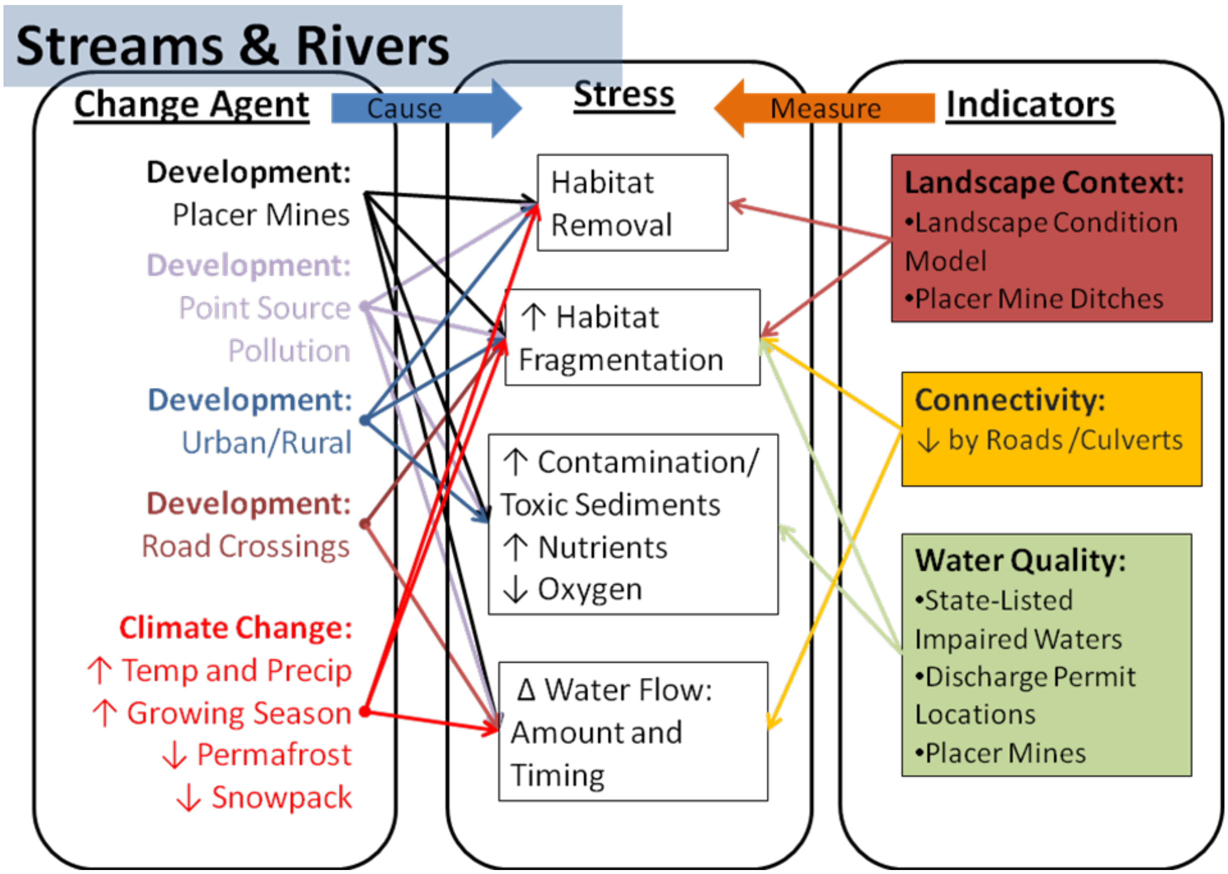


**Table E-25. Ecological status indicators for High-Gradient Rivers.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

| Indicator | Definition and Scoring | Justification |
| --- | --- | --- |
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |
| **Key Ecological Attribute: Connectivity** | | |
| Index of Fish Passage (culverts) | This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

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## E-2.5 Estuaries

**DESCRIPTION**

Estuarine habitats occur where rivers empty to the ocean and can vary in size depending on the gradient at the river outlet and the size of the river. Estuaries provide unique habitats for aquatic organisms because they span a gradient from freshwater to saltwater. The amount of saltwater influence into the estuary depends upon the river discharge and size of the tides.

**DISTRIBUTION AND ABUNDANCE**

In the REA study area, rivers with relatively well-developed estuaries at their outlets include the Kobuk, Selawik, Buckland, Serpentine, Kuzitrin, Eldorado, Fish, Tubutulik, Koyuk, and Shaktoolik rivers.

**ECOLOGICAL IMPORTANCE**

In the SNK ecoregion, estuaries provide important feeding habitat for juvenile chum and pink salmon as they migrate to the ocean. In addition, many whitefish species spend time in estuarine and nearshore waters to overwinter, such as Bering cisco, broad whitefish, humpback whitefish, and sheefish. Estuaries provided critical habitat that is disproportional to its geographic area within the watershed (Bond 2006). Uninhabited estuaries are rare in the world and there are several uninhabited estuaries within in the ecoregion. Estuaries provide habitat for wildlife and commercial species of birds, mammals, and fish. Estuaries provide nursery grounds for oceanic species (crab, salmon), are part of the migratory pathway for oceanic species.

**THREATS/STRESSORS**

The conceptual model diagram for this CE (Figure E-24) includes threats/stressors (change agents) and an illustration of how they produce stress on estuaries.

**Vulnerability to climate change:** The predicted changes of climate in the REA study area include increased precipitation, increased day time maximum and night time minimum temperatures, decreases in the winter snowpack, earlier spring snowmelt, longer growing season, increased evapotranspiration, decreased permafrost extent, increased soil active layer thickness, and earlier ice breakup and later freeze-up (Loya 2011, Schindler and Rogers 2009). Climate change may include changes to the amount and timing of freshwater inflows and sea-level rise which may shift the physical location of the estuary. Any human development along the shoreline and in nearshore waters is likely to decrease the resiliency of the estuary system to adapt to changes.

**Water pollution/contamination:** Inflow of polluted waters can have direct toxic damage to aquatic organism and degrade the quality of estuarine waters as chemical contamination at the fresh/salt water boundary affects physical state and chemical reactions of pollutants. Discharge from community wastewater treatment facilities is a potential source of water pollution in this ecoregion; even secondary and tertiary treatment regimes may not remove certain chemicals such as birth control hormones (Mairi 2009). Overland flow from paved roads, industrial sites (such as gravel mines or quarries, petroleum storage facilities), or airports can be sources of industrial chemicals (lead, cadmium, zinc), soil minerals, salts, and other chemicals. Such facilities are also generally associated with communities in the ecoregion.

**Increased human infrastructure:** The construction and maintenance of a deep water port or other harbor infrastructure is likely to have the most substantial impact on estuarine systems, resulting in direct degradation or destruction of estuarine habitat. Proposed additional roads or other infrastructure located near estuaries may also directly impact estuarine habitats. Because of their location in the stream network, estuaries are generally more likely to experience indirect effects from human activities (e.g., water quality issues from pollutant discharges upstream).

**Flow regimes** may be altered in streams, rivers, and connected lakes as a result of dams, road culverts, or other blockages. Where stream bed morphology has been significantly altered (i.e., incised and unstable) from historical, unremediated placer mines (Densmore and Karle 2009) within the stream network, this may also have altered flow regimes. As noted above, complex interactions of changes in climate (precipitation quantity, timing, type, etc.) and permafrost are also expected to significantly alter hydrologic regimes.

**Wildfire:** The results of the SNK REA indicate that the frequency of fire is likely to increase in some parts of the ecoregion (see discussion of fire in Future Conditions chapter of the SNK report). Wildfire can impact aquatic systems (whether hydrologically connected or disconnected) through a variety of complex interactions, such as increasing sedimentation due to vegetation removal and increasing peak flows due to lower evapotranspiration from loss of vegetation (Rieman and Clayton 1997). Wildfires also have the potential to increase permafrost melting by removing insulating vegetation, thereby increasing active layer depths post-fire (Yoshikawa et al. 2002), which can result in increased sediment inputs due to thermokarsting (Jorgensen and Osterkamp 2005). A large thaw slump on the Selawik River was observed in 2004 has increased sedimentation and may affect spawning sheefish habitat (Hander et al. 2008).

**Invasive species**: The impacts of invasive species on aquatic systems, such as streams, include displacement of native aquatic fauna and alteration of stream food webs (McClory and Gotthardt 2008). Non-native, invasive aquatic species have not been documented in this ecoregion as of this assessment. Aquatic invasive taxa currently known from Alaska as a whole (see McClory and Gotthardt 2008) include two invasive crayfish, *Procambarus clarkia* (red swamp crayfish; known from the Kenai Peninsula) and *Pacifastacus leniusculus* (signal crayfish; known from Kodiak Island), *Myxobolus cerebralis* (the whirling disease parasite; documented from the Anchorage Bowl) (McClory and Gotthardt 2008), *Gambusia affinis* (western mosquito fish; documented in Alaska, specific location unknown), and pondweed *Elodea canadensis* (documented from Fairbanks; Larson et al. 2010). A brief summary of potential impacts and modes of spread of the five species documented to date in Alaska is included in the non-native species section of the Future Conditions chapter of the SNK REA report.

**INDICATORS OF ECOLOGICAL STATUS**

The stressor-based indicators identified for this CE (Table E-26) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling

(e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5th-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-24. Estuary Conceptual Model/Diagram illustrating how change agents produce stress in estuaries, and what indicators can be measured to evaluate the level of stress and the ecological integrity of the estuaries.**

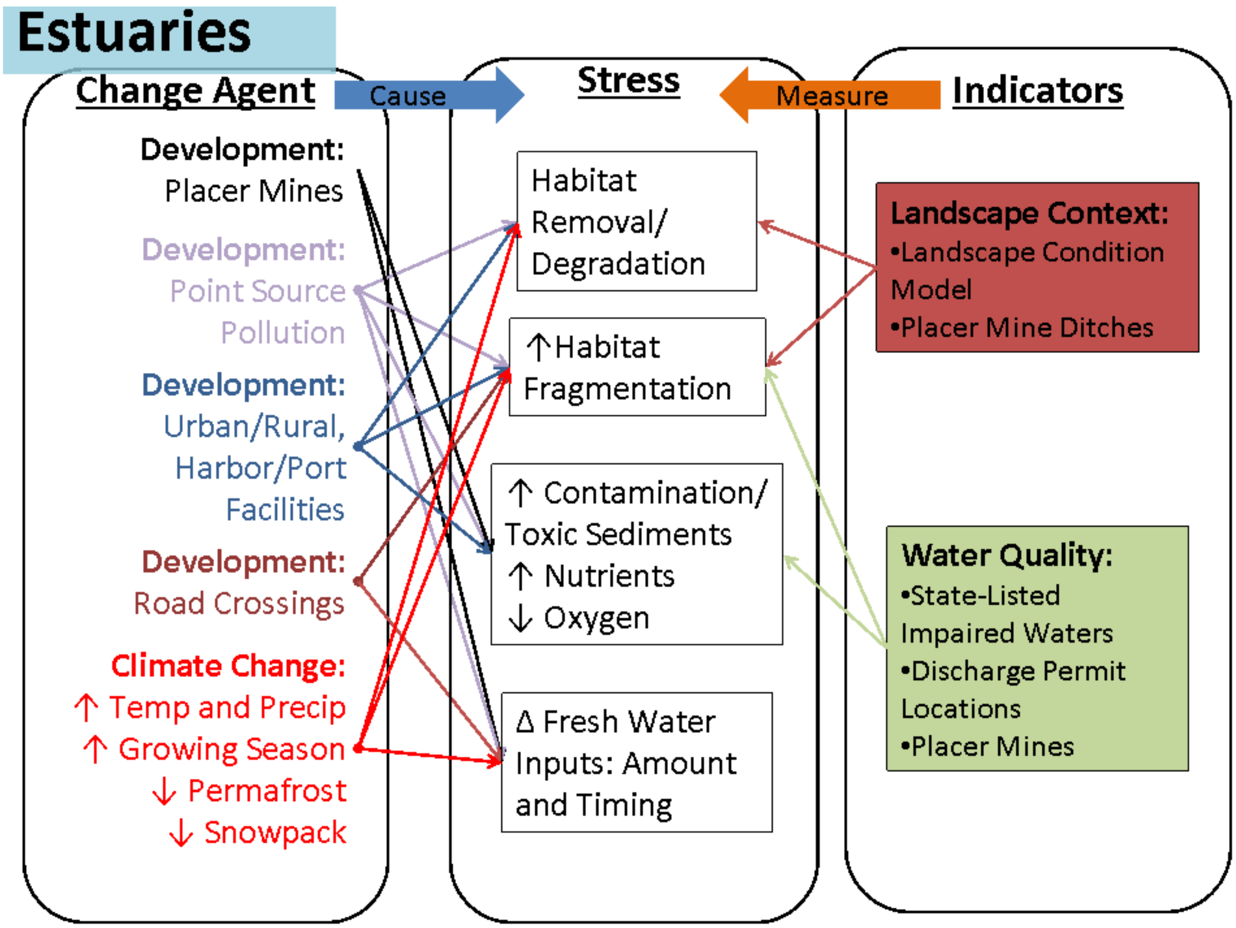

**Table E-26. Ecological status indicators for Estuaries.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |


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## E-2.6 Lakes – Large, Connected; Large, Disconnected; Small, Connected; and Small Disconnected

**DESCRIPTION**

Major lake districts identified by Arp and Jones (2008) in the REA study area include Beringia, Kobuk Delta, Selawik, and parts of the Yukon-Kuskokwim Delta and Koyukuk. The Beringia Lake District is located on the northern Seward Peninsula and includes the Bering Land Bridge National Preserve. Lake districts were defined as areas greater than 1,000 $km^2$ with lake density and lake area greater than the mean for Alaska. Smaller areas with abundant lakes in the REA study area include McCarthy's Marsh in the Fish River watershed, Death Valley in the Tubutulik River watershed; and the low-gradient river valleys associated with the Buckland, Kuzitrin, Fish, and Kobuk rivers (BLM 2006). These low-gradient areas with high lake densities separated by wetlands are the first areas to melt and warm in the springtime, providing important early season habitat for aquatic organisms (BLM 2006).

The distinction between "small" and "large" lakes was based on the definition used in Arp and Jones (2008); lakes less than 0.1 $km^2$ in areal extent were considered small, while those > 0.1 $km^2$ were classified as large. Lakes that intersected the streams dataset that was created to map the three stream CEs (headwater streams, low-gradient streams, and rivers) were classified as connected; lakes that did not intersect the streams dataset were classified as disconnected.

Large lakes connected to the stream network are more likely to be greater than two meters in depth. Their greater depth and perennial flow make it less likely that they freeze completely during winter, therefore providing important winter refuge for fish and other aquatic organisms. Very few lakes provide habitat for rearing juvenile sockeye salmon, whose distribution is limited in the REA study area. Connected lakes may also provide important habitat for northern pike, Alaska blackfish, and broad and humpback whitefish in the study area (Glesne 1986).

Lakes disconnected from the stream network may provide habitat for Alaska blackfish, but not for other fishes (Glesne 1986). Disconnected lakes are important for other aquatic organisms, such as macroinvertebrates, which are an important food resource for migrating bird populations. Small lakes also may be limited in their ability to support fish due to warm temperatures in the summertime leading to low dissolved oxygen and freezing throughout during the winter.

**ECOLOGICAL IMPORTANCE**

Fish species in the REA study area that utilize lakes at some point in their life history include sockeye salmon, Alaska blackfish, Arctic char, and several species of whitefish.

**THREATS/STRESSORS**

The conceptual model diagram for this CE (Figure E-25) includes threats/stressors (change agents) and an illustration of how they produce stress on lakes.

**Vulnerability to climate change**: Lakes are dependent on complex interactions with surface and ground water flow. Climate change is likely to alter, in complex ways, the hydrology of lakes. The predicted changes of climate in the REA study area include increased precipitation, increased day time maximum and night time minimum temperatures, decreases in the winter snowpack, earlier spring snowmelt, longer growing season, increased evapotranspiration, decreased permafrost extent, increased soil active layer thickness, and earlier ice breakup and later freeze-up (Loya 2011, Schindler and Rogers 2009). Climate change may increase the flow into connected lakes in the study area as precipitation increases in the wintertime. However, increased temperatures will increase evapotranspiration in the summertime, so the overall effect of climate change on discharge are difficult to predict (B. Bolton, pers. comm.). Due to thawing permafrost and increased active layer thickness, base flows will increase and peak flows will decrease due to a higher water-holding capacity in soils across the watershed (B. Bolton, pers. comm.). Lakes may drain entirely with permafrost melting, or lake levels may rise with increased inflow.

**Increased human infrastructure:** The building of additional roads or other infrastructure proposed in this ecoregion will result in direct degradation or destruction of lake CEs, as well as fragmentation. Draining and filling of lakes for the creation of roads and other infrastructure will disrupt lakes by reducing their size or eliminating them altogether and cutting off or otherwise altering their connectivity to other water bodies.

**Water pollution/contamination:** Inflow of polluted waters can have direct toxic damage to aquatic organism and degrade water quality of lake waters. Discharge from community wastewater treatment facilities is a potential source of water pollution in this ecoregion; even secondary and tertiary treatment regimes may not remove certain chemicals such as birth control hormones (Mairi 2009). Overland flow from paved roads, industrial sites (such as gravel mines or quarries, petroleum storage facilities), or airports can be sources of industrial chemicals (lead, cadmium, zinc), soil minerals, salts, and other chemicals. Such facilities are also generally associated with communities in the ecoregion.

**Flow regimes** may be altered in streams, rivers, and connected lakes as a result of dams, road culverts, or other blockages. Where stream bed morphology has been significantly altered (i.e., incised and unstable) from historical, unremediated placer mines (Densmore and Karle 2009) within the stream network, this may also have altered flow regimes. As noted above, complex interactions of changes in climate (precipitation quantity, timing, type, etc.) and permafrost are also expected to significantly alter hydrologic regimes.

**Wildfire:** The results of the SNK REA indicate that the frequency of fire is likely to increase in some parts of the ecoregion (see discussion of fire in Future Conditions chapter of the SNK report). Wildfire can impact aquatic systems (whether hydrologically connected or disconnected) through a variety of complex interactions, such as increasing sedimentation due to vegetation removal and increasing peak flows due to lower evapotranspiration from loss of vegetation (Rieman and Clayton 1997). Wildfires also have the potential to increase permafrost melting by removing insulating vegetation, thereby increasing active layer depths post-fire (Yoshikawa et al. 2002), which can result in increased sediment inputs due to thermokarsting (Jorgensen and Osterkamp 2005). A large thaw slump on the Selawik River was observed in 2004 has increased sedimentation and may affect spawning sheefish habitat (Hander et al. 2008).

**Invasive species**: The impacts of invasive species on aquatic systems, such as streams, include displacement of native aquatic fauna and alteration of stream food webs (McClory and Gotthardt 2008). Non-native, invasive aquatic species have not been documented in this ecoregion as of this assessment. Aquatic invasive taxa currently known from Alaska as a whole (see McClory and Gotthardt 2008) include two invasive crayfish, *Procambarus clarkia* (red swamp crayfish; known from the Kenai Peninsula) and *Pacifastacus leniusculus* (signal crayfish; known from Kodiak Island), *Myxobolus cerebralis* (the whirling disease parasite; documented from the Anchorage Bowl) (McClory and Gotthardt 2008), *Gambusia affinis* (western mosquito fish; documented in Alaska, specific location unknown), and pondweed *Elodea canadensis* (documented from Fairbanks; Larson et al. 2010). A brief summary of potential impacts and modes of spread of the five species documented to date in Alaska is included in the non-native species section of the Future Conditions chapter of the SNK REA report.

**INDICATORS OF ECOLOGICAL STATUS**

The stressor-based indicators identified for this CE (Table E-27) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling (e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5$^{th}$-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-25. Lakes Conceptual Model/Diagram illustrating how change agents produce stress on both connected and disconnected lakes, and what indicators can be measured to evaluate the level of stress and the ecological integrity of lakes.**

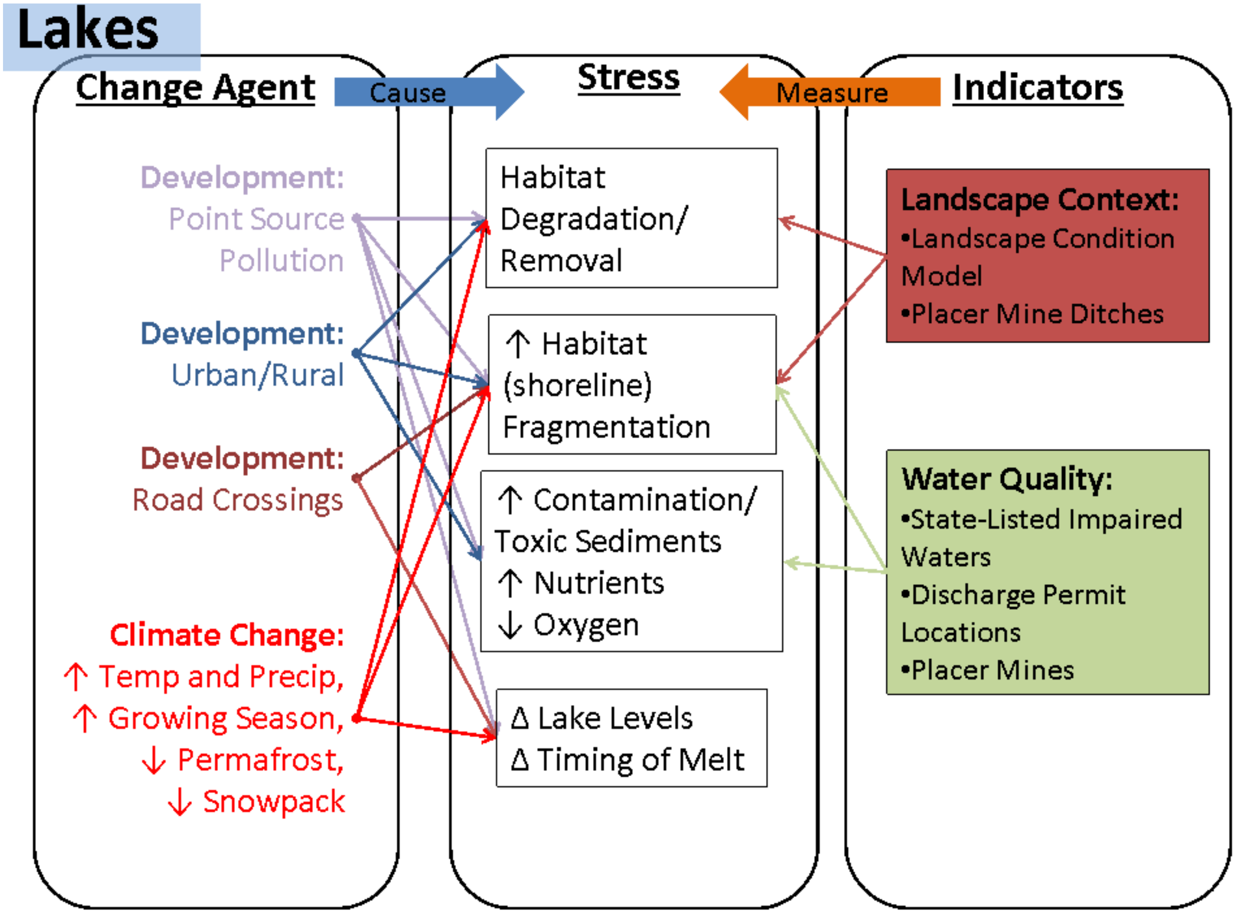


**Table E-27. Ecological status indicators for Lakes.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

## REFERENCES


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## E-2.7 Hot Springs

**DESCRIPTION AND DISTRIBUTION**

A total of ten hot springs were identified in the REA study area, six of which are found on the Seward Peninsula and another four in the Purcell Mountains along the eastern boundary of the REA study area. Temperatures reported by the Alaska Geophysical Data Center range from 20° - 81° C, with the two hottest being Serpentine and Pilgrim hot springs on the Seward Peninsula. Water chemistry of the hot springs on the Seward Peninsula indicates that their pH ranges from neutral to basic (6.75 – 10.14) (Miller 1973).

**ECOLOGICAL IMPORTANCE**

Hot springs may provide important winter refuge for aquatic organisms by maintaining open reaches in streams to which they connect, although no information on fish species associated with hot springs in Alaska is known.

**THREATS/STRESSORS**

The conceptual model diagram for this CE (Figure E-26) includes threats/stressors (change agents) and an illustration of how they produce stress on hot springs.

Direct threats to hot springs include development such as roads, infrastructure (helicopter pads, air strips, etc.), and indirect threats that may isolate a hot spring from its tributary stream.

**Vulnerability to climate change:** The predicted changes of climate in the REA study area include increased precipitation, increased day time maximum and night time minimum temperatures, decreases in the winter snowpack, earlier spring snowmelt, longer growing season, increased evapotranspiration, decreased permafrost extent, increased soil active layer thickness, and earlier ice breakup and later freeze-up (Loya 2011, Schindler and Rogers 2009). Climate change may alter the groundwater flow and even the direction of flow with melting of permafrost. How the groundwater interacts with surface water is a complex system of permeability. Changes in the depth of the active layer and the amount of permafrost will change groundwater dynamics.  Vulnerability of hot springs to these changes is currently unknown.

**INDICATORS OF ECOLOGICAL STATUS**

The stressor-based indicators identified for this CE (Table E-28) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling

(e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5th-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-26. Hot Springs Conceptual Model/Diagram illustrating how change agents produce stress on hot springs, and what indicators can be measured to evaluate the level of stress and the ecological integrity of hot springs. Given the hydrology of hot springs, it is unclear whether placer mines or pollution discharges may impact hydrology or water quality of hot springs. However, these indicators are retained here for reference.**

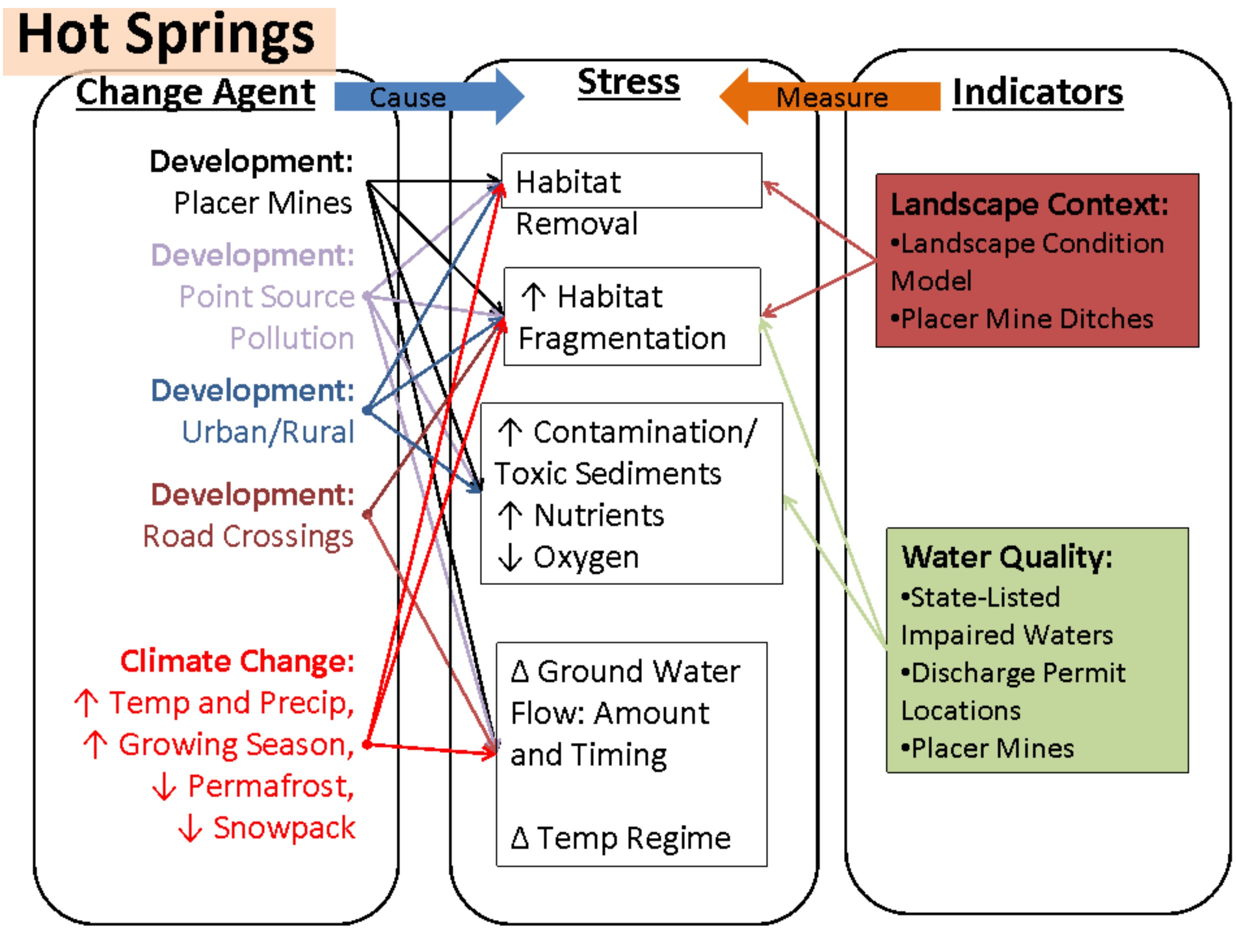

**Table E-28. Ecological status indicators for Hot Springs.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| **Landscape Condition Index** | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |
| **Index of Placer Mine Ditches** | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| **Index of Placer Mines** | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

**REFERENCES**


Densmore, R.V. and K.F. Karle. 2009. Flood effects on an Alaskan stream restoration project: the value of long-term monitoring. Journal of the American Water Resources Association 45: 1424-1433.

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Schindler, D.E. and L.A. Rogers. 2009. Responses of Pacific salmon populations to climate variation in freshwater ecosystems. American Fisheries Society Symposium 70: 1127-1142.

# E-3 Terrestrial Fine-Filter Landscape Species CEs

## E-3.1 Introduction

This section contains conceptual models – descriptive text and diagrams – for the fifteen terrestrial species conservation elements that were treated with a “landscape” approach in the SNK REA and have a spatial distribution model (Table E-29). The descriptive text includes information on the species’ taxonomy, geographic range, reproductive ecology, migration ecology, habitat, and threats/stressors. The primary purpose of these characterizations is to provide sufficient information on each species to permit the identification and characterization of assumptions about the likely effects of change agents (e.g., development, invasive species) on each species.

**Table E-29. Terrestrial fine-filter landscape species CEs for the SNK ecoregion. Subsistence species are italicized.**

| Taxonomic Group | Landscape Species |
| --- | --- |
| **Birds** | Arctic Peregrine Falcon |
| | Bar-tailed Godwit |
| | Black Scoter |
| | Bristle-thighed Curlew |
| | Common Eider |
| | King Eider |
| | Yellow-billed Loon |
| | *Cackling Goose* |
| **Mammals** | Alaskan Hare |
| | *Beaver* |
| | *Black Bear* |
| | *Brown Bear* |
| | *Moose* |
| | *Muskox* |
| | *Western Arctic Caribou* |

The descriptive information was used to identify a series of variables that can serve as indicators of the ecological integrity of each species. These indicators were used to assess the ecological status of each of these species. The conceptual model diagrams provided here illustrate our understanding of how change agents may stress the species and which of those individual stressors are expected to be reflected in the indicators of ecological integrity. The same set of indicators was identified for each of the fifteen landscape species, and the same relationships between indicators, individual stressors, and change agents are assumed.

The conceptual model diagrams illustrate our understanding of how change agents may stress the terrestrial fine-filter CEs and which of those individual stressors can be reflected in the indicators of ecological integrity. In addition to the understanding of a CE’s composition, structure, processes, and response to stressors, data availability also shaped the set of indicators that could practically be used to evaluate terrestrial fine-filter CEs. **Available data sets in the SNK ecoregion reflected ecosystem stressors**, rather than direct measures of ecological condition. The single indicator that could readily be assessed for individual terrestrial fine-filter CEs *emphasizes development-related ecosystem stressors*; this indicator is the landscape condition model or index. A spatial modeling approach was previously developed to evaluate this indicator for the ecological status assessments of terrestrial fine-filter CEs. The definition and justification for the single indicator is provided in paragraph form in each CE's conceptual model. The indicator is scored with values ranging from 0 to 1, with 1 indicating highest ecological status and 0 indicating lowest status (and presumably transitional to a wholly different ecological state).

The descriptive information was compiled from two major sources: the original descriptive text provided by the Alaska Natural Heritage Program for the SNK REA and species summaries generated from the program's Biotics database. Additional literature surveys were conducted by NatureServe to characterize threats and stressors for each species. This compiled information was used to develop the conceptual diagrams illustrating this information and associated assumptions.

The species information included in the AKNHP's documents was obtained from the Alaska Heritage Program's installation of Biotics, a biodiversity database developed centrally at NatureServe and maintained through the combined efforts of the member heritage programs and NatureServe. The member program biodiversity databases are coordinated with the central NatureServe database; these databases are dynamic, maintained and refined through updates made to reflect current changes to taxonomy, and by the periodic import of new records that are developed according to standard methodology by natural heritage member program scientists and other collaborators, including government agencies, universities, natural history museums and botanical gardens, and additional conservation organizations. This ongoing process of adding and revising information and records helps to maintain currentness and enhance completeness of the data.

NatureServe member programs' biodiversity databases contain an array of information about elements of biodiversity, with particular emphasis on those that are more threatened across their range. Tracked data includes taxonomy, conservation status, ecological and life history, habitat requirements, and distribution, with primary sources of this information consisting of scientific literature, museum specimen records, reliably documented observation records, species lists, range maps, external databases, and experts, including scientists from natural heritage member programs. While centrally NatureServe maintains range maps and/or data representing all native full species vertebrates and vascular plants, within individual member programs resources generally limit the tracking of specific locations of species and other elements of biodiversity within their jurisdictions to those having the highest conservation concern.

## E-3.2 Arctic Peregrine Falcon (*Falco peregrinus tundrius*)

**Classification/Taxonomic Information:** The Arctic peregrine falcon (*Falco peregrinus tundrius*) is one of three subspecies of peregrine falcon. Plumage is paler than that of other North American subspecies. It nests in tundra regions of Alaska and northern Canada, and the ice-free perimeter of Greenland (USFWS 1993). It is a long-distance migrant that winters in the Caribbean and Central and South America (USFWS 1993).

**Geography/Location:** Considered a rare migrant and breeder on the Seward Peninsula, where it is usually associated with coastal seabird colonies and block-field habitats (Kessel 1989).

**Life History & Ecology:** Arctic peregrine falcon is a medium-sized falcon with long pointed wings, a dark crown and nape, and a dark wedge extending below the eye; forehead is pale in immatures, which are mainly brownish above rather than black/gray as in adults (NGS 1983). It is a long distance migrant. It is a diurnal carnivore that preys almost exclusively on medium-sized birds such as waterfowl, but will occasionally hunt small mammals (especially bats), small reptiles, or even insects.

Birds reach sexual maturity at one year, and mate for life and nest in a scrape or shallow depression, normally on cliff edges. Generally three to four eggs are laid in the scrape. They are incubated for 29 to 33 days, mainly by the female. Chicks fledge 42 to 46 days after hatching, and remain dependent on their parents for up to two months

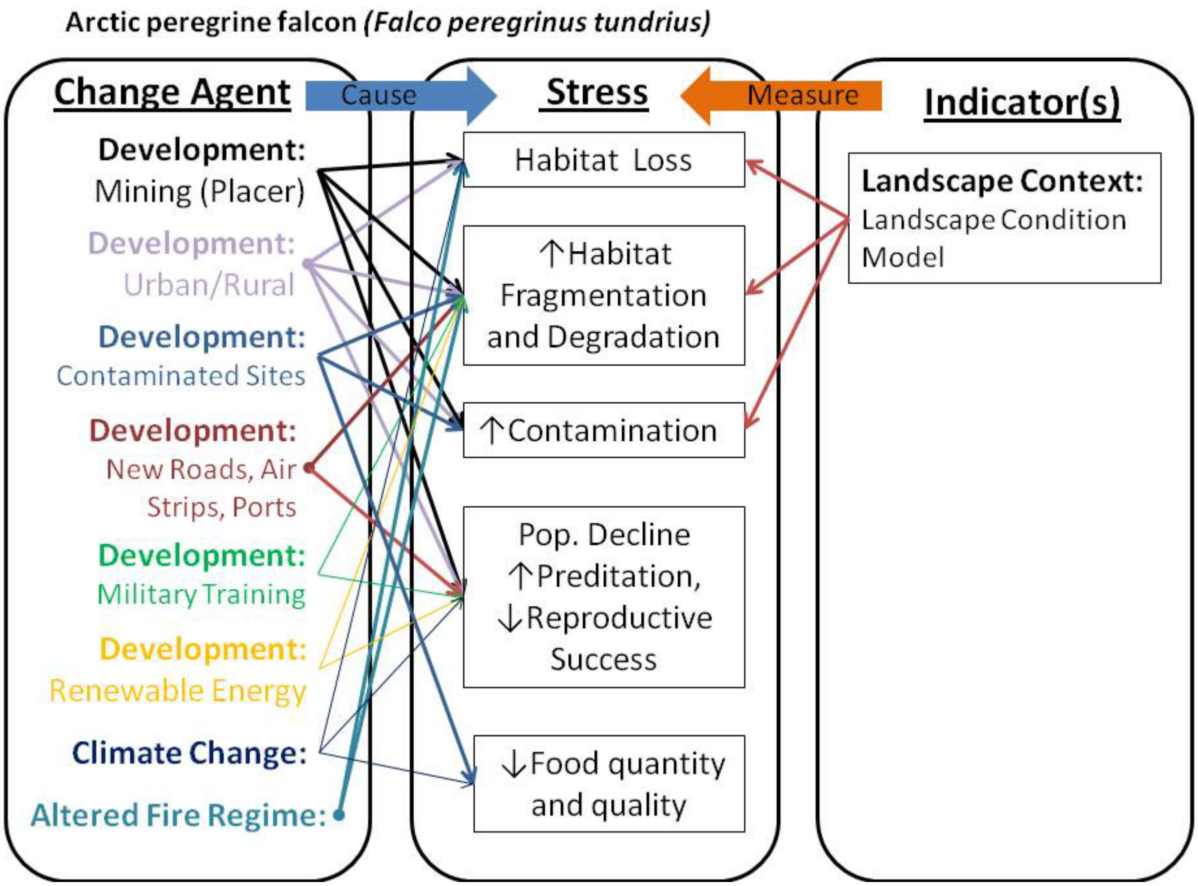
Habitats include bay/sound, herbaceous wetland, lagoon, river mouth/tidal river, tidal flat/shore, bare rock/talus/scree, cliff, tundra (NatureServe 2012). More information is needed on habitat condition, especially to determine if there are changes in food availability on wintering grounds and along migration routes.

**Migration Ecology:** It breeds across North American tundra from northern Alaska east across northern Canada to the ice-free perimeter of Greenland. It is a long-distance migrant that winters in Latin America from Cuba and Mexico south through Central and South America (Palmer 1988, USFWS 1993).

**Habitat Description:** Peregrine nesting habitat, in general, usually occurs on gentle open slopes to low embankments, low or high rock outcrops, or tall sheer cliffs. It nests near rivers and lakes (Wheeler 2003, Ritchie et al. 2004). It uses tussock-heath tundra with lakes and sedge grass marshes and riparian areas for foraging (White and Nelson 1991).

**Threats/Stressors:** Habitat loss, human disturbance, pesticide poisoning on the wintering grounds, and illegal take may all affect the recovery of this subspecies. However, while the rate of habitat modification in nesting, migration, and wintering areas is increasing, the numbers of Arctic peregrines nearly tripled between the mid-1970s and early 1990s. This suggests that habitat modification does not currently threaten the continued existence of the subspecies (USFWS 1993). Although DDT and associated organochlorine pesticides were banned in the United States and Canada in the early 1970s, such chemicals are still in use in Latin America where the birds winter. Records of egg shell contamination, however, have shown a steady decline in the amount of pesticide residue found in the shells. The levels now appear to be below that which affects productivity (USFWS 1993). Illegal take (including egg collecting, shooting, and harvest for falconry) can occur, but these activities are so regulated by federal and international laws that they are not considered to have a significant effect on the reproductive success of the subspecies.

**Figure E-27. Arctic peregrine falcon Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for *individual CEs* were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.3 Bar-tailed Godwit *(Limosa lapponica)*

**Classification/Taxonomic Information:** The Bar-tailed Godwit *(Limosa lapponica)* is a widespread migrating shorebird protected under the Migratory Bird Treaty Act. No taxonomic issues.

**Geography/Location:** The Bar-tailed Godwit is a common summer visitant and common breeder on the Seward Peninsula (Kessel 1989). Global breeding range is just inland from the coasts across northern and western Alaska (east to Sagavanirktok River), northern Scandinavia, across northern Russia and northern Siberia to Chukotski Peninsula and northern Anadyrland. Global non-breeding range includes Eurasia, Africa, Indian Ocean islands, southeastern Asia, Indonesia, Australia, New Zealand (AOU 1983, Johnson and Herter 1989).

**Life History & Ecology:** This species is a long-distance migrant and breeds in solitary pairs, although it may also form small colonies (del Hoyo *et al.* 1996 as cited in BI 2012a). Adults disperse after breeding to coastal moulting sites, the onward migration to wintering grounds then continuing in fall. The species often flies in large flocks and forages in groups outside of the breeding season (del Hoyo *et al.* 1996 as cited in BI 2012a), occasionally aggregating into huge flocks on preferred sites. When breeding the species feeds on insects, annelid worms, mollusks and occasionally seeds and berries (del Hoyo *et al.* 1996 as cited in BI 2012a).

*Non-breeding:* In intertidal areas, this species' diet consists of annelids (e.g. *Nereis* spp. and *Arenicola* spp.), bivalves, and crustaceans, although it will also take cranefly larvae and earthworms on grasslands and occasionally larval amphibians (tadpoles) and small fish (del Hoyo *et al.* 1996 as cited in BI 2012a). The nest is a simple depression in dry, elevated upland site such as tundra ridge or hummock. In Europe, apparently seeks nest protection by breeding near nesting Whimbrels (*Numenius phaeopus*), which are more actively defensive against predators (Larsen and Moldsvor 1992).

**Migration Ecology:** The Bar-tailed Godwit is long distance migrant. Nesting birds from Alaska probably winter in southeastern Asia and on South Pacific islands (Johnson and Herter 1989). Adults begin fall migration before juveniles, which usually depart nesting areas shortly after mid-August. Migration path is through Hawaiian, Aleutian, and Pribilof Islands, along Bering Sea coast of Alaska Peninsula, through Europe and Pacific (AOU 1983). Lagoons along north shore of Alaska Peninsula are important fall staging areas (Johnson and Herter 1989).

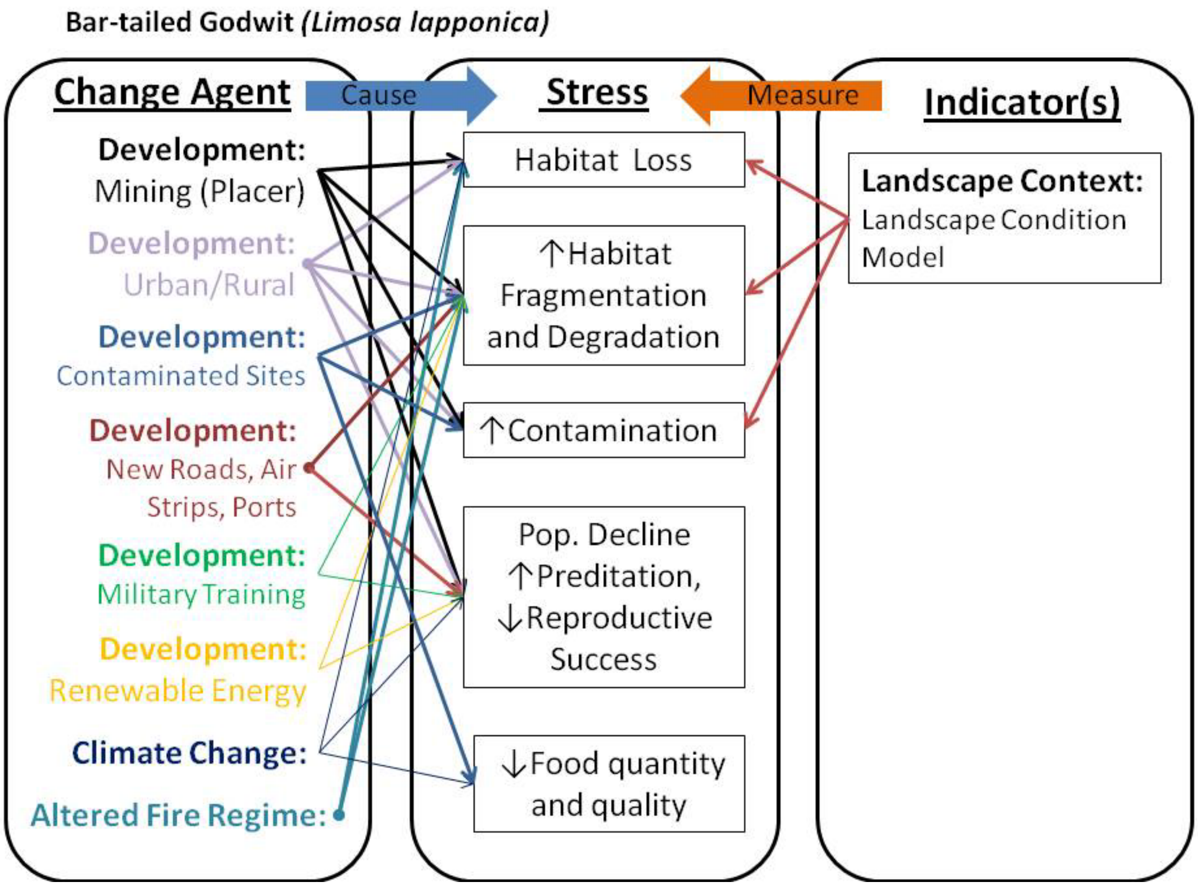
**Habitat Description:** The Bar-tailed Godwit is a common summer visitant and common breeder on the Seward Peninsula (Kessel 1989). Breeds on coastal tundra and sedge-dwarf shrub tundra of foothills from the sub-Arctic to Arctic. Breeding sites on the Seward Peninsula are widespread throughout the southern and northern uplands, west of tree line (Kessel 1989). Preferred breeding habitat is wet sedge meadows with hummocks covered by dwarf shrubs and moss and gently sloping dwarf shrub and graminoid meadows. These slopes are often shared with breeding Whimbrels (*Numenius phaeopus*) (Kessel 1989).

Breeders are rare on flat, wetter lowlands, although some nest on mesic sites along the inner sides of coastal lagoons or basins, such as Lopp Lagoon, Safety Sound Flats and Imuruk Basin. They are also known to use the flats along lower river courses, such as the Shishmaref and Arctic rivers and also at McCarthy's Marsh (Kessel 1989).

Throughout the summer, non- and post-breeding birds aggregate along protected coastal lowlands, especially river estuaries where rivers form deltas in lagoons (Kessel 1989). Known concentration areas on the Seward Peninsula include: Buckland and Nugnugaluktuk river estuaries, at the mouths of the Serpentine and Arctic rivers, on the mud flats at the northeast end of Lopp Lagoon and the mouth of the Kuzitirn River in Imuruk Basin. Also occur at the drained lagoon east of the mouth of the Sinuk River, and the mud flats at Safety Sound. During spring and fall, inhabits intertidal mudflats, sand flats near river mouths, along bays and shorelines, on offshore shoals, and in estuaries.

**Threats/Stressors:** This long distance migrant is threatened by the degradation of wetland foraging sites along migration routes from land reclamation, pollution, human disturbance (del Hoyo *et al.* 1996, Kelin and Qiang 2006 as cited in BI 2012a), reduced river flows (Kelin and Qiang 2006) and loss of feeding habitat from the invasion of mudflats and coastal salt marshes by mangroves. The species may be threatened by future outbreaks of avian influenza (Melville and Shortridge (2006 as cited in BI 2012a).

**Figure E 28. Bar-tailed Godwit Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for *individual CEs* were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.4 Black Scoter (*Melanitta americana*)

**Classification/Taxonomic Information:** Black Scoter (*Melanitta americana)* was formerly treated as conspecific with *M. nigra* (Linnaeus, 1758) [Black Scoter] of Eurasia, but separated on the basis of courtship calls (Sangster 2009) and color, form, and feathering of the bill in adult males and most adult females (Collinson et al. 2006) (AOU 2010). It is a widespread migrating shorebird protected under the Migratory Bird Treaty Act. No taxonomic issues.

**Geography/Location:** On the Seward Peninsula, the Black Scoter is a fairly common breeder that is widely distributed throughout the area (Kessel 1989). Global breeding range in North America includes western and southern Alaska, Aleutians, scattered areas in central and eastern Canada, including southern Keewatin, northern Quebec, and Newfoundland. Also found (and may breed) from southern Yukon and Mackenzie east to Labrador and Newfoundland. In Eurasia it ranges from Iceland, British Isles, Spitsbergen, and Scandinavia east across Russia and Siberia to Anadyrland, Sakhalin, and Kamchatka.

Global non-breeding range in North America includes Pacific coast from Pribilofs and Aleutians to southern California, Great Lakes, Atlantic coast from Newfoundland to South Carolina, Florida. In Eurasia it ranges from breeding grounds south to Mediterranean Sea, Korea, eastern China, and Japan. It is accidental in Hawaii (Midway) and in North America to Gulf Coast (AOU 1983). In the U.S. and southern Canada, areas of winter abundance include coastal areas of southern New Jersey, South Carolina, British Columbia, and Washington (Root 1988). In the early 1990s, USFWS Winter Sea Duck Survey in eastern North America found the highest densities of scoters (all species) in Virginia, New York, Maine, and Massachusetts (descending order of abundance, Kehoe 1994).

**Life History & Ecology:** Black Scoter (*Melanitta americana)* is a long distance migrant. It nests near lakes and pools on grassy or brushy tundra and in northern taiga (AOU 1983). On the Yukon-Kuskokwim Delta, Alaska, Black Scoters use disturbed areas such as river banks and sloughs, preferring areas of tall grass to conceal nests (C.P. Dau per. comm. in Bordage and Savard 1995).

Information in not available in Seward Peninsula, but in northern Quebec, egg laying began in the first week of June; hatching occurred in the second and third weeks of July (Savard and Lamothe 1991, Can. Field-Nat. 105:488-496). Clutch size is 5-8 (often 8). Incubation lasts 27-28 days (Terres 1980). Young are tended by female, independent in 6-7 weeks (Harrison 1978).

Except in inland habitats, mollusks comprise a majority of the diet; the blue mussel (*Mytilus edulis*) often is a major food (Bellrose 1976). Also eats crustaceans, some fishes and plant foods, the latter being most important in inland habitats. Usually feeds in protected areas where water is no more than 25 ft deep.

**Migration Ecology:** Migrates northward March-May, southward September-October. Atlantic Flyway wintering population is thought to come from Labrador and the west coast of Hudson Bay (Kehoe 1994).

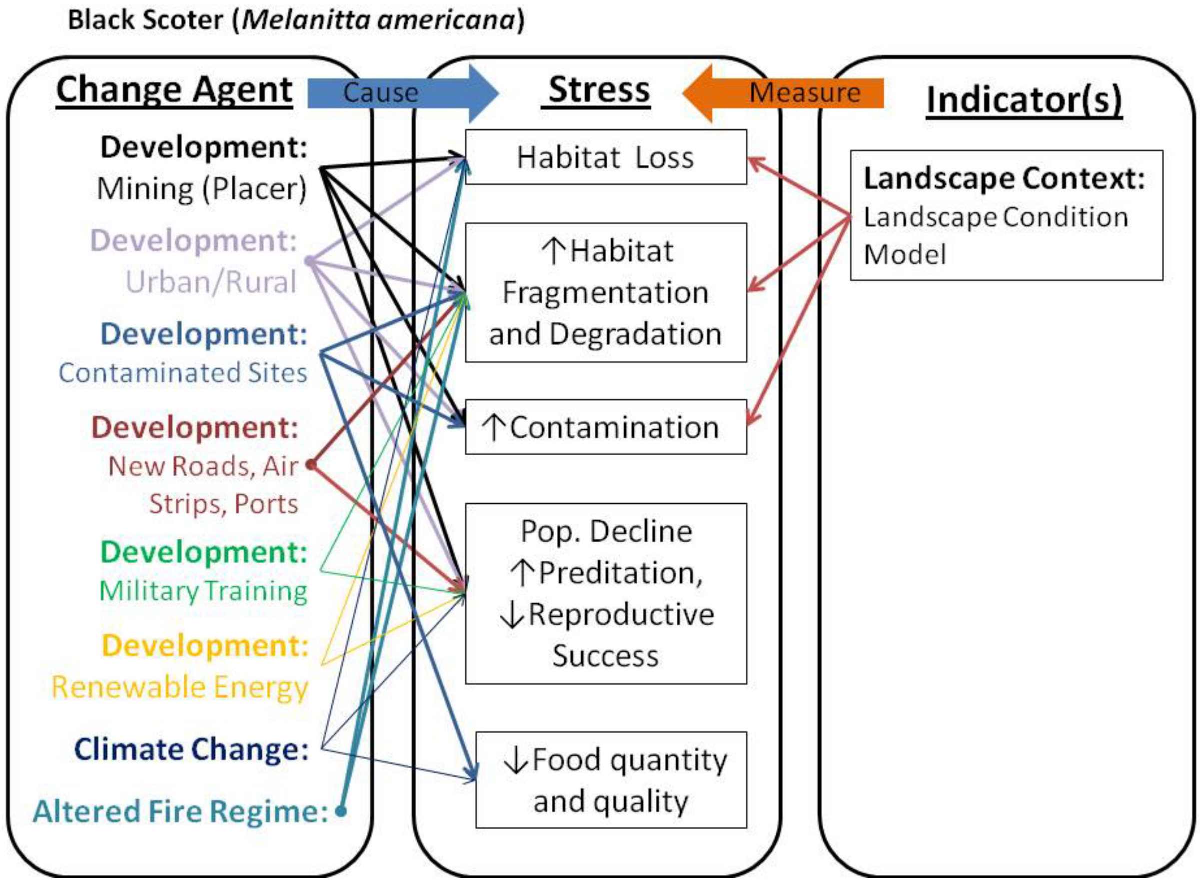
**Habitat Description:** Preferred breeding habitat is near ponds where coastal lowlands adjoin upland habitats. Species is commonly found using pond areas above the estuaries of large rivers such as the Buckland, Serpentine, Arctic, Kuzitrin, Flambeau and Fish, and is generally absent from lowland areas such as Cape Espenberg and Lopp Lagoon (Kessel 1989). Non-breeders utilize coastal inshore waters.

Winter habitat requirements are poorly understood. Black Scoters prefer areas with gravel and cobble substrates, similar to areas favored by Harlequin Ducks (*Histrionicus histrionicus*) (Bordage and Savard 1995). Palmer (1976) stated that among scoters, the Black Scoter is most likely to occur in exposed areas and on open water rather than seek shelter in a bay or calmer water.

**Threats/Stressors:** According to Sea Duck Joint Venture (2003), this species is thought to be declining in western Alaska and to be stable on the Arctic coastal plain. Numbers also appear to be declining in the Atlantic flyway, whereas no statistically significant population trend is apparent in the results of a fixed-wing aerial survey covering the Atlantic coast for the period 1991-1999 (SDJV 2003).

No specific threats were identified, but as a long distance migrant, it is likely impacted by the degradation of wetland foraging sites along migration routes.

**Figure E-28. Black Scoter Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for *individual CEs* were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.5 Bristle-thighed Curlew (*Numenius tahitiensis*)

**Classification/Taxonomic Information:** Bristle-thighed Curlew *(Numenius tahitiensis)* is the current name (AOU 1998). Whimbrel (*Numenius phaeopus*) is generally accepted as the closest relative of *N. tahitiensis* (Marks et al. 2002). Differs from the whimbrel (*Numenius phaeopus*) in being tawnier and by having a tawny unbarred rump, less streaking on the breast, and a paler bill. Bill is much shorter than that of long-billed (*Numenius americanus*) and far eastern curlews (*Numenius madagascariensis*), longer, thicker, and more curved than in Eskimo curlew (*Numenius borealis*; which averages 7 cm shorter).

It is a migrating shorebird protected under the Migratory Bird Treaty Act.

**Geography/Location:** Bristle-thighed Curlew *(Numenius tahitiensis)* breeding range encompasses remote mountainous regions of western Alaska in the Andreafsky Wilderness Area north of the Yukon River mouth and on the central Seward Peninsula (McCaffery and Peltola 1986, Kessel 1989, Gill et al. 1990, Marks et al. 2002). Non-breeding individuals occur in summer on coastal tundra from Kotzebue Sound south to Hooper Bay and occasionally in the Hawaiian Islands (AOU 1998).

Critical migration staging areas in Alaska include the coastal portions of the central and southern Yukon-Kuskokwim River Delta. The only currently known critical stopover site south of Alaska is the Northwestern Hawaiian Islands. Other possible migration stopover areas include the southern Line Islands, and the Phoenix, or Marshall Island groups (Palmisano 1993).

During the non-breeding season, this species occurs on Pacific Ocean islands and atolls from the Hawaiian (most commonly from Midway east to French Frigate Shoals) and Marshall islands south to the Fiji, Tonga, Samoa, Marquesas, and Tuamotu islands (Gill and Redmond 1992, AOU 1998, Marks et al. 2002). Bristle-thighed curlew is unique among migratory shorebirds in wintering on remote islands (Marks et al. 1990). Subadults may remain in the Pacific until they are nearly 3 years old (Collar et al. 1992).

**Life History & Ecology:** Bristle-thighed Curlew *(Numenius tahitiensis)* is a long distance migrant. Spring migrants usually arrive singly or in groups of two, occasionally in flocks. Males often precede mates by 1-6 days. Females rarely observed before mates in same year. Nest building begins within 1-3 days of arrival. At Nulato Hills (1987-1991), most nests initiated during last two weeks of May with successful nests hatching from 15-30 June. At Neva Creek, median clutch initiation was 24-31 May, about two weeks after arrival of females. Late clutches (initiated 9-18 June) attributed to late arriving females rather than renesting attempts. Median hatching dates 22-28 June with only a few nests hatching in July. Between 95-100% of pairs hatched nests within 8-10 days in two early years and 21-22 days in one late year at Neva Creek. A second brood per season is not known to occur (Marks et al. 2002).

Clutch size is typically four eggs (Kyllingstad 1948, McCaffery and Peltola 1986) which are incubated by both sexes for 24-25 days (McCaffery and Gill 1992). In the Nulato Hills of the Yukon Delta National Wildlife Refuge, 80 percent of nests beneath tundra willows hatched, whereas only about 33 percent of nests in the open were successful. Curlew nests constructed near nest sites of aggressively defensive Long-tailed Jaegers (*Stercorarius longicaudus*) were more successful than those in more isolated areas (McCaffery and Gill 1992). Seven of 9 nests examined by McCaffery and Peltola (1987) in the Nulato Hills were lost to predation.

Chicks are precocial and leave the nest within 12 hours of hatching. Young can fly when 21-24 days old (Lanctot et al. 1995). When they are 1-4 weeks old, juveniles congregate in brood aggregations (Lanctot et al. 1995). These groups typically remain intact until juveniles depart for staging areas in early August. Brood aggregations generally consist of fewer than 20 juveniles, but can contain up to 30 (McCaffery and Gill 1992, Lanctot et al. 1995). Brood groups studied by Gill et al. (1990) contained an average of 6.5 young (range = 1-12) from a minimum of 1-3 different broods. However, aggregations can include young from as many as 10 broods (Lanctot et al. 1995). Brood aggregations are tended by up to 14 parent birds, sometimes even if the aggregation does not contain any of their own young (Gill et al. 1990, McCaffery and Gill 1992, Lanctot et al. 1995). Brood aggregations move up to two kilometers per day (McCaffery and Gill 1992). Males attend aggregations 10-14 days longer than females (Gill et al. 1990). Brood aggregations often include young of other birds such as Bar-tailed Godwit (*Limosa lapponica*), American Golden-Plover (*Pluvialis dominica*), Pacific Golden-Plover (*Pluvialis fulva*), Whimbrel, Long-tailed Jaeger, and Western Sandpiper (*Calidris mauri*) (Lanctot et al. 1995). Curlews become reproductively mature in their third year (Marks 1993).

Breeding territories encompass approximately 0.5-1.5 square kilometers (Gill et al. 1990) and average densities range from 0.45 birds per square kilometer in early July to 0.04 birds per square kilometer in late July (Gill and Handel 1987). Territory size varies with topography, particularly configuration of drainages, and is smaller for southern population (40-100 ha in Nulato Hills) than for northern population (150-275 ha at Neva Creek). During incubation, adults at Neva Creek regularly travel from nesting territories to communal feeding and roosting areas up to 7 km away. Adults with broods move away from nesting sites, traveling on average 0.3-1.0 km in first week, 0.5-1.6 km (up to 4.4 km) in second and third weeks, and 0.6-1.0 km (up to 2.6 km) in fourth and fifth weeks (Lanctot et al.1995).

On staging grounds, gathers in communal nocturnal roosts (in shallow water ponds) of up to approximately 120 individuals (Tibbitts 1990). The average diurnal flock size on the staging grounds is 3.1 birds (range 1-33) (Handel and Dau 1988). Flock size in non-breeding habitat ranges from a few to more than 100 individuals (Pratt et al. 1987). While on the Pacific islands, many birds lose so many primaries and secondaries during molt that they become flightless for about two weeks; during molt, birds are extremely secretive by day, hiding in dense vegetation (Marks 1993). Adults molt from July through December and juveniles throughout the year (Marks et al. 1990, Marks 1993). Estimated annual survivorship for wintering birds is 80-90% (Marks 1992). The oldest known individual was one killed on Laysan Island that had been banded 23 years, 10 months earlier (Marks 1992).

Potential predators on the breeding grounds include Golden Eagles (*Aquila chrysaetos*), Rough-legged Hawks (*Buteo lagopus*), Northern Harriers (*Circus cyaneus*), Merlins (*Falco columbarius*), Short-eared Owls (*Asio flammeus*), Long-tailed Jaegers, Short-tailed Weasels (*Mustela erminea*), red foxes, and brown bears (*Ursus arctos*; McCaffery 1990b, Lanctot et al. 1995). On breeding grounds, known predators of adults include Gyrfalcon (*Falco rusticolus*); of eggs, Parasitic Jaeger (*Stercorarius parasiticus*) and Common Raven (*Corvus corax*); and of chicks, red fox (*Vulpes vulpes*), Northern Harrier (*Circus cyaneus*), Gyrfalcon (*Falco rusticolis*), Sandhill Crane (*Grus canadensis*), and Long-tailed Jaeger (McCaffery 1990b, Lanctot et al. 1995, Marks et al. 2002)

Forms temporary associations with American and Pacific Golden-Plover (*Pluvialis dominica* and *P. fulva*), Whimbrel, Bar-tailed Godwit, Western Sandpiper and Long-tailed Skua (*Stercorarius longicaudus*). Curlews and other larger-bodied species commonly attack-mobbed predators together, whereas smaller-bodied species generally give alarm calls and circle predators (Lanctot et al.1995).

**Migration Ecology:** Flies at least 4,000 km nonstop between Alaska and the northern end of the non-breeding range in the northwestern Hawaiian Islands. Apparently most curlews residing in the Central and South Pacific fly over Hawaii during northward and southward migrations, undertaking nonstop flights of more than 6,000 kilometers twice each year (one of the longest nonstop flights known for any bird) (Marks et al. 2002). Birds departing the Laysan Islands leave in small flocks (1-22 individuals, mean = 10.7), 25 percent of which are in the company of Pacific Golden-Plovers. Most birds that remain year-round on the Pacific islands are subadults (Marks and Redmond 1994b).

Most northbound migrants arrive at breeding areas in Alaska during first three weeks of May. At Mountain Village, Alaska, the southern end of breeding range, first birds seen 9-18 May from 1944-1947. More recently, first arrivals 3-6 May 1988-1991 in Nulato Hills, 32 km north of Mountain Village, and 8-18 May 1990-1992 at Neva Creek, suggesting earlier arrival for southern population (Marks et al. 2002).

From June-August, gathers on the coastal lowlands of the Seward Peninsula, the coastal fringe of the Yukon-Kuskokwim Delta and the Nushagak Peninsula of Bristol Bay, Alaska, prior to southward migration over ocean (R. Gill, pers. comm. 1998). Birds spend from a few weeks to two months on the staging grounds (Handel and Dau 1988, Gill 1998). Limited information suggests length of stay on Yukon Delta staging area is 2-3 weeks, where birds fatten on fruits that provide energy to fuel southward migration. Juveniles head for staging grounds slightly after adults and leave Alaska from mid-August to early September, unaccompanied by their parents (Marks et al. 2002).

**Habitat Description:** The Bristle-thighed Curlew breeds in the low, mountainous regions northeast of the lower Yukon River (Nulato Hills) and uplands of the Seward Peninsula, Alaska (Handel and Dau 1988, Marks et al. 2002). Physiography is markedly different between the Seward Peninsula and Nulato Hills, the latter characterized by lower relief, gentler slopes, more complex drainage patterns, and smaller areas of specific habitats (Marks et al. 2002). Breeding habitat encompasses a mosaic of sub-Arctic and Arctic tundra, including low shrub/tussock, mixed shrub thicket/tundra, and shrub meadow. Sedge and lichen meadows are also important.

Habitat use changes throughout the breeding season. Pre-nesting curlews tend to be found primarily in shrub meadow/tundra (33%) and low shrub/tussock (47%). During nesting, birds shift their activities to mostly shrub meadow/tundra and during brood rearing, adults attending young increase their use of sedge meadows. Younger broods tend to use habitats with a moderate level of tussocks and shrub cover. After fledging, they prefer sedge and lichen meadows. Staging habitats include sedge and graminoid meadows and upland tundra.

**Threats/Stressors:** Bristle-thighed Curlew *(Numenius tahitiensis)* has a low population size. Breeding population consists of only 3,200 pairs in small areas in Alaska; trend is unknown; wintering populations may be threatened by significant habitat loss, predation, and disturbance (NatureServe 2012).

*Breeding:* Apparently no immediate anthropogenic threats exist in breeding habitat (Gill and Handel 1987, Marks et al. 2002). However, resurgence in gold mining on the Seward Peninsula could potentially affect habitat. Travel across the tundra in heavy machinery by mining personnel can lead to localized habitat damage (Lanctot 1990). Oil/mineral exploration is presently not a serious threat due to the financially important Bering Sea fisheries resource; however, oil/mineral exploration may one day replace fisheries as the most economically important commodity in the region (R. Gill, pers. comm. 1998).

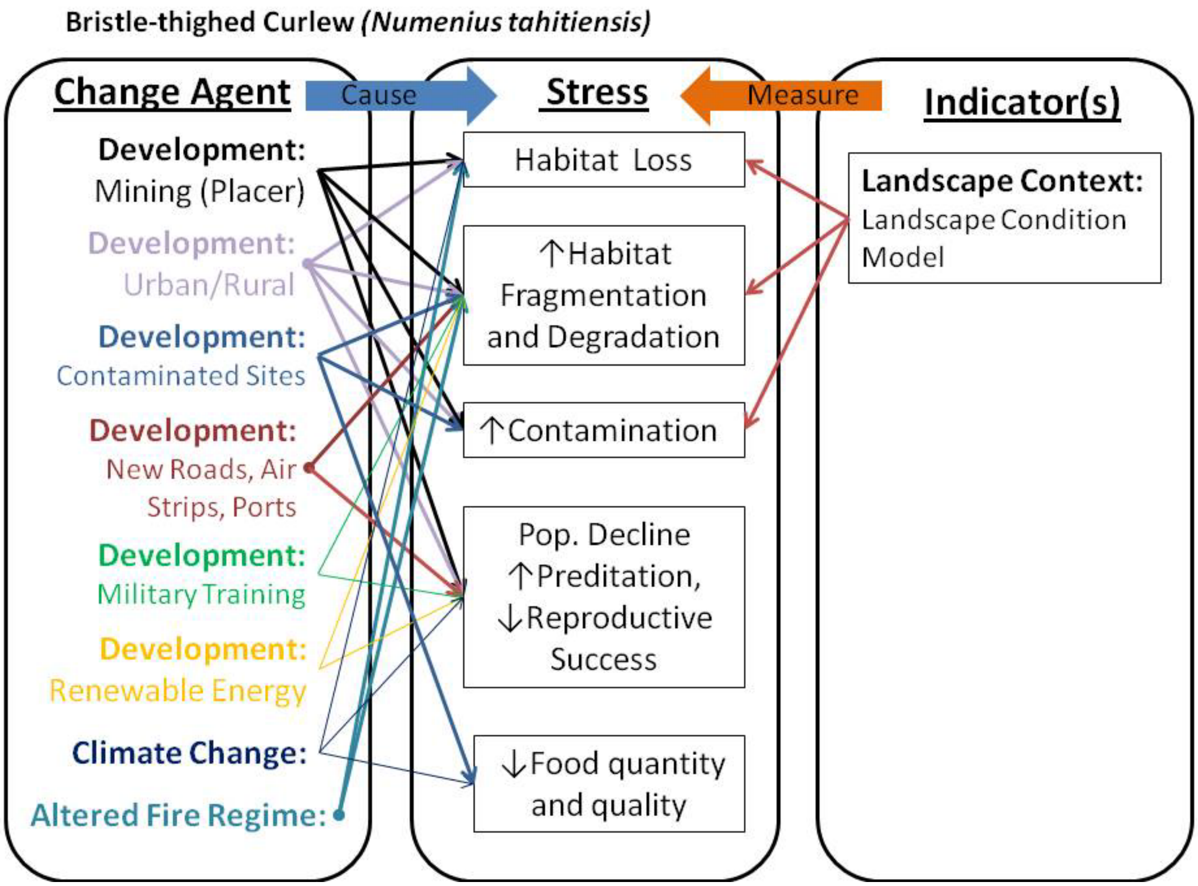
Open dumps in villages near the Yukon-Kuskokwim Delta have resulted in an unnaturally high population of Common Ravens, known predators of curlew eggs and chicks. However, predation is not known to be a significant threat.

*Staging:* Subsistence hunting may pose a threat to birds on the Yukon-Kuskokwim Delta. Hunter surveys indicate a substantial increase in the take of large shorebirds by Native Americans. Because hunter survey forms do not distinguish between curlews, whimbrels, and Bar-tailed Godwits, the extent of curlew harvest is unknown, but estimated from 2002 reports to be between 90 and 100 birds (*fide* B. McCaffery in R. Gill, pers. comm. 2004. NatureServe 2012).

*Non-breeding:* Potential threats include predation by a variety of introduced species, including rats (*Rattus* spp.), mongoose (*Herpestes auropunctatus*), feral pigs (*Sus scrofa*), dogs (*Canis familiaris*), and cats (*Felis catus*). They are most susceptible to predation during molting period when wintering curlews are flightless and are very vulnerable to predation and disturbance from a variety of introduced human commensal animals (cats, dogs, pigs) (Marks et al. 1990, Palmisano 1993) and are readily captured at this time by human subsistence hunters (Marks et al. 1990, Marks and Redmond 1994a). However, the degree of predation and its impact on the population are not known. Subsistence harvest is believed to be much lower now than in the past (see Marks et al. 2002). The presence of curlews on atolls in the Tuamotu Archipelago suggests they are resilient to the occurrence of Pacific rats and to the alteration of native habitats. However, lack of data on their historic numbers at these sites makes it difficult to assess the full affect of altered conditions (Tibbitts et al. 2003). Birds are also hunted and captured on steel hooks baited with pieces of coconut (*Cocos nucifera*; Gill 1998). Habitat is being lost to development of tourist facilities (Marks and Redmond 1994a), and some habitat has been degraded by introduced mammals.

Residents of Rangiroa Atoll in the Tuamotu Archipelago of French Polynesia have indicated that the population has declined in recent years (Gill and Redmond 1992). Fossil evidence suggests that the birds were once common among the main Hawaiian Islands, yet today they are uncommon during migration and rarely overwinter (Marks and Redmond 1994a). It is unclear, however, whether these observations (and other data for localized areas) represent population declines or shifts in island use (Marks et al. 2002).

**Figure E-29. Bristle-thighed Curlew Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for *individual CEs* were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.6 Common Eider (*Somateria mollissima*)

**Classification/Taxonomic Information:** Common Eider (*Somateria mollissima)* contains two groups: *Somateria mollissima mollissima* of north Atlantic and western Europe and *S. mollissima v-nigrum* of the north Pacific (AOU 1998).

**Geography/Location:** Considered a common breeder on the Seward Peninsula, where it is commonly found in coastal lowland areas and in nearshore and inshore waters. Breeding densities of as many as 500 birds have been reported from Cape Espenberg. Also considered a common breeder in the Nugnugaluktuk River estuary and along the northwest coast of the Seward Peninsula on the outer fringes of Lopp and Arctic Lagoons (Kessel 1989). It is a migrating shorebird protected under the Migratory Bird Treaty Act.

The global breeding range of this widespread species extends from Alaska across the Arctic to Labrador and Greenland and south to Maine and New Hampshire; from Iceland, the Faroe Islands, Spitsbergen, and Franz Josef Land south to northern British Isles, northern Europe, and southern Scandinavia; and from Wrangel Island, New Siberian Islands, and northeastern Siberia south to Kamchatka and Commander Islands. Winter range in western North America extends from the ice pack south to the Aleutian Islands and Cook Inlet and on the Pacific coast south to Washington and Oregon. Winter range in eastern North America is in Hudson and James bays and from Labrador south to Long Island (New York). Winter range in the western Palearctic extends from the breeding range south to central Europe; and in eastern Eurasia south to Kamchatka (AOU 1998). In North America, concentrations occur around Cape Cod and Penobscot Bay, Maine (Root 1988). In the early 1990s, USFWS Winter Sea Duck Survey found the highest densities in Maine and Massachusetts (Kehoe 1994).

**Life History & Ecology:** This is a heavy-bodied duck with a relatively short, stout neck and distinctive long triangular (wedge-shaped) bill and head profile. Nesting in Maine occurs from late April to early July. Nesting in the Beaufort Sea region begins in mid- to late June (Johnson and Herter 1989). Clutch size averages 3-5. Incubation, by the female, lasts 24-30 days. The female relies on endogenous energy reserves during incubation. Eggs hatch mainly mid- to late July (sometimes into August) in the Arctic regions of Alaska and Canada. Young are led to water soon after hatching, are tended by the female, soon join young of other broods, and are independent at around 60-75 days). Female first breeds at 2-3 years, generally not until at least 3 years old. Females rarely renest if the clutch is lost, unless the loss occurs during laying or early incubation.

Common eiders commonly nest in loose aggregations or colonies (usually a few dozen pairs, but up to several thousand pairs in some areas). Females commonly deposit eggs in the nests of other females. Female common eiders that nested successfully lead their young to water and may be accompanied by non-breeding females that participate in chick protection. Broods often join to form "crèches" of up to many dozens of young. Once formed, a crèche tends to stay together throughout the brood rearing period, although some of the adult females attending it may depart.

Common Eider eats mainly mollusks and crustaceans. Often feeds in fairly shallow waters around submerged ledges and reefs of rocky shores. In winter in the Gulf of St. Lawrence, Quebec, feeds on small blue mussels in kelp beds, on green sea urchins over urchin barrens, and on spider crabs and urchins over AGARUM beds (Guillemette et al. 1992). However, females do not feed during incubation; during initial part of breeding period, uses nutritional reserves accumulated in winter and in staging areas.

Predation by herring gull and great black-backed gull causes most nesting failures on islands in Maine, but eider nesting success may be enhanced in nests close to a gull colony (gulls defend area against other avian predators). Arctic fox is sometimes an important predator on nesters in Alaska. Ravens, raccoons, and mink sometimes destroy nests. Annual survivorship of adult generally is relatively high, with sport hunting likely the major cause of mortality in the Atlantic flyway (Kehoe 1994).

**Migration Ecology:** Spring migration generally begins in March and extends into April for early nesters and to mid-June in Arctic nesters. During June and July, males depart from breeding areas to molt (immatures and non-breeding females may also undertake such migrations). Fall migration varies regionally but occurs mainly in October and November, though females and young may begin moving toward wintering areas in late August-early September (Johnson and Herter 1989). By mid-December most wintering populations have peaked in numbers. Populations that nest in different areas (e.g., St. Lawrence Estuary, Gulf of St. Lawrence, and Atlantic coast) share the same wintering range (Krohn et al. 1992).

Some populations do not migrate, and in other populations migration may be partially facultative, depending on conditions. A non-migratory population occurs in Hudson Bay, Ontario and Quebec (Bellrose 1980). Part of the female population in Maine is migratory, part is resident on or near breeding area (see Blumton et al. 1988).

**Habitat Description:** In general, Common Eiders prefer small islands and islets in freshwater lakes, ponds, lagoons, near an outlet to the sea (Nakashima 1986, Cornish and Dickson 1997) and low-lying points of land for breeding. Nests are on the ground in grass or brush, usually close to salt water, often on an island or rocky headland or along the shore of a pond or lagoon. Nests are often but not always concealed by plants (forest, shrub, or herbaceous), rocks, logs, driftwood. When on shore on the Seward Peninsula, most commonly found in wet meadow, salt grass meadow, and *Elymus* grass meadow habitats in close proximity to the shoreline of ponds, lagoons or outer coastline (Kessel 1989). Within these habitats, it selects for features offering protection from mammalian and avian predators, such as sites that are isolated by deep water or near some type of concealing factor such as *Elymus* grasses, rocks, or under a pile of driftwood (Kessel 1989). Often nests are in the same site in successive years.

Non-breeding habitat includes rocky seacoasts, bays, and estuaries. Rocks, sandbars, and ice are used as resting sites. In winter in the Gulf of St. Lawrence, eiders concentrated in areas with shallow water reefs and high prey density (Guillemette et al. 1993). Most migration is coastal. See Blumton et al. (1988) for habitat suitability index model.

**Threats/Stressors:** Alaskan seabirds such as Common Eiders generally nest in areas that are inaccessible and far from human population. This reduces many of the direct threats/stressors from human actions such as disturbing nesting birds by walking or making noise near their colony sites. Adult seabirds, when frightened, can hurt their young chicks when they fly away in a panic. However, indirect effects of humans may have larger impact on bird mortality: Common eider in the high Arctic is subject to hunting, especially in spring, by indigenous peoples for food (Kear 2005b as cited by BI 2012b). This subsistence hunting is likely to be sustainable at current levels (Byers and Dickson 2001 as cited by BI 2012b). The species is also shot for sport in North America (this harvest may exceed sustainable levels in some areas).

*Oil Spills:* Like many seabirds this species is vulnerable to coastal oil pollution, especially oil spills in areas where large wintering concentrations occur (del Hoyo *et al.* 1992, Kear 2005b, Nikolaeva *et al.* 2006 as cited by BI 2012b). Oil coats the birds' feathers and allows water to penetrate feathers and make them susceptible to the cold sea water. Both large and small spills can kill sea birds that come in contact with oil.

*Non-Native Invasive Animals:* Ground-nesting bird species lack defenses against introduced predators (Norway rate and Arctic Fox) and the young are especially vulnerable. Not only do introduced predators devastate island seabirds' populations, Croll et al. (2005) found that the introduction of Arctic fox to some Aleutian islands caused cascading effects to lower trophic levels. Nutrient transport form seabird guano to island soil fertility was interrupted by fox predation on seabirds causing shifts in plant community productivity and composition transforming grasslands to dwarf shrub/forb-dominated ecosystems (Croll et al. 2005, Maron et al. 2006).

*Commercial Fisheries:* Commercial fisheries and shellfish industry are a source of stress through competition for prey. The birds eat many of the same species that are commercially harvested by the fishing industry. Their major food source, mollusks and crustaceans, is affected by the shellfish aquaculture industry which can significantly deplete food resources (Kear 2005b, Nikolaeva *et al.* 2006). Fish and shellfish populations and harvests need to be monitored so fish populations are productive enough for birds and human use. Fisheries by-catch mortality can significantly affect seabird species populations. Between 14,500 and 160,000 seabirds are killed by commercial fishing operations each year (NPFMC 2000, Artyukhin and Burkanov 2000). Birds are usually drowned when incidentally caught in fishing gear, either on hooks or in nets (Jones and DeGange 1988). Longline gear accounted for 90 percent of seabird by-catch, trawls for 9 percent and pots for 1 percent (Whol et al 1995).

*Pollution:* Various types of pollutants can directly affect seabirds. Birds can get tangled in plastic trash such as six-pack rings, fishing line, etc. and get injured or drown. Toxic chemicals such as mercury end up in the oceans and work up the food chains. It is unknown how these will affect seabird populations in the future.

*Vulnerability to Climate Change*: Climate change in the Arctic over the past 50 years has been significant and climate models indicate continued warming in future (Kittel et al. 2010). In addition to changes in temperature and precipitation, other weather elements such as changes in frequency and intensity of storms may occur (Kittel et al. 2010). Changes in climate also have complex interactions with landscapes and biotic communities and will affect sea ice, coastal erosion rates, and hydrological impacts of melting of permafrost (Kittel et al. 2010).

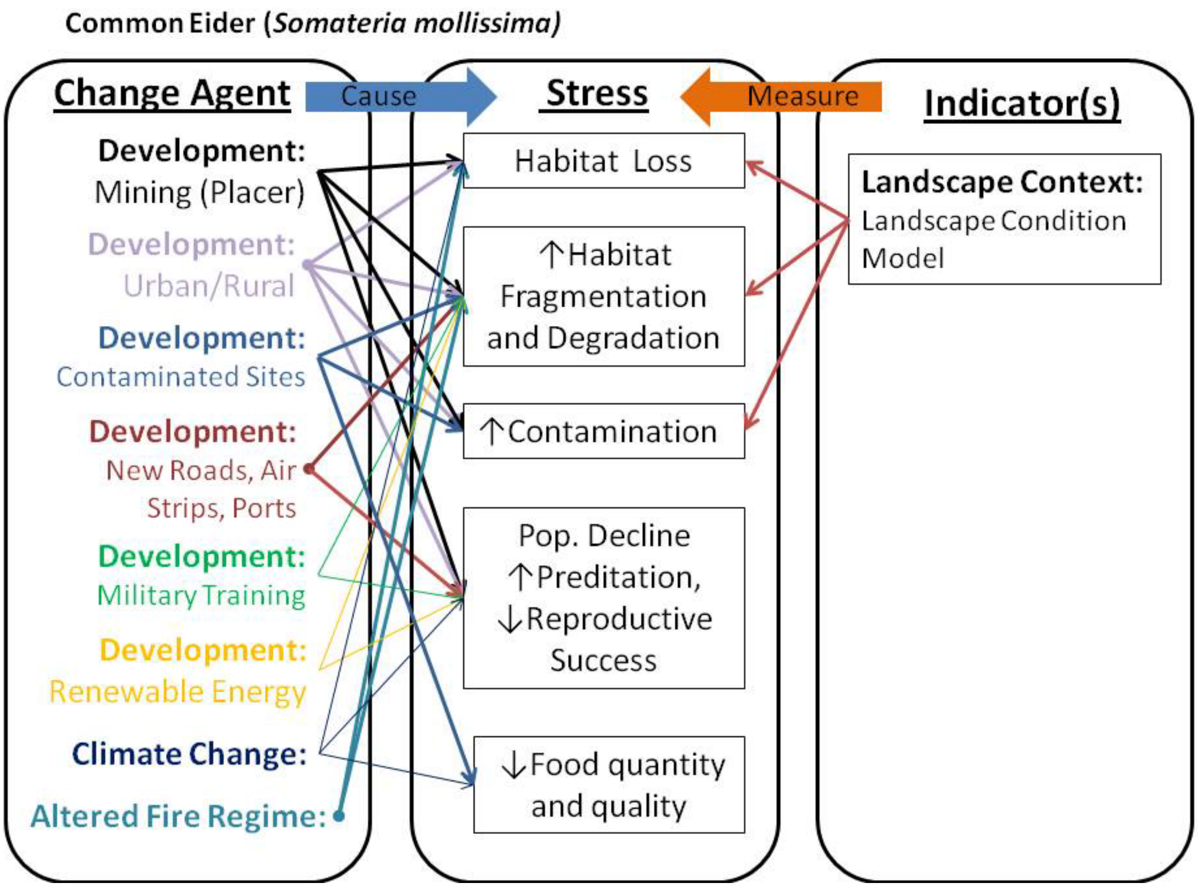
*Possible impacts to seabird populations:* Meehan et al. (1999) lists many possible impacts to seabird populations if warming climate trend persists. Examples include:

a) If sea ice extent continued to decline, some species of seabirds may benefit (increased productivity, range extensions) by being able to feed in open water near nesting areas earlier in spring and fledge young before fall freeze-up. However species dependent on feeding at the ice edge may adversely affected. More open water could increase severity of rough seas, potentially causing increased winter mortality of birds at sea.
b) If surface sea temperatures change substantially, the distribution of seabird prey will shift. For some species and sites, the shift may be beneficial (e.g., species that feed on prey that local conditions now favor), but for others it could be detrimental (e.g., surface feeders whose prey has been driven too deep for them to access). Initially, productivity of seabirds would be affected and ultimately population change would occur.
c) Earlier snow melt in spring will make nesting sites available sooner. This could be beneficial for some species at locations where productivity, particularly survival of young, has been reduced due to the shortness of the available nesting period. In contrast, it is possible that enhanced vegetation growth during extended growing seasons could cover crevices used by auklets.
d) If average spring air temperatures continue to increase, coastal permafrost could thaw, potentially making new areas available to burrow-nesting seabirds.
e) If warming causes increased storminess (duration and/or frequency), mortality of seabird chicks at nest sites could occur and adult mortality in winter might also result due to rough seas interfering with feeding and dispersing prey.

f) If precipitation in summer were to increase, burrow nesting seabirds may experience increased chick mortality from flooding.

g) If warming causes significant increases in sea level, low-lying nest sites on barrier islands and nearshore scree nesters might be lost.

Figure E-30. Common Eider Conceptual Model/Diagram

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## E-3.7 King Eider (*Somateria spectabilis*)

**Classification/Taxonomic Information:** The King eider *(Somateria spectabilis)* is grouped with common eider (*Somateria mollissima*) in subgenus *Somateria*; spectacled eider (*S. fischeri*) is included in subgenus *Lampronetta* (Livezey 1995). Genetic distinctiveness of North American east Arctic and west Arctic wintering populations of king eiders is unknown (SDJV 2003).

**Geography/Location:** The King Eider is considered a very rare breeder on the Seward Peninsula, with the only confirmed breeding records from Cape Espenberg (Kessel 1989). However, throughout the summer, individual birds and small groups of non-breeders will feed and molt in inshore waters, especially off Safety Sound and also in the vicinity of Sledge Island and adjacent to the mainland off the outer coast (Kessel 1989).

The global range of this Holarctic species is one of the most northerly of the nesting ducks; it is also a northerly winterer (Palmer 1976). Two populations exist in North America: one winters in the eastern Arctic (Atlantic), the other in the western Arctic (Pacific) (Suydam 2000, SDJV 2003). Breeding occurs along the Arctic coast and islands from northern Alaska east to Greenland, west coast of Hudson Bay, James Bay, and probably northern Labrador; Banks and Victoria islands are important nesting areas. The species also nests along the Arctic coast from northern Russia east to Chukotski Peninsula and St. Lawrence and St. Matthew Islands. Small numbers nest in northern Finland, Sweden, Norway, and in northern coastal Greenland (Suydam 2000).

The non-breeding range in the Pacific extends from Kamchatka and the Bering Sea south to the Kurile, Aleutian, and Shumagin Islands. In the Atlantic, wintering extends primarily from Labrador and Greenland south to New England (less frequently eastern New York and New Jersey), and uncommonly in interior North America to the Great Lakes. Birds breeding in western Siberia and Scandinavia winter from the White Sea to western Norway and eastern coast of Iceland; small numbers are found as far south as England and Ireland (Suydam 2000). Casual non-breeding visitors occur to points south of the normal southern limits of range (AOU 1983).

Molting areas are poorly documented but presumably are in marine environments. The western Arctic population in North America molts primarily in the Bering Sea and to lesser extent in the Chukchi Sea (SDJV 2003). A small number may also molt in the eastern Beaufort Sea (Johnson and Herter 1989). Satellite telemetry has identified several key molting sites: off the south and east coasts of the Chukotsk (Chukchi) Peninsula, south of St. Lawrence Island, and northern Bristol Bay (Dickson et al. 1999). The eastern Arctic population is known to molt in areas of western Greenland around Disko Bay and in eastern Greenland at Clyde Inlet (Suydam 2000).

**Life History & Ecology:**
*Reproduction*: Eggs are laid in June-July; few nests started after 10 July. Clutch size usually is 4-6. Incubation, by female (male departs), lasts 22-24 days. Young are tended by female. Young of different broods may flock together. Females begin breeding at 2 years. Severe weather may cause widespread nest failure.

*Food Comments*: Eats mainly mollusks, crustaceans, and insects; sometimes eats significant amounts of plant material and forages mostly under water (Palmer 1976). Mass starvation and low productivity can occur in years when low temperatures, ice, and snow persist in northern breeding areas (Johnson and Herter 1989). Winter flocks may include up to 15,000 birds.

**Migration Ecology:** This sea duck is a long distance migrant. It nests from Beaufort Sea region winter in Bering Sea and along southwestern Greenland. First large pulse of migrants arrives in north-central Alaska around mid-May, Canadian Beaufort Sea coast in early June (or late May in some areas). Hundreds of thousands may migrate past Point Barrow in a single day in late May. The development in spring of offshore lead systems in pack ice is major determinant of routing and timing of spring migration (Johnson and Herter 1989). Males make extensive migration to molting areas in early to mid-summer (see Johnson and Herter 1989 for details for Beaufort Sea region). Most have departed from Beaufort Sea region by late September, though commonly observed there later. They arrive in Bering Sea in September-October.

**Habitat Description:** In general, King Eiders select for breeding habitat that is located along seacoasts and large river valleys, and in the vicinity of ponds and pools in open tundra (AOU 1983). They nests on the ground away from, but not distant from, water in open tundra, often in graminoid meadows within a few miles of the coast (Palmer 1976). Distance from coast varies, but generally nests further inland than Common and Spectacled Eiders (*Somateria mollissima, S. fischeri*) (Palmer 1976). King Eiders moves to fresh or salt water habitats to rear broods, feeding in shallow ponds with sedges along the way and eventually ending up in salt water where fledging occurs (Suydam 2000).

**Threats/Stressors:** Declines have been documented in both eastern (Mosbech and Boertmann 1999) and western Arctic populations (Suydam et al. 1997, Suydam et al. 2000). In northern Alaska and the western Canadian Arctic, the breeding population apparently declined by 56% from 1976 to 1996, based on standardized migration counts (Suydam et al. 2000). These data are corroborated by results of breeding-pair surveys in the western Canadian Arctic (Dickson et al. 1997), but results should be viewed with caution, and there is currently no breeding survey evidence indicating a decline in the Alaska population. A significant decrease in King Eider numbers in the Rasmussen Lowlands, N.W.T., was observed between 1975 and 1995 (Suydam 2000). Little information is available on the status of the eastern Arctic breeding population, but regional declines have been reported on the Melville Peninsula and Boothia Peninsula (SDJV 2003), and surveys of molting birds off Greenland suggest present numbers are only half of 1950s numbers (Mosbech and Boertmann 1999).

Reasons for the apparent large decline in northern Alaska and the western Canadian Arctic are unknown (Suydam et al. 2000). Annual mortality from hunting in that area ranged from 2.5 to 5.5% of the total population, but this is within the sustainable harvest limits of other sea ducks (Suydam et al. 2000). Small numbers are hunted during spring migration (Madge and Burn 1988).

Alaskan seabirds such as King Eiders generally nest in areas that are inaccessible and far from human population. This reduces many of the direct threats/stressors from human actions such as disturbing nesting birds by walking or making noise near their colony sites. Adult seabirds, when frightened, can hurt their young chicks when they fly away in a panic. However there was significant mortality from exposure on nesting grounds (50,000 females and young perished in one season in the Beaufort Sea) (Barry 1968). Severe weather conditions during spring migration have resulted in adult starvation in 1964 (~100,000, or 10% of the Beaufort Sea population)(Barry 1968). Also disturbance from uncontrolled commercial shipping on wintering grounds.

Indirect effects of human activities may have a larger impact on bird mortality as described below.

*Oil Spills:* Like many seabirds this species is vulnerable to coastal oil pollution especially oil spills in areas where large wintering concentrations occur (del Hoyo *et al.* 1992, Kear 2005b, Nikolaeva *et al.* 2006 as cited by BI 2012c). Oil pollution coats the birds' feathers and allows water to penetrate feathers and make them susceptible to the cold sea water. Both large and small spills can kill sea birds that come in contact with oil. This species is especially threatened by oil spills when concentrated in large non-breeding flocks.

*Non-Native Invasive Animals:* Ground nesting bird species lack defenses against introduced predators (Norway rate and Arctic Fox) and the young are especially vulnerable. Not only do introduced predators devastate island seabirds' populations, Croll et al. (2005) found that the introduction of Arctic fox to some Aleutian islands caused cascading effects to lower tropic levels. Nutrient transport form seabird guano to island soil fertility was interrupted by fox predation on seabirds causing shifts in plant community productivity and composition transforming grasslands to dwarf shrub/forb-dominated ecosystems (Croll et al. 2005, Maron et al. 2006).

*Commercial Fisheries:* Fisheries by-catch mortality can significantly affect seabird species populations. Between 14,500 and 160,000 seabirds are killed by commercial fishing operations each year (NPFMC 2000, Artyukhin and Burkanov 2000). Birds are usually drowned when incidentally caught in fishing gear, either on hooks or in nets (Jones and DeGange 1988). Longline gear accounted for 90 percent of seabird by-catch, trawls for 9 percent and pots for 1 percent (Whol et al 1995).

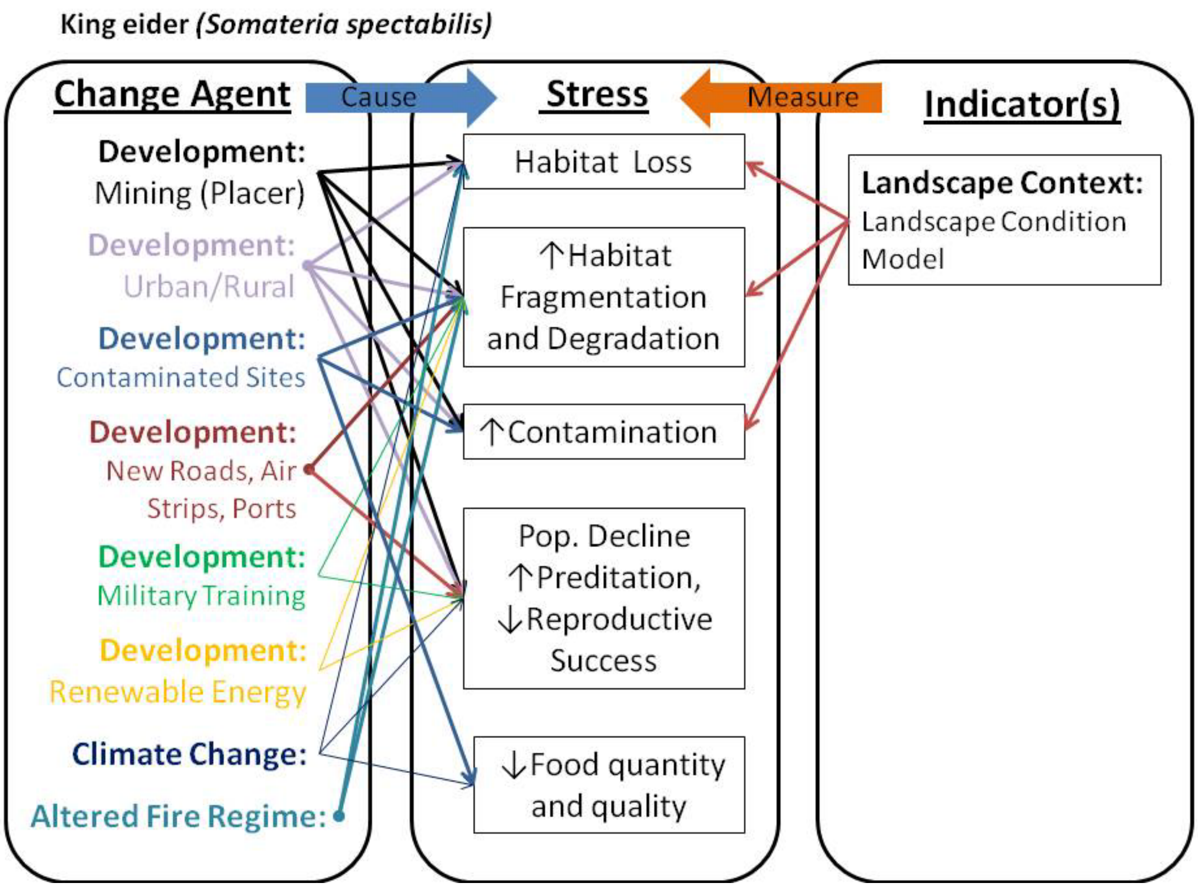
*Pollution:* Various types of pollutants can directly affect seabirds. Birds can get tangled in plastic trash such as six-pack rings, fishing line, etc. and get injured or drown. Toxic chemicals such as mercury end up in the oceans and work up the food chains. It is unknown how these will affect seabird populations in the future.

*Vulnerability to Climate Change:* Climate change in the Arctic over the past 50 years has been significant and climate models indicate continued warming in future (Kittel et al. 2010). In addition to changes in temperature and precipitation, other weather elements such as changes in frequency and intensity of storms may occur (Kittel et al. 2010). Changes in climate also have complex interactions with landscapes and biotic communities and will affect sea ice, coastal erosion rates, and hydrological impacts of melting of permafrost (Kittel et al. 2010).

*Possible impacts to seabird populations:* Meehan et al. (1999) lists many possible impacts to seabird populations if warming climate trend persists. Examples include:

a) If sea ice extent continued to decline, some species of seabirds may benefit (increased productivity, range extensions) by being able to feed in open water near nesting areas earlier in spring and fledge young before fall freeze-up. However, species dependent on feeding at the ice edge may adversely affected. More open water could increase severity of rough seas, potentially causing increased winter mortality of birds at sea.
b) If surface sea temperatures change substantially, the distribution of seabird prey will shift. For some species and sites, the shift may be beneficial (e.g., species that feed on prey that local conditions now favor), but for others it could be detrimental (e.g., surface feeders whose prey has been driven too deep for them to access). Initially, productivity of seabirds would be affected and ultimately population change would occur.
c) Earlier snow melt in spring will make nesting sites available sooner. This could be beneficial for some species at locations where productivity, particularly survival of young, has been reduced due to the shortness of the available nesting period. In contrast, it is possible that enhanced vegetation growth during extended growing seasons could cover crevices used by auklets.
d) If average spring air temperatures continue to increase, coastal permafrost could thaw, potentially making new areas available to burrow-nesting seabirds.
e) If warming causes increased storminess (duration and/or frequency), mortality of seabird chicks at nest sites could occur and adult mortality in winter might also result due to rough seas interfering with feeding and dispersing prey.
f) If precipitation in summer were to increase, burrow nesting seabirds may experience increased chick mortality from flooding.
g) If warming causes significant increases in sea level, low-lying nest sites on barrier islands and nearshore scree nesters might be lost.

**Figure E-31. King Eider Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for *individual CEs* were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.8 Yellow-billed Loon *(Gavia adamsii)*

**Classification/Taxonomic Information:** Yellow-billed Loon *(Gavia adamsii)* constitutes a super-species with the common loon (*Gavia immer*) (AOU 1998).

**Geography/Location:** This long distance migrant is considered an uncommon breeder on the Seward Peninsula, except for the northern half of the peninsula where it is fairly common (Kessel 1989). It occurs where suitable water bodies are present in both upland and lowland habitats, but appears to be most numerous where an assemblage of suitable lakes occur at the junction of coastal lowlands with uplands (e.g., at the foot of Potato Mountain). In contrast, the species is considered a rare breeder at coastal wetland sites such as Cape Espenberg, Shishmaref Inlet and Lopp Lagoon (Kessel 1989).

Breeding range extends patchily throughout the sub-Arctic and Arctic tundra of northern Alaska, Canada, and Eurasia. In Alaska, nesting occurs from the Canning River westward to Point Lay and also includes St. Lawrence Island and coastal areas of the Seward Peninsula. In Canada, breeding extends from just east of the MacKenzie River Delta to Hudson Bay, including northern islands. Breeding is most common on Banks and Victoria Islands and in the Lake District from Great Slave Lake northeast to northern Hudson Bay; nesting occurs sparsely elsewhere. In Russia, nesting occurs in narrow strip of coastal tundra from the Chukchi Peninsula in the east to the Taymyr Peninsula and the areas of the Novaya Zemlya River and Pechora River in the west. Small numbers have been reported breeding in Finland and Norway (Earnst 2004).Migration occurs regularly along the coastlines of northern Canada and northern and northwestern Alaska and rarely along the western Alaska coast (Earnst 2004). In winter, the species is regularly but sparsely distributed in nearshore marine waters from Kodiak Island though Prince William Sound, and throughout southeast Alaska and British Columbia. Irregular wintering occurs southwest of Kodiak Island along the Aleutian Islands and along the coast from Washington to

Baja California. Several reliable inland sightings exist for migrating and wintering loons in western and central North America. Immatures and possibly some non-breeding adults remain on wintering grounds throughout the year. Eurasian population winters primarily around Scandinavia and along the Pacific Coast of Siberia, uncommonly in northern Japan, and rarely in China, Great Britain, and continental Europe (Earnst 2004).

**Life History & Ecology:** Pair formation occurs upon arrival on breeding territory; nests are constructed early to mid-June (North 1994). Nests comprised of peat, pendant grass (*Arctophila fulva*), sedges (*Carex* spp.) and sometimes lined with other vegetation (North and Ryan 1988 in Earnst 2004); nests from previous years frequently reused. Eggs are laid in June-July (some July nests represent renestings after loss of eggs); first nests generally are in mid-June in Arctic Alaska, but peak nesting may be delayed by late ice melt on lakes. Clutch size: 2. Incubation, by both sexes, lasts 27-28 days. Chicks are dry and active within hours of hatching; brooding by both parents occurs in nest for ~3 days, then little on-shore brooding after ~9 days (North 1994). In some areas, chicks 9-16 days old have been observed riding on parent's back (Sjolander and Agren 1976 in North 1994). Adults forage to feed young for up to 45 days (Earnst 2004). Reproductive maturity probably reached at or after 4 years.

*Breeding*: Nests in low-lying treeless tundra regions, usually coastal, at around 62-74 degrees latitude on larger (in Alaska, 8-229 ha), clear, low-rimmed lakes. Breeding sites may also be on inland lakes or large river deltas with untapped lakes (North 1994, Fair 2002). Requires nesting and brood-rearing lakes that are large enough to allow easy take-off from open water; form an ice-free moat around shore in early spring; have clear water supporting a substantial overwintering population of small fishes; have segments of gently sloping shoreline in which nesting and brooding occurs; and have sheltered, vegetated areas, where young chicks rest and take refuge during disturbances (Earnst 2004). Lake size, depth, connectivity to streams, shoreline complexity and proportion of shoreline in moist to aquatic cover types were each significant predictors in a survey of 757 lakes in northern Alaska (Earnst 2004). Nests are placed at the water's edge, typically in a low, gently sloping area. Deep open water with islands is a preferred habitat for nesting relative to its availability. Most nests are placed on the leeward lake or island shore (Earnst 2004). Breeding density is low compared to other loons (estimated at one individual per 10 square kilometers in Alaska) (Johnsgard 1987); defends large territory, usually 17 ha to > 100 ha, used for nesting and brood rearing (Earnst 2004).

*Non-breeding:* Little studied, generally near shore, in protected waters, from 50-61 degrees N (North 1994). Spend roughly eight months exclusively in marine environments. During migration, prefer open-water leads for resting and refueling (Earnst 2004).

A large diving bird that forages in deep open water by repeated, lengthy dives. May forage at lake adjacent to nesting lake. An opportunistic forager, takes prey in relation to availability and ease of capture, and consumes underwater. Chicks are fed small, minnow-sized fish. Important prey species include ninespine stickleback (*Pungitius pungitius*), least cisco (*Coregonus sardinella*), Alaska blackfish (*Dallia pectoralis*), fourhorn sculpin (*Myoxocephalus quadricornis*), isopods, and amphipods (Earnst 2004).

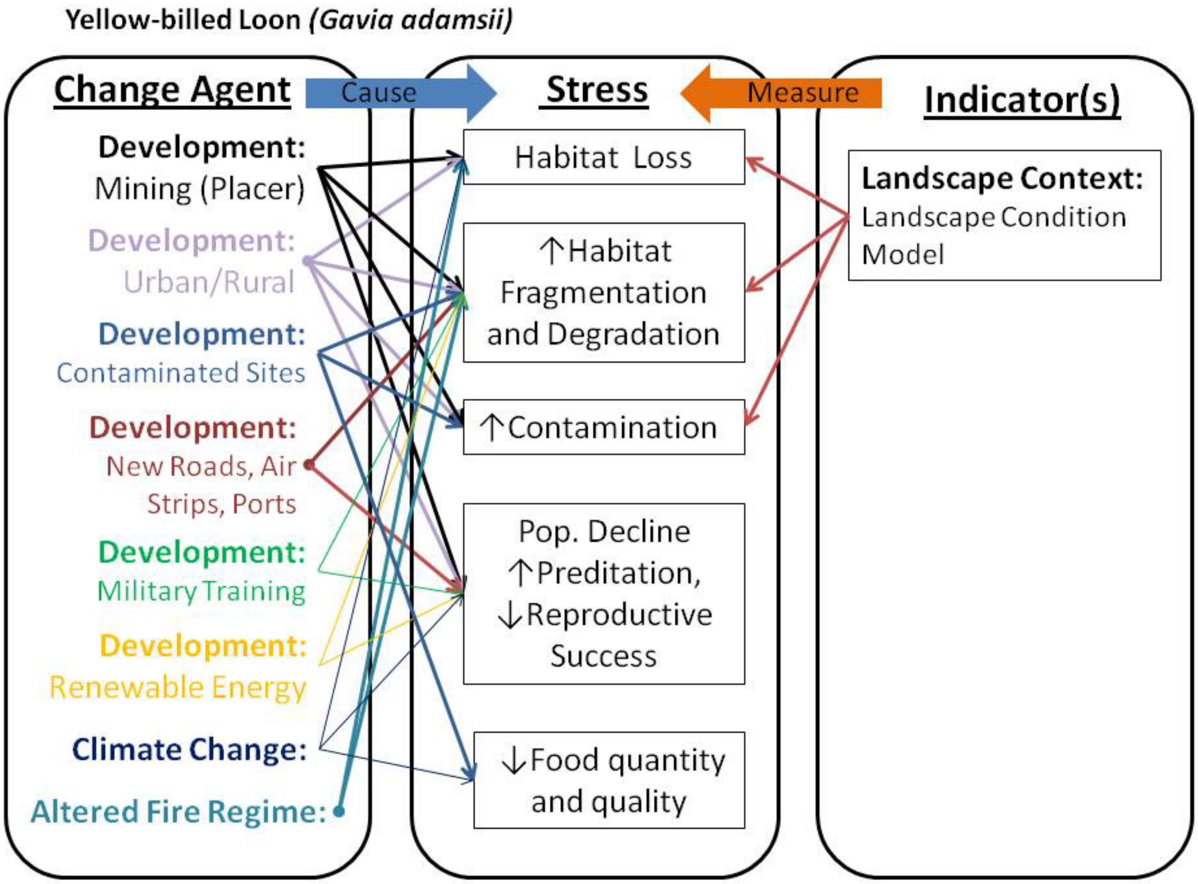
**Migration Ecology:** Migrates between breeding range in Arctic tundra regions and non-breeding areas farther south and east. Arrival dates along Alaska coast from St. Lawrence Island to Colville River Delta usually May 15-June 1; at Colville River Delta, usually May 31-June 3; east of Colville River and in Canada, usually June 1-15 (North 1994). Departure in fall generally occurs from late August to mid-September in Alaska, to October in Canada; closely associated with fledging of offspring (Earnst 2004). Migrates singly, in pairs or in loose flocks; occasionally stages in larger groups in the fall (North 1994).

**Habitat Description:** Nests in low-lying treeless tundra regions, usually coastal, in clear, low-rimmed lakes. Breeding sites may also be on inland lakes or large river deltas with untapped lakes (North 1994, Fair 2002). Requires nesting and brood-rearing lakes that are large enough to allow easy take-off from open water; form an ice-free moat around shore in early spring; have clear water supporting a substantial overwintering population of small fishes; have segments of gently sloping shoreline in which nesting and brooding occurs; and have sheltered, vegetated areas, where young chicks rest and take refuge during disturbances (Earnst 2004). Lake size, depth, connectivity to streams, shoreline complexity and proportion of shoreline in moist to aquatic cover types were each significant predictors in a survey of 757 lakes in northern Alaska (Earnst 2004). Nests placed at the water's edge, typically in a low, gently sloping area. Deep open water with islands is a preferred habitat for nesting relative to its availability. Most nests are placed on the leeward lake or island shore (Earnst 2004).

**Threats/Stressors:** The USFWS published a finding on a petition to list *Gavia adamsii* as threatened or endangered with critical habitat. They found that listing the yellow-billed loon range-wide was warranted, but precluded by other higher priority listing actions (Federal Register, 2009 March 25). It was added to the candidate list on November 9, 2009.

The species is vulnerable to coastal oil spills in both its breeding and wintering ranges (del Hoyo *et al.* 1992 as cited by BI 2012d). It may be threatened by oil development activities on its Alaskan breeding grounds, as c.90% of birds nesting on the Arctic Coastal Plain are in the National Petroleum Reserve-Alaska, and 29% are on tracts have already been leased for oil and gas exploration (North and Ryan 1989 as cited by BI 2012d). Wintering individuals are also potentially threatened by heavy metal pollution and by drowning in fishing nets (particularly in the north Pacific) (del Hoyo *et al.* 1992 as cited by BI 2012d). Although rates of harvest are currently thought to be at sustainable levels (USFWS 2009), exact harvest numbers are unknown, and a record of c.1,000 individuals taken in the Bering Sea region in 2007 indicates that this may pose the greatest threat to the species (USFWS 2009). Threats are exacerbated by a low reproductive rate and very specific breeding habitat requirements (USFWS 2009).

**Figure E-32. Yellow-billed Loon Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for individual CEs were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.9 Cackling Goose (*Branta hutchinsii*)

**Classification/Taxonomic Information:** Cackling Goose (*Branta hutchinsii*) was formerly treated as part of Canada Goose *(Branta canadensis),* but is now separated on the basis of several genetic studies. The distribution of this small-bodied form includes that of the subspecies *B. c. hutchinsii*, *asiatica*, *leucopareia*, *taverneri*, and *minima* as recognized by Delacour (1954).

**Geography/Location:** The Cackling Goose is a fairly common widespread breeder on the Seward Peninsula (at least 20,000 geese). Breeding has been observed on the northern and southern uplands and in the interior lowlands. Significant numbers breed at McCarthy's Marsh, also throughout the entire Lava Lake-Noxapaga-Kuzitrin-Pilgrim river drainage system and the Imuruk Basin. Also uses the wetlands complexes northwest, north and northeast of North Killeak Lake, and in the Burnt and Inmachuk river drainages. During summer, may also use the coastal lowlands for breeding, where they have been observed inland from exposed coastal areas in wetland flats of rivers (Kessel 1989).

Global range includes breeding populations on the Aleutian Islands, Semidi Islands (off Alaska Peninsula), formerly Bering Island and Kuriles; western and northern Alaska east to northern Yukon and Mackenzie Delta, south to Bristol Bay, the Alaska Peninsula, and central Yukon; and near the Arctic coast of Northwest Territories and Nunavut from Queen Maud Gulf east to Melville Peninsula, Southampton Island, and western Baffin Bay. It winters from British Columbia south to California, east to northern Mexico and western Louisiana. Formerly wintered in Japan. Casual or accidental in Hawaii and east to the Florida panhandle, and the Atlantic coast of the United States from Maine to South Carolina (NatureServe 2012).

**Life History & Ecology:** These birds feed mainly on plant material, both upland and aquatic. When feeding in water, they submerge their heads and necks to reach aquatic plants, sometimes tipping forward like a dabbling duck. Flocks of these birds often feed on leftover cultivated grains in fields, especially during migration or in winter. They also eat some insects, mollusks and crustaceans.

**Migration Ecology:** Like most geese in North America, Cackling Goose migrates north to summer breeding range from milder winter range.

**Habitat Description:** This species uses a wide variety of habitats including estuarine habitats such as bay/sound, herbaceous wetland, lagoon, river mouth/tidal river, tidal flat/shore; riverine habitats including low-gradient large and medium rivers, creeks; lacustrine habitats such as shallow water lakes and ponds; palustrine habitats including herbaceous wetlands, riparian zones; and terrestrial habitats such as cropland/hedgerow, grassland/herbaceous, tundra (NatureServe 2012).

**Threats/Stressors:** While hunting and other direct mortality takes a substantial toll, this species along with *Branta canadensis* has increased its range and population since the 1940s in North America (Mowbray et al. 2002). However, locally some populations are decreasing, while others are stable or increasing so the overall trend is uncertain (Wetlands International 2006). The data used to estimate population changes are based on Breeding Bird Survey and/or Christmas Bird Count which combine *Branta canadensis* and *B. hutchinsii*, creating additional uncertainty in trends (Butcher and Niven 2007 as cited by BI 2012e).

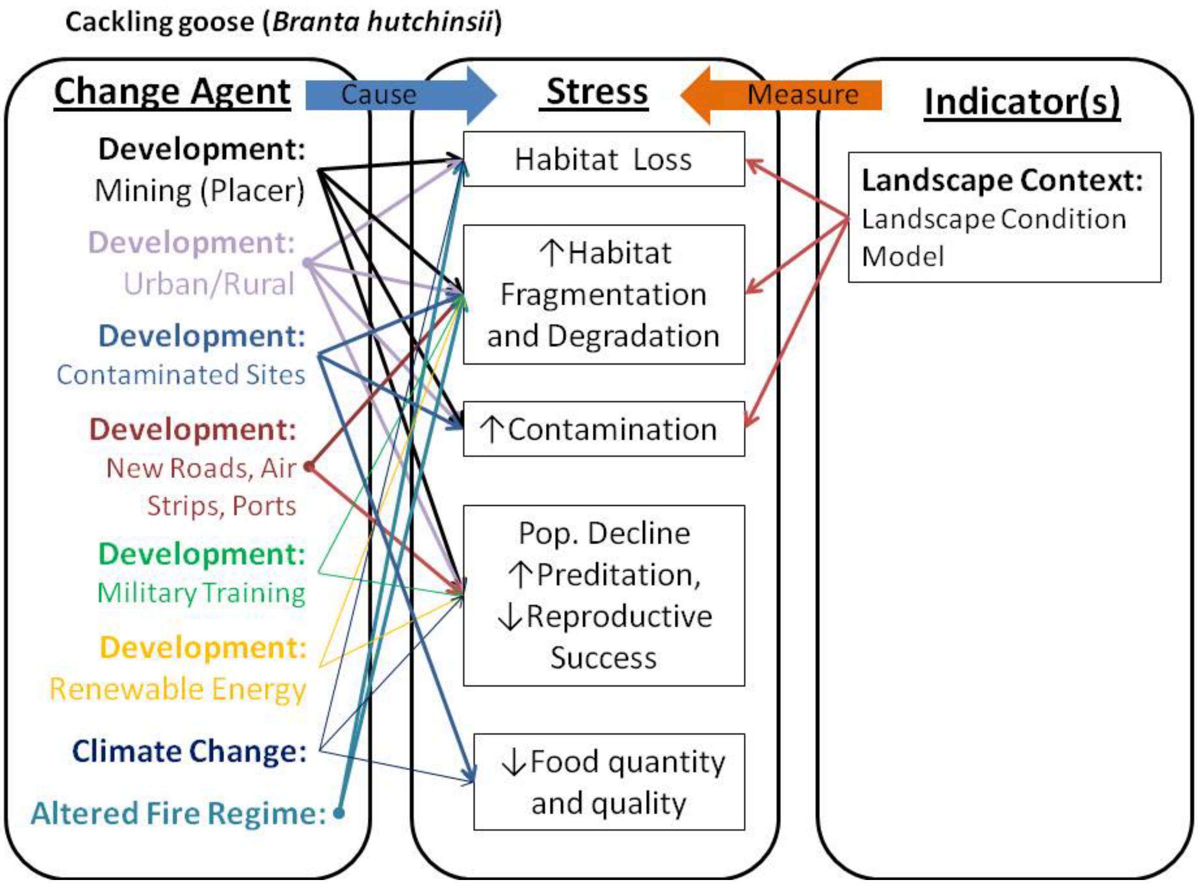
The subspecies, Aleutian Canada Goose *(Branta hutchinsii leucopareia)* was removed from the federal list of threatened and endangered wildlife and plants on March 20, 2001. It has a relatively small breeding range in the Aleutian and Semidi Islands; winters mainly in the San Joaquin Valley, California. Recovery efforts have led to a dramatic population increase in the 1990s, reaching over 62,000 individuals by 2003 (Drut and Trost 2003). There is, however, a continuing and increasing threat of habitat loss on migration and wintering grounds, and the subspecies remains susceptible to illegal hunting, disease, and increasing human disturbance. The Semidi Islands geese wintering on the Oregon coast have numbered fewer than 150, largely because of poor recruitment.

Predation by Arctic foxes, introduced onto the Aleutian Islands for fur farming, is believed to be the principal cause of the decline of the Aleutian Canada goose. Foxes remain on many of the islands and are a significant deterrent to the full recovery of the geese across their former range (Bailey 1993). Nesting geese are susceptible also to Norway rats that were introduced before or during World War II, and predation by bald eagles may be an important factor in limiting reestablishment of geese on fox-free islands (Byrd 1998).

Although the amount of protected migration and wintering habitat generally is considered sufficient for the security of Aleutian geese (USFWS 2001a), continuing urbanization and changing agricultural practices could cause changes unfavorable to the geese, particularly in the central San Joaquin Valley and eastern San Francisco Bay. The rapidly growing Aleutian goose population is creating conflicts with agricultural producers in northwest California, mostly during February and March. Landowners have begun hazing geese in spring, and a resolution is needed to accommodate the population at the objective level. Adverse climatic conditions, such as the extended drought recently experienced in California, may accentuate the decline in available habitat and favor undesirable land use practices that could reduce the quality and availability of suitable habitat (USFWS 1991).

With Aleutian geese at 60,000 birds and growing, a low level of illegal hunting no longer poses a threat to the population, but incidental take and human disturbance may have negative impacts. Outbreaks of disease (primarily avian cholera) historically have affected Aleutian geese on their wintering grounds and could pose a continuing challenge in the future as the number and density of geese increase.

**Figure E-33. Cackling Goose Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for individual CEs were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.10 Alaskan Hare *(Lepus othus)*

**Classification/Taxonomic Information:** *Lepus arcticus* and *L. othus* formerly were included in *L. timidus*. Jones et al. (1992) and Hoffman (in Wilson and Reeder 1993) treated *L. timidus, L. arcticus*, and *L. othus* as separate species. Angermann (in Wilson and Reeder 1993) regarded *L. timidus, L. arcticus*, and *L. othus* as probably conspecific (in which case the specific name *timidus* has priority). Some evidence based on cranial variation suggests that only *Lepus arcticus* and *L. timidus* should be recognized (Baker et al. 1983). Halanych et al. (1999) found minimal genetic differences between *L. arcticus* and *L. othus*, and they questioned the validity of *L. othus* as a distinct species. However, Halanych et al. (1999) noted the need for further taxonomic study of the Arctic hare group. Pending further study, the North American mammal checklist by Baker et al. (2003) retained *L. othus* as a valid species, as did Hoffman and Smith (in Wilson and Reeder 2005).

MtDNA data presented by Waltari et al. (2004) are partially consistent with recognition of *L. arcticus*, *L. othus*, and *L. timidus* as different species but also highlight the need for further study. These authors noted that Shimodaira-Hasegawa tests did not reject monophyly of each Arctic hare species [*L. arcticus*, *L. othus*, and *L. timidus*]. This molecular perspective supports the existing [three-species] taxonomy but also identifies a genetic discontinuity in *L. timidus* at the Kolyma and Omolon Rivers, as well as additional genetic structure in this species in western Europe. In addition, placement of a Korean hare (*L. coreanus*) within the Arctic hares suggests that identity and relationships of East Asian species of *Lepus* warrant additional investigation.

**Geography/Location:** The range encompasses western Alaska, from the Selawik-Kotzebue area in the north to the Cold Bay area in the south, including all of the Seward Peninsula, most of the Alaska Peninsula, and most of the western coast of Alaska. The range often has been shown to include part of the North Slope, but apparently there are no verifiable records from that area (Best and Henry 1994). However, Klein (1995) reported that this species was present in Alaska north of the Brooks Range from the Colville River westward (Bee and Hall 1956) but that there have been no records from that region since 1951. Centers of abundance are the western Seward Peninsula and the Yukon-Kuskokwim Delta region, although numbers have remained low there since population highs in the 1970s (Klein 1995). Densities are low on the Alaska Peninsula; high densities were last reported there in the winter of 1953-54 (Schiller and Rausch 1956). Hoffman (in Wilson and Reeder 1993) stated that the species possibly occurs also in eastern Chukotsk (Russia); mtDNA data indicate that this species does occur in eastern Asia (Waltari et al. 2004).

**Life History & Ecology:** One of the largest species of hares (total length 565-690 mm) (Best and Henry 1994, Whitaker 1996). During summer; dusky brown coat, grizzled with gray, darker on top of head; white under parts; dark cinnamon or buff hair marking nose and mouth; white ring around dark eyes; dusky ears washed with gray and tipped with black. Winter; all white with black-tipped ears (75-78 mm).

Conception occurs in April. Gestation lasts about 46 days. Young born in late May-June, full grown by mid-August (Whitaker 1980) or September, weaned in about 5-9 weeks. Litter size generally 5-7. One litter/year. Basically solitary, except during the mating season when groups of 20 or more have been observed.

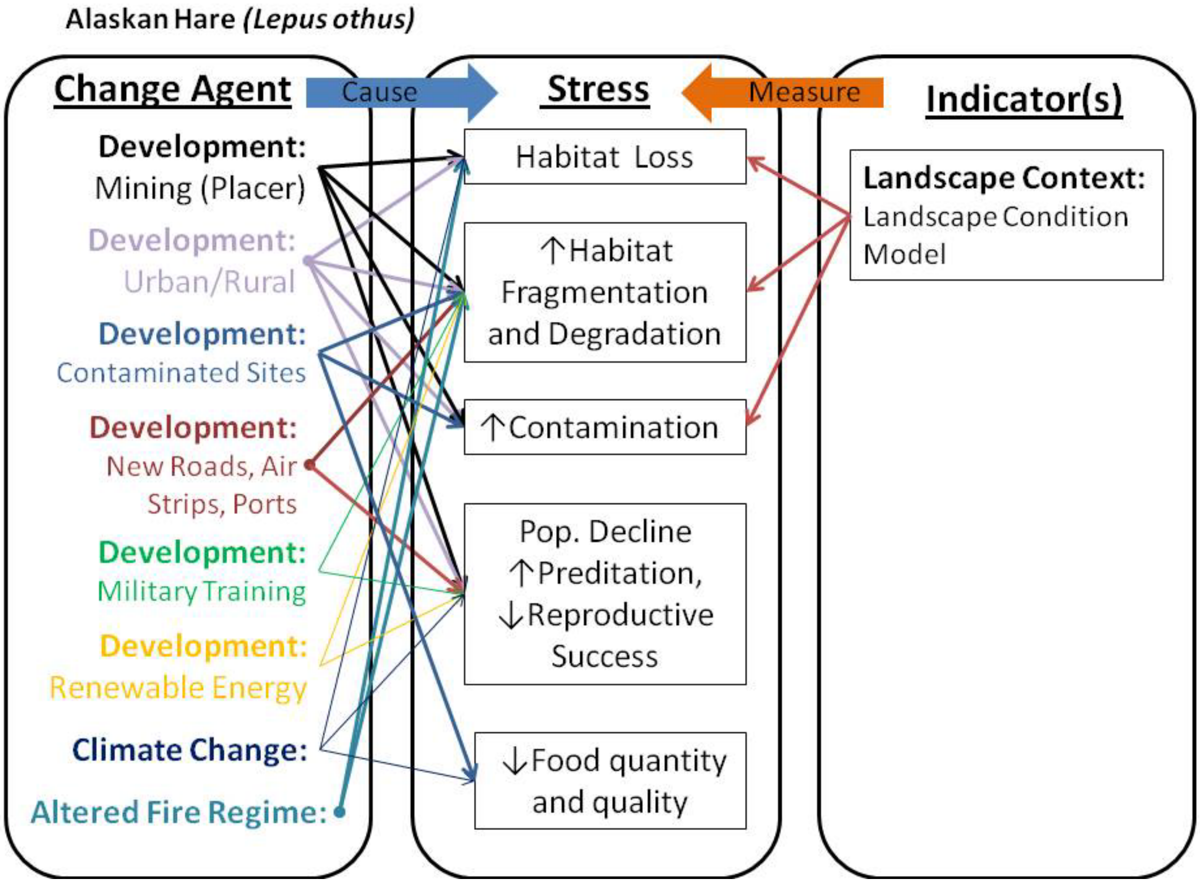
**Migration Ecology:** N/A

**Habitat Description:** Habitat includes tundra, alluvial plains, coastal lowlands, alder thickets, sedge flats, wet meadows; basically open tundra, but these lagomorphs use brush when available. Young may be born in the open in small depressions or in thick shelter of willow or alder brush (Best and Henry 1994).

**Threats/Stressors:** Potential threats include high predator numbers following peak numbers of snowshoe hares (*Lepus americanus*) and possibly interference competition from snowshoe hares.

Assessment and regulation of mining expansion and oil development projects within the distribution of the tundra hare are needed to assure protection of important habitats.

**Figure E-34. Alaskan Hare Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for individual CEs were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.11 American Beaver (*Castor canadensis*)

**Classification/Taxonomic Information:** The currently accepted scientific name for the American beaver is *Castor canadensis* Kuhl. The subspecies differ in size, proportion, color, and skull characteristics.

**Geography/Location:** North America except Arctic tundra, peninsular Florida, and much of the desert area of the Southwest, including parts of the northern edge of Mexico; introduced into Eurasia.

**Life History & Ecology:** Mating is monogamous. Outbreeding is the rule, with rare parent-progeny mating; matings between parent and offspring apparently occur only when a family unit is disrupted by the death of one adult (Taylor 1970, Svendsen 1980). In Ohio, Svendsen (1989) found that 56% of all pairs were formed in September, October, and November. Pair-bonds tended to last longer in areas with more stable conditions (lakes) than they did in comparatively unstable sites (streams).

Breeding (i.e., copulation) occurs January-March in the middle part of the range, mainly February-March in cold northern areas, mid-February in Newfoundland (Bergerud and Miller 1977), and over a longer season (late October-March) in the south (near the winter soltice in Mississippi; Wigley et al. 1983).

Gestation is thought to be 105-107 days, though also reported as about 128 days (Miller 1983) or around 100 days (Bergerud and Miller 1977). Parturition occurs in April, May, or June in Missouri (Schwartz and Schwartz 1981), April or May in Texas, generally late March and early April in Mississippi (Wigley et al. 1983), late May or early June in Newfoundland (Bergerud and Miller 1977), and June in Saskatchewan (Gunson 1970). In Ohio, Svendsen (1980) first heard the whining of kits in lodges in June.

Litter size ranges from one to nine, with three or four being typical in many areas. Factors influencing litter size include food supply, growing season, female size and age, and harvest rate. A female beaver produces one litter per year. Weaning occurs at an age of about six weeks and a weight of 4 pounds (1.8 kg).

In most cases, the young disperse from their family group in late winter or early spring, at an age of almost two years, before the new kits are born, or dispersal may occur later in summer. Some authors state that dispersal occurs at the end of the first year. Dispersal occurs over land and via waterways (Leege 1968). Apparently the young may remain in the family group longer than two years in high quality habitats and/or in habitats that are saturated with beavers (Boyce 1974, Gunson 1970, Bergerud and Miller 1977, Novakowski 1965). Dispersers often move to another area and begin a new pond. Sometimes they may return to their natal site (Svendsen 1980, Ryden 1988).

Survival of the young can be quite high in untrapped populations. Svendsen (1980) found that survival of the kits through their second summer was 95% (based on cohorts that lived long enough to emerge from their natal lodge). Some other studies also found that losses in the first year were very low, but other research indicates higher mortality rates (see Novak 1987a).

Compared to other rodents, beavers attain sexual maturity at a relatively late age. Females normally first give birth on or near their third birthday, and may remain productive for up to at least ten years (Stegeman 1954), though only a few live that long. Sometimes females breed when one (rarely) or two years old, though this is rare at the northern and southern range limits (Hill 1982). Males generally first breed at an age of about 21 months, though a variable proportion of yearlings may breed and sometimes older males may be functionally sterile.

A typical beaver “colony” is a family group (Payne 1982) of 3-6 individuals, with one breeding female (Novak 1977). Typical densities range from 0.4 to 0.8 families per square kilometer (Naiman et al. 1986) or from 0.09 to 1.2 families per stream km (Voight et al. 1976); saturation densities 0.4-1.9 families per km. In Newfoundland, reach greatest density in early succession (Northcott 1964). In Massachusetts, density increased with increasing hardwoods and with decreasing gradient, watershed size, and stream width (Howard and Larson 1985).

The American beaver is a keystone species that has profound effects on aquatic and riparian ecosystems (Naiman et al. 1986). In boreal systems, it may influence 20-40% of the length of 2nd- to 5th-order streams (Ford and Naiman 1988). Open patches created by beaver in New York and Wisconsin varied from less than 0.5 ha to 30 ha (Remillard et al. 1987, Dickinson 1971, Knudsen 1962), but averaged less than 4 ha. Among the many changes that occur with beaver activity are the following (see Johnston and Naiman 1987 and Naiman et al. 1988):

- Storage of precipitation and reduced discharge variability (Naiman et al. 1986, Hill 1982).
- Increased depth and surface area of water (Hill 1982, Naiman et al. 1986).
- Increase in open canopy (Naiman et al. 1986).
- Reduction of riparian deciduous trees (Beier and Barrett 1987, NYDEC 1991).
- Enhancement or degradation of fish habitat (Neff 1957, Gard 1961, Hill 1982, Churchill 1980, cited in Munther 1983).
- Habitat enhancement for species dependent on wetlands or dead trees (Reese and Hair 1976, Hill 1982, Ermer 1988, Dieter and McCabe 1989, Arner and Hepp 1989, Dubec et al. 1988, 1990, NYDEC 1991, Novak 1987a).
- Increased plankton productivity and an increase in aquatic insects (Naiman et al. 1986).
- Increased trapping of sediment and decreased turbidity downstream (Naiman et al. 1986).

- Enhancement of beaver food plants such as willow and alder (Slough and Sadleir 1977).
- Increase in carbon and nutrients in the channel (Hodkinson 1975, Naiman et al. 1986, Naiman and Mellilo 1984, Francis et al. 1985).
- Increased resistance of ecosystem to perturbation (Naiman et al. 1986).

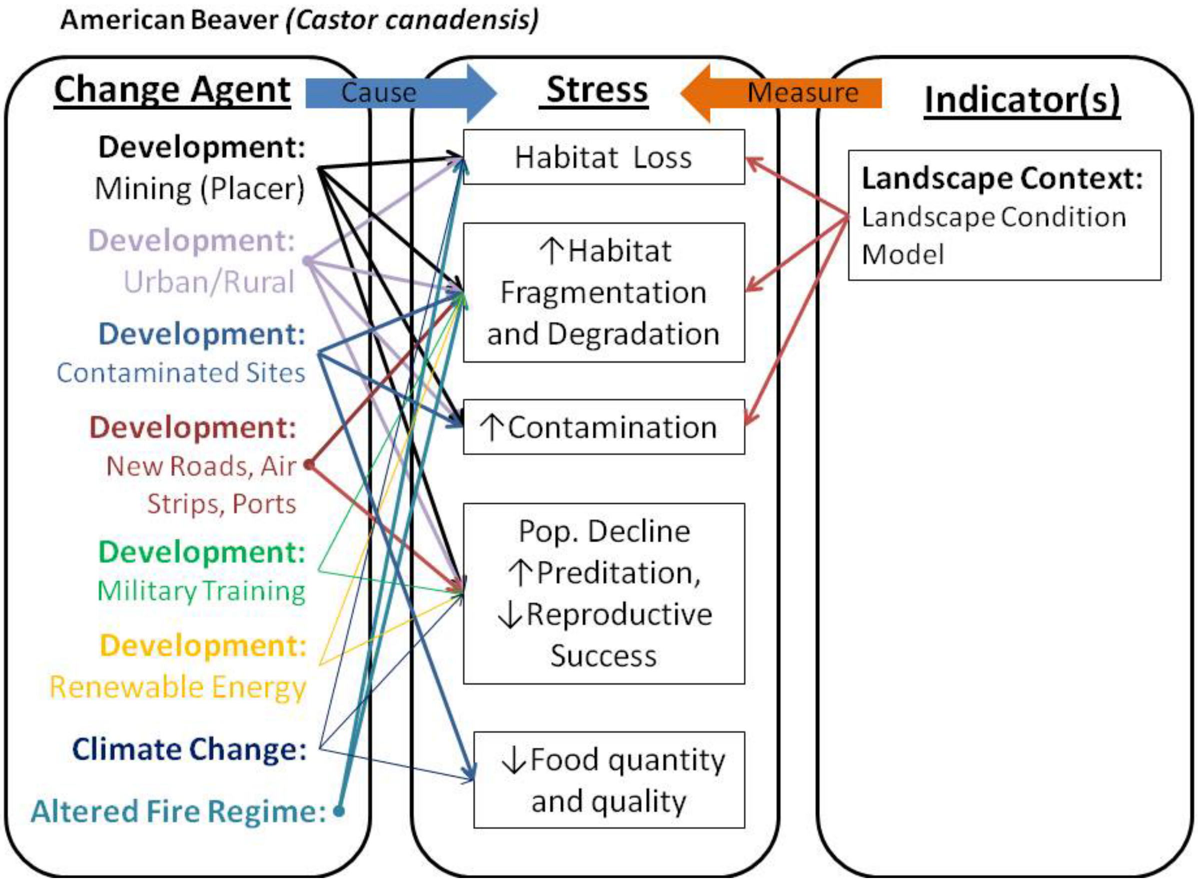
Beaver ponds are a shifting mosaic of habitats, dependent on pond age and size, successional state, substrate, hydrology, and nutrients. In boreal regions, there is a complex pattern of ecosystem development that involves the formation of marshes, seasonally flooded meadows, and forested wetlands, which appear to persist in a somewhat stable condition for centuries (Naiman et al. 1988). Food shortage probably is the major factor affecting colony longevity (Hodgdon 1978).

**Migration Ecology:** Beavers usually stay within 0.8 km of the den (Schwartz and Schwartz 1981). The longest movements are made by dispersing two-year-olds (Hill 1982); these average 8-16 stream km but range up to 238 stream km (108 air km, Hibbard 1958). Families generally are at least 0.8-1.6 km apart (reviewed in Novak 1987a).

**Habitat Description:** Beavers inhabit lakes, ponds, marshes, rivers, streams, and most permanent sources of water from sea level to 3400 meters in mountains. Prefer low gradient streams, ponds, and small mud-bottomed lakes with dammable outlets (Slough and Sadleir 1977, Beier and Barrett 1987, Novak 1987, McComb et al. 1990). Beavers readily occupy artificial ponds, reservoirs, and canals if food is available. They generally avoid lakes with strong wave action or fluctuating flow or water levels and fast- moving streams. In larger rivers ($9^{th}$ order or larger streams), beavers use floodplains and backwaters. In the north, they require water that is deep enough such that it does not freeze to the bottom and allows the accumulation of a substantial food pile beneath the ice. Beavers are associated with deciduous tree and shrub communities (NatureServe 2007).

**Threats/Stressors:** Humans are the only significant predators in most areas. Wolves may prey on beavers when ungulate populations are low (Voight et al. 1976, Shelton and Peterson 1983). In some regions tularemia (the bacterium *Francisella tularensis*) has caused large die-offs (see Novak 1987a, Addison et al. 1987). However, most unexploited populations have a low mortality rate (less than 5- 7%), and can grow quickly in areas with abundant resources.

**Figure E-35. American Beaver Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for individual CEs were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.12 American Black Bear *(Ursus americanus)*

**Classification/Taxonomic Information:** The currently accepted scientific name for American black bear is *Ursus americanus* Linnaeus. There are 16 subspecies in North America.

**Geography/Location:** Black bears exist throughout most of North America north of central Mexico, except the desert region of the southwestern United States, from north-central Alaska across boreal Canada to Labrador and Newfoundland, and south to central California, northern Nevada, northern Nayarit and southern Tamaulipas (Mexico), and Florida (Wozencraft, in Wilson and Reeder 1993). However, the species has been eliminated from most of the Midwest by intensive agriculture and human settlement. Now it occurs primarily in remaining large forested tracts.

**Life History & Ecology:** Pelage is usually black, brown, or reddish, but some in Pacific Northwest are bluish or whitish. Snout is tan or grizzled, straight or slightly convex in side view. Males grow larger than females, may reach several hundred pounds. Head and body length 150-180 cm, tail about 12 cm, mass about 90-140 kg for females, 115-270 kg for males (Nowak 1991, Burt and Grossenheider 1964).

Differs from the grizzly bear in having the claws of the forefeet only a little longer than those on the hind feet (about twice as long in the grizzly), length of second upper molar less than 29.5 mm (in part of range where grizzly occurs), snout profile straight rather than dished, and in lacking a prominent hump at the shoulders; maximum size of black bear is less than that of the grizzly (170-280 cm head and body length) (Nowak 1991, Hall 1981).

Breeding occurs in June-July. Implantation is delayed about 4 months (also reported as 5-6 months). Gestation lasts 7-7.5 months (average 220 days). Females give birth every 2 years at most. Young are born in January-February, stay with mother until fall of second year. Litter size is 1-5 (modal number generally is 2 or 3, average is less than 2 in western North America). Females generally first give birth at 2-5 years (usually 4-5 years).

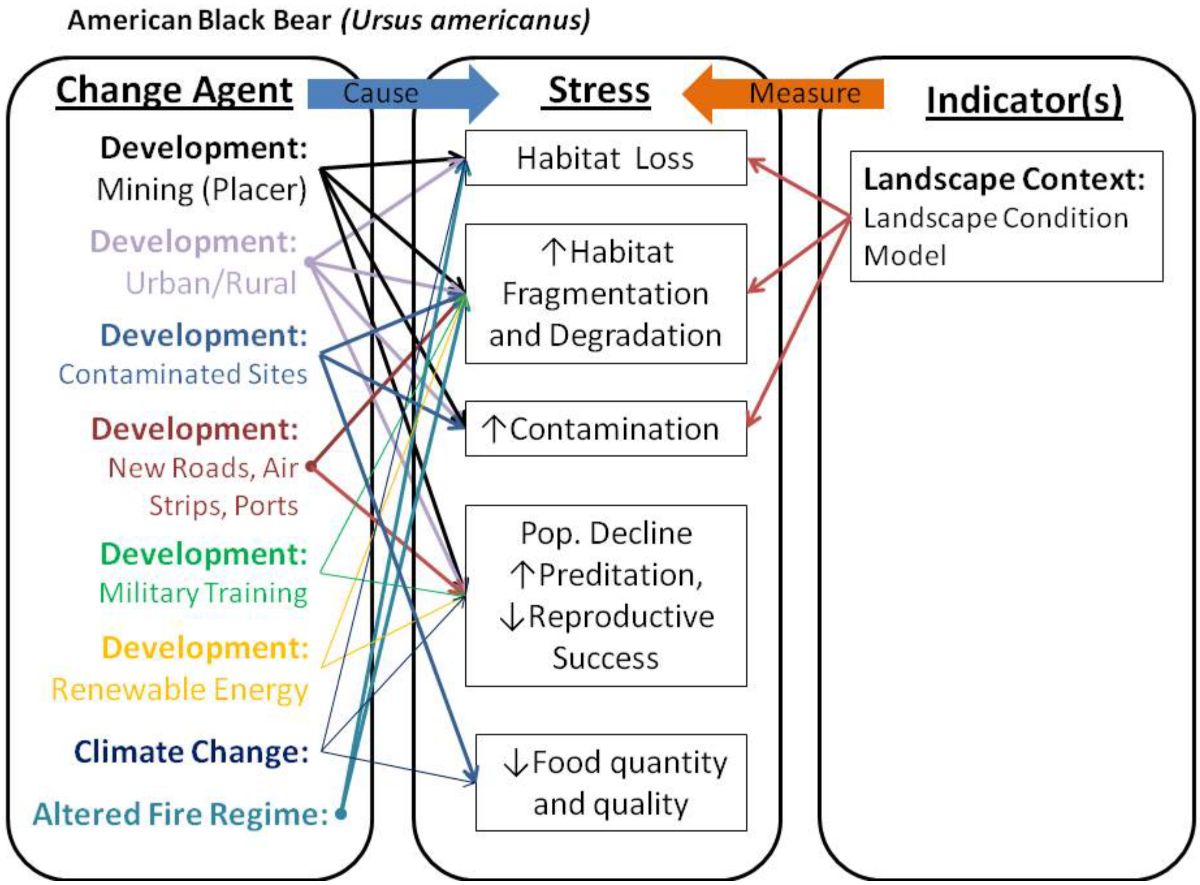
A female bear's reproductive success is dependent on her condition when she enters winter dormancy. A female that has fed well in autumn puts on much body fat and gives birth to usually 2 (rarely up to 5) cubs, whereas a female in poor condition does not produce any cubs. In the southern Appalachians, productivity and survival of young were enhanced when fall food (especially hard mast) supply was favorable (Eiler et al. 1989).

**Migration Ecology:** Home ranges vary considerably in size. This distance based on a conservatively small male home range of 1000 hectares.

**Habitat Description:** The American black bear requires a mosaic of vegetation associations rather than one plant community, so habitat diversity is important. Generally inhabits forested habitats from sea level to alpine areas. Prefers semi-open areas with fruit-bearing shrubs and herbs, lush grasses, and succulent forbs. Extensive open areas are avoided (ADFG 1973, Lariviere 2001). In general, meadows are preferred for foraging on grasses and forbs during spring. Riparian habitat, avalanche chutes, and early-successional habitat created by logging or fire are preferred for foraging during summer, and mature forest containing hard mast is preferred during fall. For denning and cover, mature or old-growth forest containing coarse woody debris, snags, and adequate cover are typically preferred (ULEV 2007). In the Yukon-Tanana uplands of interior Alaska, preferred spring forage areas with river bottoms containing brush ≥2.5 feet (0.8 m) tall and paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), and black cottonwood (*P. balsamifera* ssp. *Trichocarpa*). River bottoms contained new green leaves and abundant horsetail (*Equisetum* spp.), which composed 86% of their spring diet. During summer, American black bears preferred foraging for bog blueberries (*Vaccinium uliginosum*) in "old" burns (age not given) dominated by willow (*Salix* spp.), alder (*Alnus* spp.), and dwarf birch (*B. nana*; Hatler 1972).

**Threats/Stressors:** Locally threatened by habitat loss and interference by humans. Black market value of gall bladder and paws has led to an increase in the illegal harvest of this species.

**Figure E-36. American Black Bear Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for individual CEs were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.13 Brown Bear (*Ursus arctos*)

**Classification/Taxonomic Information:** Recent genetic studies of brown bears indicate that the traditional morphology-based taxonomy of brown bears is highly discordant with bear phylogeny as indicated by geographic patterns of mtDNA variation. Based on recent and permafrost-preserved Pleistocene material, there is no genetic (mtDNA) support for the validity of any of the commonly recognized North American subspecies (e.g., *horribilis*, *middendorffi*), and North American brown bears do not represent a distinct lineage with respect to brown bears in northern Asia and Europe (Waits et al. 1998, Leonard et al. 2000, Barnes et al. 2002). If a sub-specific name is to be applied to North American brown bears, it should be *Ursus arctos arctos*, a taxon whose range encompasses both North America and parts of Eurasia. This name has been adopted for North American brown bears by ITIS (http://www.itis.usda.gov/index.html), which lists *U. a. horribilis* and *U. a. nelsoni* as invalid because they are junior synonyms of *U. a. arctos*.

**Geography/Location:** Formerly throughout western North America, north from northern Mexico; northwestern Africa, all of the Palearctic from western Europe, Near and Middle East through the northern Himalayas to western and northern China and Chukot (Russia) and Hokkaido (Japan) (Wozencraft, in Wilson and Reeder 1993); see Pasitschniak-Arts (1993) for additional details. In North America, present range includes Alaska, northern and western Canada, northern Continental Divide in Montana, Cabinet/Yaak mountains in Montana/Idaho, Selkirk Mountains in Idaho/Washington, Northern Cascades in Washington, and Yellowstone area, Wyoming/Montana/Idaho. Some bears in the Cabinet-Yaak ecosystem of Montana and Idaho and Selkirk ecosystem of Idaho and Washington mingle in the Purcell Mountains in southern British Columbia, and movement data indicate that the Cabinet-Yaak and Selkirk populations are connected to a much larger population (several hundred bears) extending north into British Columbia (USFWS 1999). However, the listed distinct population segment is confined to the U.S. portion of these ecosystems. Common only in Alaska, parts of the Yukon, northern and coastal British Columbia, and portions of the northern Rocky Mountains. USFWS has proposed reintroduction in the Bitterroot ecosystem of east-central Idaho and adjacent Montana. In Europe, apart from northern Europe, distribution has shrunk to a few isolated populations in the Pyrenees, the Apennines, the Alps, the Balkan Peninsula, and the Carpathians (see Hartl and Hell 1994).

**Life History & Ecology:** Color ranges from pale yellowish to dark brown; usually white tips on the hairs, especially on the back, resulting in a frosted or grizzled effect; facial profile concave; claws on front feet of adults about 4 inches long and curved; noticeable hump above shoulders; head and body of adults about 6-8 feet, height at shoulders 3-4.5 feet (Burt and Grossenheider 1964).

This species' reproductive ecological is characterized by a long life span, late sexual maturity, and protracted reproductive cycles. Breeds in late spring and early summer. Implantation is delayed; gestation lasts about 184 days. Litter size is 1-4 (average 2). Young are born in winter and usually remain with mother the first two winters. Breeding interval generally is 2-4 years. In North America, first parturition occurs at 5-6 years in the south, 6-9 years in the north. A few live as long as 20-25 years.

**Migration Ecology:** In North America, often exhibits discrete elevational movements from spring to fall, following seasonal food availability (LeFranc et al. 1987); generally at lower elevations in spring, higher elevations in mid-summer and winter.

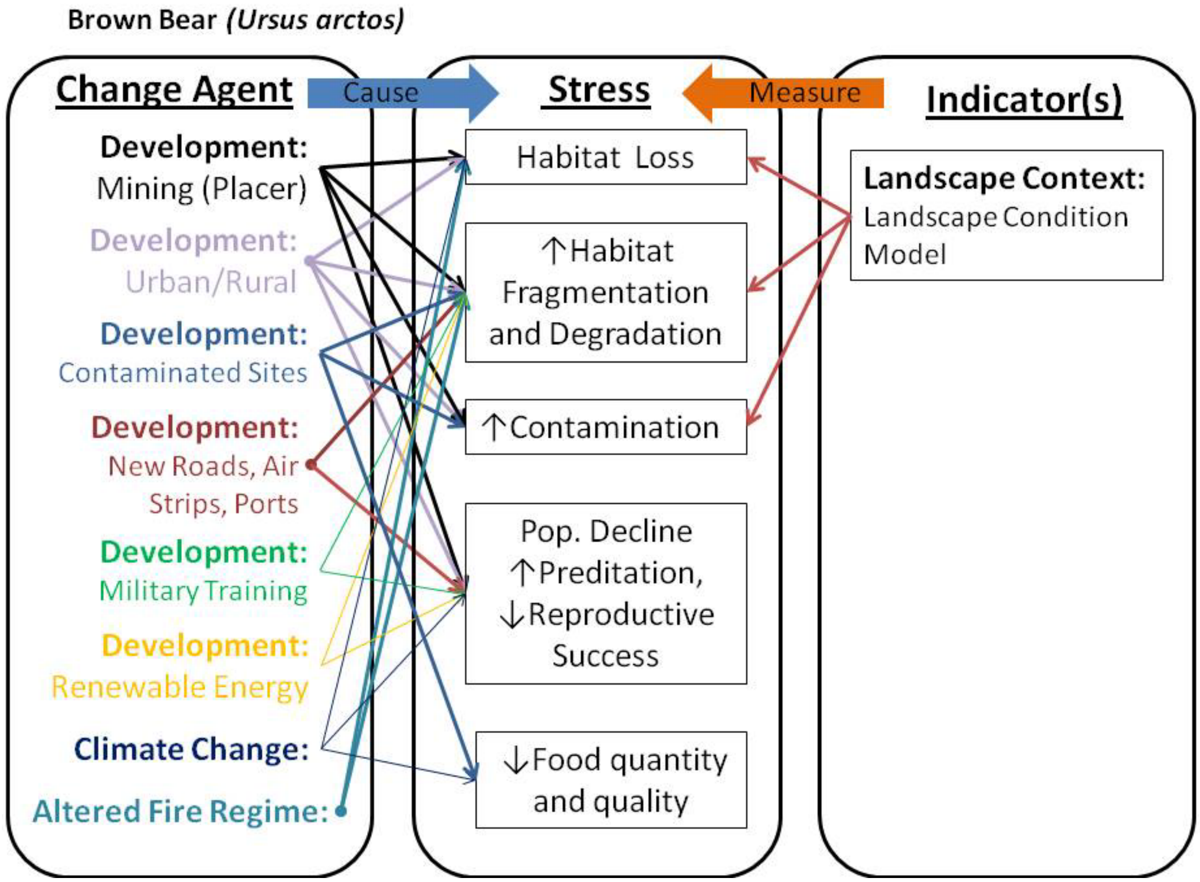
Home range exhibits much variation among different individuals, areas, and seasons; male range generally is larger than that of female; annual range varies from less than 25 square kilometers (Kodiak Island) to more than 2000 square kilometers (see LeFranc et al. 1987), generally several hundred square kilometers (Banci 1991, Pasitschniak-Arts 1993). Range from 2,000 to 60,000 hectares in Yellowstone, averaging 8,000 hectares (Craighead 1976); male home ranges in the Yukon averaged 41,400 hectares (Pearson 1975).

**Habitat Description:** In Alaska, most common in open Arctic, alpine tundra, grassland, and subalpine forests. Prefer open, shrub communities, alpine and low elevation meadows, riparian areas, seeps, alpine slabrock areas, and avalanche chutes (Willard and Herman 1977, Servheen 1983, Zager et al. 1983). In forests, typically occur near mountain meadows muskegs, sedge flats, and other grasslands (ADFG 1973, Schoen and Gende 2007, NatureServe 2007b). Den sites are often on hillsides (MacDonald and Cook 2009). They typically choose low elevation riparian sites, wet meadows, and alluvial plains during spring (Willard and Herman 1977, Reichert 1989). During summer and fall, brown bears more frequently use high elevation meadows, ridges, and open, grassy timbered sites (Servheen 1983, Reichert 1989).

In northwestern Alaska, brown bears primarily occur in upland and mountainous areas, but may occur in lowland and coastal areas. Concentrations of bears may be found along rivers when spawning salmon are present, at beached marine mammal carcasses along the Chukchi Sea coastline, and in reindeer and caribou calving areas and migration corridors. Spring concentration areas include Cape Espenberg to Goodhope Bay coastline, Cape Rodney to Tiksuk River, coastline near Bluff, and coastline from Unalakleet to St. Michael (NABCMP 2006).

**Threats/Stressors:** This species has disappeared over much of its Holarctic range, and continues to decline in the face of habitat alienation, alteration, and loss, as well as increased human access to wilderness. Low reproductive rate limits recovery rate. Stable populations occur in some large wilderness areas; protection and management are necessary for long-term survival.

**Figure E-37. Brown Bear Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for individual CEs were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.14 Moose (*Alces americanus*)

**Classification/Taxonomic Information:** The scientific name for moose is *Alces americanus* (Linnaeus). Wilson and Reeder [299] consider Eurasian elk (*Alces alces*) and moose distinct species. Five subspecies of moose are recognized globally, 4 of which are found in North America.

**Geography/Location:** Alaska and Canada south through Rockies, northern Great Lakes, and New England; Russia, east of the Yenisei River, east to Anadyr region (eastern Siberia) and south to northern Mongolia and northern China; introduced but now extirpated in New Zealand (Boyeskorov 1999; Grubb, in Wilson and Reeder 2005). This range does not include that of the Eurasia elk (Alces alces) here recognized as a distinct species, following Boyeskorov (1999) and Grubb (in Wilson and Reeder 2005).

**Life History & Ecology:** Breeds September-late October; peak in mid-September. Gestation lasts 240-246 days. One calf (less commonly 2) born late May-early June. Sexually mature in 1.5 years, though females do not reach peak productivity until age 4 years and most males do not breed until 5-6 years old due to intrasexual competition.

Depending on habitat, home range may be up to several thousand hectares (Lawson and Rodgers 1997). Population density has been reported as up to 1-3 per square mile (= 11.6 per 10 square kilometers) (Peterson 1955), but 18-20 per 10 square kilometers in un-hunted area in eastern Quebec (Crete 1989). May herd in winter.

Winter weather (snow accumulation) may strongly affect populations, even more so than wolf density (Mech et al. 1987); however, Messier (1991) found that competition for food, but not wolf predation and snow, had a regulatory impact on moose. Van Ballenberghie and Ballard (1994) found that in naturally regulated ecosystems predation by bears and wolves often is limiting and may be regulating under certain conditions. See also Messier (1994, Ecology 75:478-488) for population models of moose-wolf interactions.

Under favorable conditions, capable of large annual increases (20-25%) in population size; large populations may degrade habitat, resulting in population crash. See Albright and Keith (1987) for study of population dynamics of introduced population in Newfoundland: poor winter condition but high rate of calf survival [few predators].

Nudds (1990) discusses the relationships between white-tailed deer, moose, and meningeal (brain) worms. Brainworm may limit moose populations in areas where white-tailed deer are common. Deer are not negatively impacted by the brainworm, the larval stage of which is passed in deer feces. Snails, often inadvertently ingested by moose feeding on vegetation, are the intermediate host for the worm. Deer, through worm-mediated impacts, commonly are believed to exclude moose and caribou from areas where deer occur; however, an analysis by Schmitz and Nudds (1994) concluded that moose may be able to coexist with deer, albeit at lower densities, even in the absence of habitat refuges from the disease. Whitlaw and Lankester (1994) found that the evidence that brainworm has caused moose declines is weak.

Moose may alter the structure and dynamics of boreal forest ecosystems. At Isle Royale, Michigan, moose browsing prevented saplings of preferred species from growing into the tree canopy, resulting in a forest with fewer canopy trees and a well-developed understory of shrubs and herbs; also, browsing may have caused an increase in spruce and a decrease in balsam fir (McInnes et al. 1992).

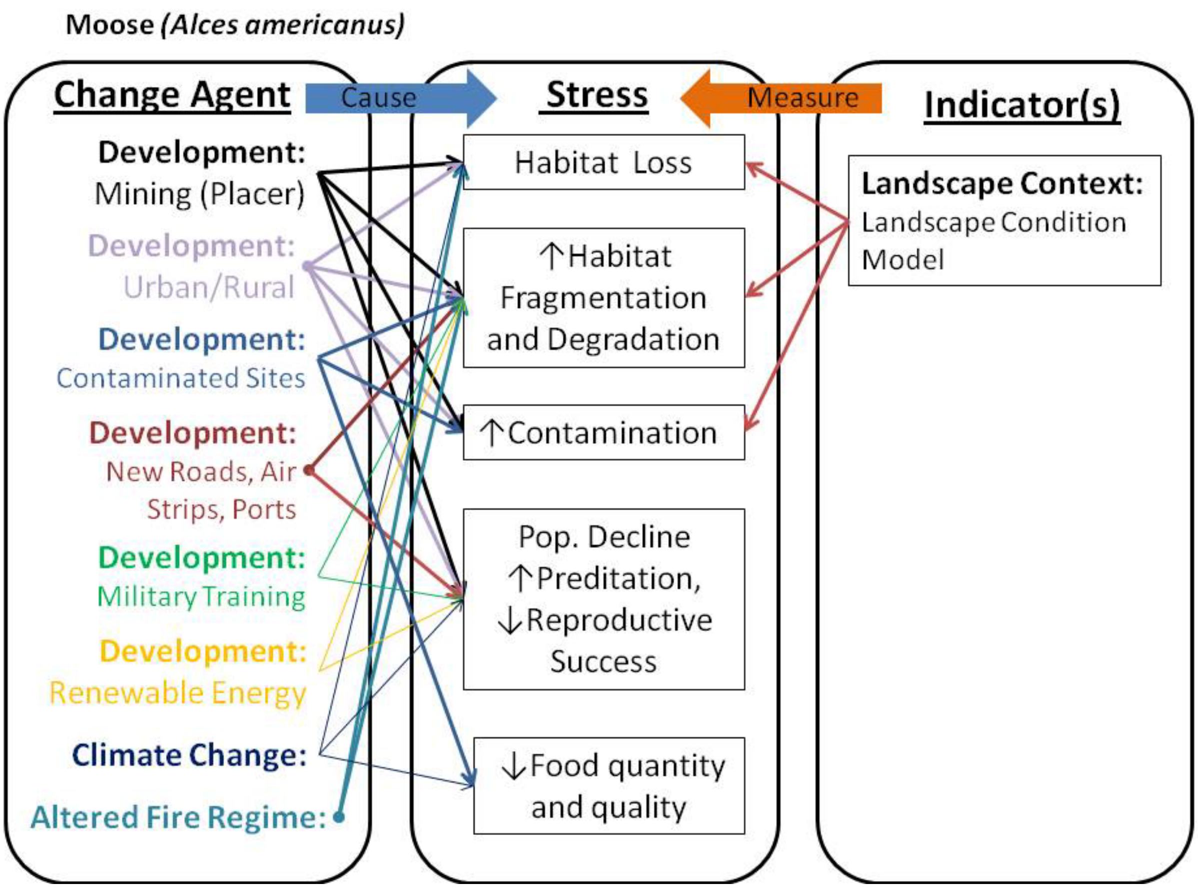
**Migration Ecology:** Home ranges up to at least 4,000 hectares (minimum convex polygon; Lawson and Rodgers 1997). In some populations, however, individuals migrate up to 179 kilometers (LeResche 1974). Unsuitable habitat includes extremely rugged mountains, open water and, near the southern limits of the species' range, warmer lowland areas below the boreal or subalpine zones.

**Habitat Description:** Moose generally select for habitats that offer the highest density, highest biomass, and most nutritious forage (Telfer 1978, Peek 2007, Thompson et al. 2007). Across the moose's range in North America, important moose habitats include mature, closed-canopy conifer or conifer-hardwood forests and high forage-producing, early-successional forests, shrublands, and aquatic habitats (Geist 1998, Feldhamer et al. 2003, Peek 2007). Moose appear to require both young and old forests in their home ranges (Thomas 1990). Seasonally, moose use high forage-producing, open-canopy habitats in spring and early summer and again in late fall and early winter. They shift to denser cover in late summer and in midwinter. Habitat use is largely governed by forage availability, except when severe winter weather favors use of closed-canopy forests (Peek et al. 1976).

Associated with a wide variety of forest, shrub (particularly willow), and wetland habitats at various elevations. Forages on shrubs and early successional trees (popular, birch) in forested areas. In Alaska, traditionally move between mountains and adjoining lowlands seasonally (ADFG 1973, Franzmann 1981, Peterson 1955). Abundant in recently burned areas and naturally disturbed areas that have dense stands of willow, aspen, cottonwood, and birch. Often abundant along riparian corridors in patches of willow.

**Threats/Stressors:** The main threat to the species comes from habitat alteration. Although the moose is quite tolerant of disturbed habitats, forestry and agricultural practices have reduced the extent of boreal forest. Collisions with motor vehicles and trains also cause a significant number of moose deaths (Franzmann 1981)

**Figure E-38. Moose Conceptual Model/Diagram**



**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for individual CEs were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.15 Muskox (*Ovibos moschatus*)

**Classification/Taxonomic Information:** *Ovibos moschatus* is the accepted scientific name for this species. Groves (1997) examined mtDNA variation and found low levels of variability and no support for the recognition of the two nominal subspecies.

**Geography/Location:** Muskox was extirpated from Alaska, then reintroduced from Greenland; it is currently found in north central, northeastern, and northwestern Alaska, on Nunivak Island, Nelson Island, the Seward Peninsula, the Yukon-Kuskokwim Delta, and in domestic herds across the state. Outside Alaska, its range includes northern Canada mainland, most Arctic islands, and Greenland. Introduced populations occur in Scandinavia and Taimyr Peninsula. Distribution may fluctuate somewhat in response to long-term climatic variation.

**Life History & Ecology:** Breeds August-September. Litter size usually is 1. Young are born mainly April-early May in some areas (e.g., Banks Island), mainly May (first 3 weeks) in northern Alaska. Calf nurses until after first winter. Females usually first breed at 3 years and may not breed every year.

Forms herds of up to about 100 (generally 5-45); group sizes are larger in winter than in summer; density generally less than 1/sq km (Heard 1992). Breeding age bulls are solitary or in single-sex groups except when they join herd during summer rutting season. Basic social unit: females and young. Productivity and mortality are greatly influenced by weather. Major predator is the gray wolf; sometimes preyed on by brown bears and polar bears in summer.

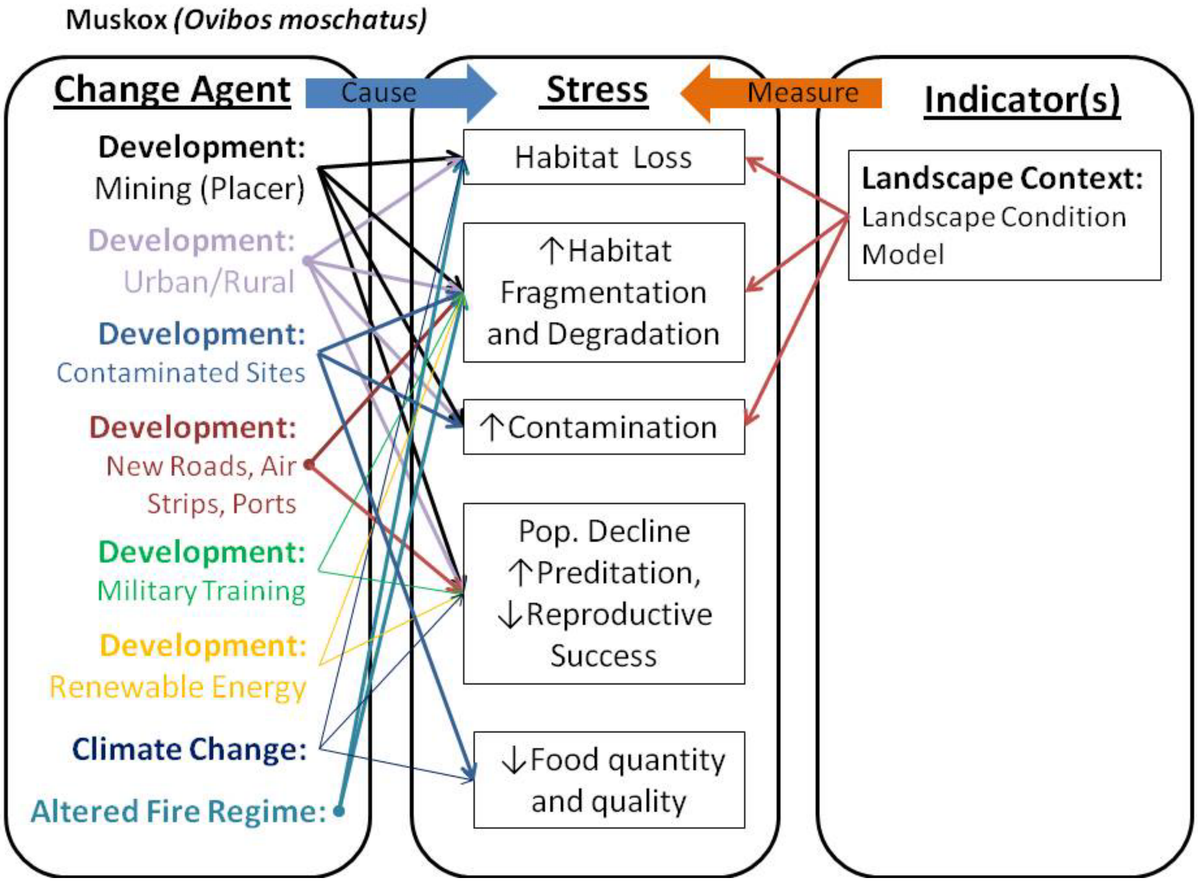
**Migration Ecology:** The muskox migrates from sheltered, moist lowlands in the summer to higher, barren plateaus in winter. The primary reason for this is food: exposed plateaus do not accumulate snow due to high winds, therefore making food easier to find. The distance travelled between summer and winter areas generally does not exceed 80 kilometers / 48 miles.

**Habitat Description:** Inhabits Arctic tundra. In the high Arctic, usually associated with well-vegetated sedge slopes on low-elevation coastal sites and valleys of water courses. On mainland, vegetation mostly willow and birch thickets associated with sedges, grasses, and forbs. Feeds in wet meadows in summer, in lowland meadows or on windswept ridges in winter. In summer, prefers moist habitats and riparian vegetation, where sedges and sometimes shrubs play a major role in their summer diet (Lent 1988). In winter, may shift to hilltops, slopes, and plateaus (Nowak 1991).

A small population of muskox is found in northwestern Alaska, mostly along the Cape Thompson and northern Seward Peninsula areas. Muskox eat a wide variety of plants, including grasses, sedges, forbs, and woody plants. They are poorly adapted for digging through heavy snow for food, so winter habitat is generally restricted to areas with shallow snow accumulations or areas blown free of snow (NABCMP 2006). On the Seward Peninsula, sites with mountain avens-lichen heath and hummocky lichen mats are important feeding areas. Hilltops often offer both high lichen availability and shallower, softer snow than lower slopes and valley bottoms in the winter (Ihl and Klein 2001).

**Threats/Stressors:** Historically this species declined because of over-hunting, but population recovery has taken place following enforcement of hunting regulations. Management in the late 1900s was mostly conservative hunting quotas to foster recovery and recolonization from the historic declines. Currently, there is increasing realization that periodically on some Arctic islands, die-offs of up to 40% of the island's muskoxen occur when warmer fall weather leads to icing and deeper snow which restrict forage availability. On the North American mainland, muskoxen have typically expanded their range by re-colonizing historic ranges; however, behind the colonizing edge, abundance declines at least partially due to predation by wolves and grizzly bears. A persistent concern of people is that muskox through their presence (smell) and foraging are detrimental to caribou (*Rangifer tarandus*). The environmental consequences of climate warming are likely to have an impact on this species.

**Figure E-39. Muskox Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

Climate change and its synergistic relationships with fire regimes and permafrost are expected to have substantial impacts on habitats throughout the SNK ecoregion, as well as varying degrees of impact on species. However, these change agents are not readily modeled at the scale of individual CEs with currently available data and modeling tools; therefore, measurable indicators of the effects of these change agents for individual CEs were not identified. (These change agents are instead assessed with general reference to CEs as a whole or groups of CEs for the SNK ecoregion.) Relative impacts of development change agents such as roads, mining, and local renewable energy projects on the ecological status of CEs are assessed with the landscape condition indicator. Given available data and modeling tools, the landscape condition indicator is the single indicator that could readily be evaluated for individual terrestrial CEs.

**Landscape condition model (LCM) index:** This indicator is measured in a GIS by intersecting the mapped area or habitat distribution map of the CE with the NatureServe condition model layer (Comer and Hak 2009) and reporting the overall condition index for the CE or habitat by the 2 x 2 kilometer pixel reporting units used for terrestrial CEs. The results are an index of landscape condition ranging from 0 to 1, with 1 being very high landscape condition and 0 having very poor condition.

**Justification for the LCM index indicator:** Infrastructure and other anthropogenic land uses have a range of impacts on ecological systems and species, including direct habitat loss, habitat fragmentation, and variable off-site or indirect impacts.

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## E-3.16 Western Arctic Caribou *(Rangifer tarandus)*

Note: This summary is for caribou (*Rangifer tarandus*) as a whole. The Western Arctic Herd is considered to be a barren ground subspecies, *Rangifer tarandus granti*.

**Classification/Taxonomic Information:** Cronin (1992) found considerable variation in mtDNA among populations in Alberta, Labrador, Newfoundland, and Alaska; geographic differentiation was evident, but woodland and barren ground subspecies were not distinguishable by mtDNA genotypes. Populations of *R. t. pearyi* on the Queen Elizabeth Islands are genetically and possibly ecologically distinct from all other forms of *Rangifer*, including those on the southern tier of arctic islands (south of 74 degrees N latitude, excluding Baffin and Bylot islands) (Miller, 1991 COSEWIC report). See Grubb (in Wilson and Reeder 2005) for brief discussion of currently recognized subspecies and subspecies groups.

**Geography/Location:** Circumboreal in tundra and taiga. The range formerly extended as far south as central Idaho, the Great Lakes area, and northern New England in North America and into central Germany in Europe. North America: wild populations currently extant in Alaska, Canada, Washington, and northern Idaho. Reintroduced from Newfoundland to Maine in 1986. Introduced and feral in Iceland, Kerguelen Islands, South Georgia Island, Pribilof Islands, St. Matthew Island; extirpated in Sweden (Grubb, in Wilson and Reeder 1993, 2005). See Bernard and Horn (1989) for summary of introductions in eastern North America.

**Life History & Ecology:** Breeds mostly in October. Gestation lasts about 227-230 days. Cows bear usually 1, sometimes 2, young in May and June (early June in northern British Columbia). Calves precocious. Adult females sometimes skip reproduction for a year, in response to nutritional stress (Cameron, 1994, J. Mamm. 75:10-13). In northeastern Alaska and adjacent Canada, 80% of adult females (age 3 years or older) gave birth each year (Fancy et al. 1994).

Gregarious; in tundra, usually in bands of 10-50 or loose herds of about 1,000 individuals. Sexes may segregate seasonally. May form herds after fawning (not in southeastern Manitoba). Tundra caribou may travel extensively in summer in attempt to avoid bothersome insects (Fancy et al. 1989).

Often incurs high calf loss, mostly due to predation (Bergerud et al. 1984). In south-central Alaska, Bergerud and Ballard (1988) concluded that wolf predation limited caribou recruitment, though winter starvation was proposed as the important population control by another researcher.

In northeastern Alaska and adjacent Canada, first-year survival of calves was 51%; mean annual survival rate was 84% for adult females and 83% for adult males; hunting mortality for the herd averaged 2-3% annually (Fancy et al. 1994).

In Quebec, home range size of adult females averaged 148 square kilometers and did not vary seasonally or annually (Ouellet et al. 1996).

White-tailed deer carry and disperse into the environment meningeal worms that usually are fatal to moose and caribou but are clinically benign in deer; hence, white-tailed deer, through worm-mediated impacts, commonly are believed to exclude moose and caribou from areas where deer occur (see Schmitz and Nudds 1994).

**Migration Ecology:** In areas where still ranges freely, may form herds and migrate seasonally. Tundra populations may migrate 800 miles between summer and winter ranges; other populations make seasonal elevational migrations. In northern Alaska, winters in northern foothills of Brooks Range, females reach calving areas along coastal plain by mid-May; population highly aggregated near Arctic coast and river deltas in July (Carruthers et al. 1987); begin return migration to winter range in September-October; cows annually may travel over 5000 km (Fancy et al. 1989). Heard and Williams (1992) described the migration in the Northwest Territories, Yukon, and Alaska as follows: cows begin migration to tundra in March-April, reach calving grounds in time for early June parturition; adult males migrate later but most reach tundra by June; return to tree line by early September, may not enter forest until October. Did not migrate in southeastern Manitoba (Darby and Pruitt 1984).

**Habitat Description:** Caribou are generally associated with Arctic tundra (including tussock tundra and sedge meadow), sub-Arctic taiga, mature coniferous forest, semi-open and open bogs, rocky ridges with jack pine, and riparian zone. Migratory herds in Alaska, Yukon, and Northwest Territories winter in boreal forest, summer in tundra. In northern British Columbia, seeks high south slopes in mountains as calving site (Bergerud et al. 1984). Porcupine Herd of northeastern Alaska and northwestern Yukon: females give birth on patches of bare ground within snowfields (Eastland et al. 1989); cows select areas north of the foothills (snow conditions permitting), thereby reducing exposure of calves to predators.

The Western Arctic herd is the largest caribou population in Alaska, occupying the northwestern quarter of the state. The herd's summer range in the approximately 140,000 square mile range consists of the northern foothills and mountains of the Brooks Range west of the Trans-Alaska pipeline. The calving grounds are located near the center of this summer range. Important insect relief areas are from Point Lay to Cape Lisbourne and in the mountains. In their annual migrations between summer and winter ranges, Western Arctic caribou travel through a variety of Brooks Range passes and along the western coastal plain and foothills (WACH Working Group, 2003).

In most years since the mid-1980s, at least half of the herd wintered in the eastern third of the Seward Peninsula and in the Nulato Hills as far south as the Unalakleet River drainage. Since 1996 the herd expanded its winter range westward on the Seward Peninsula. Also, in the late 1990s, many Western Arctic caribou wintered in the upper Koyukuk River drainages and on the North Slope between Atqasuk, Wainwright and Umiat (WACH Working Group, 2003).

The vegetation in the core winter range of the Western Arctic caribou herd is dominated by lowland, treeless tussock tundra (primarily *Eriophorum vaginatum*), but also contains rolling hills (up to 900 m in elevations ) and large riparian corridors. Terricolous forage lichens in unburned areas are important areas for caribou (Joly et al. 2007). During the winter, caribou concentrate in areas where shallow snow cover allows them to reach lichens, grass, sedges, and shrubs. Lichens grow slowly, typically requiring over 50 years to develop a stand that can sustain caribou. Caribou often feed in different locations in successive years in an apparent adaptation to the slow growth of depleted lichen ranges (NABCMP 2006).

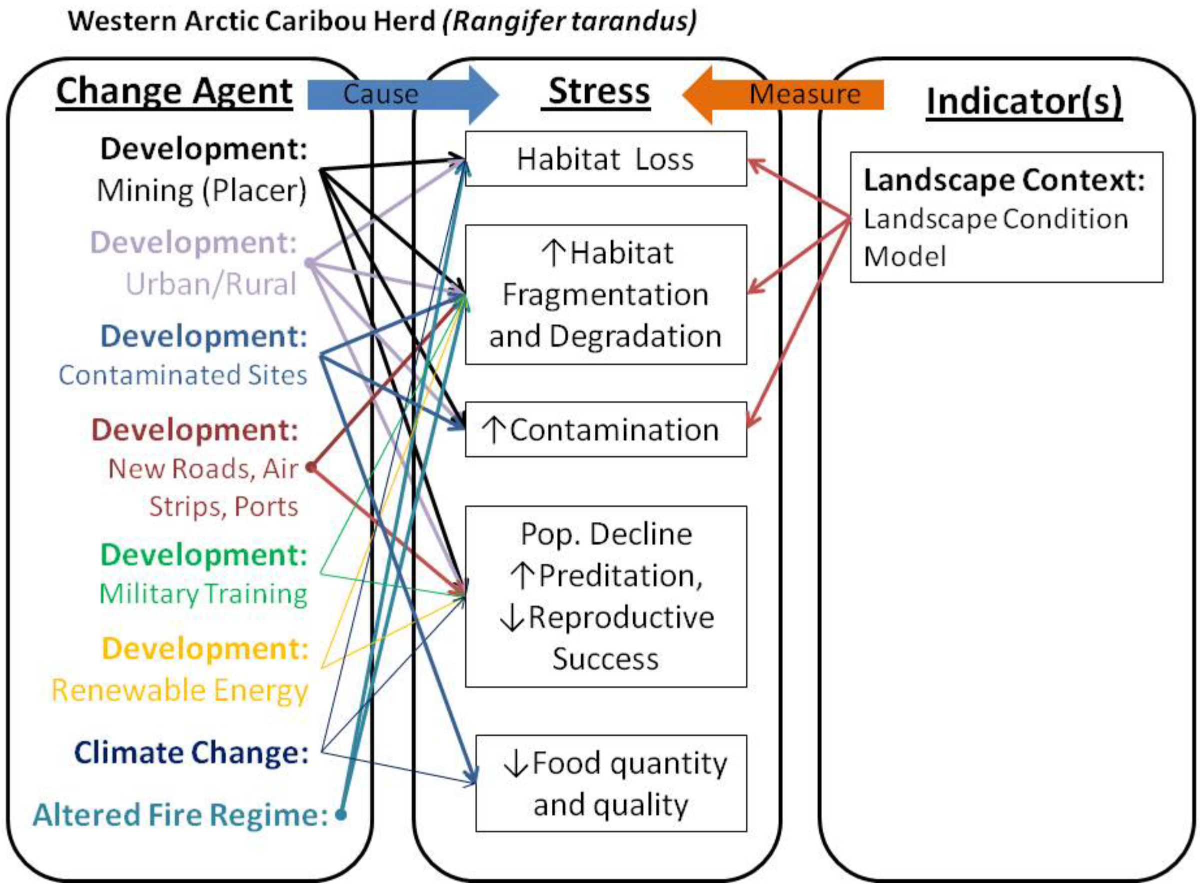
**Threats/Stressors:** Recent global declines in caribou and reindeer populations appear to be associated with changes in phenology, spatiotemporal changes in species overlap (e.g., other ungulate species, predators, disease organisms), and increased frequency of extreme weather events (Vors and Boyce 2009). Changes in availability of lichen forage are a possible consequence of the interactions of climate change with fire regimes; lichens are slow to regrow after fire. This may impact caribou populations within the SNK ecoregion.

The Porcupine caribou herd in northeastern Alaska and adjacent northwestern Canada and the adjacent Central Arctic herd are potentially threatened by onshore petroleum exploration and development; industrial development on the coastal plain of the Arctic National Wildlife Refuge could increase calf mortality if calving were displaced south and east of potential development areas (Fancy and Whitten 1991). However, Pollard et al. (1996) documented high use of oil fields by caribou during periods of high mosquito and fly activity.

In other portions of the global range of caribou, the following threats have been documented:

- Peary caribou (subspecies *pearyi*) face high winter mortality, low reproduction, and minimal recruitment, with additional pressure from hunting and disturbances associated with industrial activities (see 1991 COSEWIC report by F. L. Miller; also 1979 COSEWIC report by Gunn et al.).
- Failed reintroductions often result when white-tailed deer are common; caribou probably contract meningeal worm disease from white-tailed deer (Bernard and Horn 1989).
- Predation by an expanding coyote population threatened a remnant caribou herd in southeastern Quebec (Crete and Desrosiers 1995).
- Long-term steady decline in the taiga-dwelling population in Ontario has been associated with the expansion of forest harvesting (Schaefer 2003).

**Figure E-40. Western Arctic Caribou Conceptual Model/Diagram**




**ECOLOGICAL STATUS INDICATORS**

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# E-4 Aquatic Fine-Filter Landscape Species CEs

## E-4.1 Introduction

This section contains conceptual models – descriptive text and diagrams – for the nine fish conservation elements that are being treated with a "landscape" approach in the SNK REA and have a spatial distribution model. All except for the Alaska blackfish are considered subsistence species.

The descriptive text includes information on the species' taxonomy, geographic range, reproductive ecology, migration ecology, habitat, and threats/stressors. The primary purpose of these characterizations is to provide sufficient information on each species to permit the identification and characterization of assumptions about the likely effects of change agents (e.g., development, invasive species) on each species. The descriptive information was used to identify a series of variables that can serve as indicators of the ecological integrity of each species. These indicators were used to assess the ecological status of each of these species in a subsequent step in the REA.

The conceptual model diagrams illustrate our understanding of how change agents may stress the aquatic CEs and which of those individual stressors can be reflected in the indicators of ecological integrity. In addition to the understanding of a CE's composition, structure, processes, and response to stressors, data availability also shaped the set of indicators that could practically be used to evaluate aquatic CEs. **Available data sets in the SNK ecoregion reflected ecosystem stressors**, rather than direct measures of ecological condition. The five indicators that could readily be assessed for individual aquatic CEs *emphasize development-related ecosystem stressors*. Various spatial modeling approaches were developed to evaluate these indicators for the ecological status assessments of aquatic CEs. The definition and justification for each of the indicators *relevant to the individual aquatic CE* is provided, in a simple Ecological Status Indicator table for each of the aquatic CE conceptual models. The indicators are scored with values ranging from 0 to 1, with 1 indicating highest ecological status and 0 indicating lowest status (and presumably transitional to a wholly different ecological state.

The descriptive information was compiled from two major sources: the original descriptive text provided by the Alaska Natural Heritage Program for the SNK REA and species summaries generated from the program's Biotics database. Additional literature surveys were conducted by NatureServe to characterize threats and stressors for each species. This compiled information was used to develop the conceptual diagrams illustrating this information and associated assumptions.

The species information included in the AKNHP's documents was obtained from the Alaska Heritage Program's installation of Biotics, a biodiversity database developed centrally at NatureServe and maintained through the combined efforts of the member heritage programs and NatureServe. The member program biodiversity databases are coordinated with the central NatureServe database; these databases are dynamic, maintained and refined through updates made to reflect current changes to taxonomy, and by the periodic import of new records that are developed according to standard methodology by natural heritage member program scientists and other collaborators, including government agencies, universities, natural history museums and botanical gardens, and additional conservation organizations. This ongoing process of adding and revising information and records helps to maintain currentness and enhance completeness of the data.

NatureServe member programs' biodiversity databases contain an array of information about elements of biodiversity, with particular emphasis on those that are more threatened across their range. Tracked data includes taxonomy, conservation status, ecological and life history, habitat requirements, and distribution, with primary sources of this information consisting of scientific literature, museum specimen records, reliably documented observation records, species lists, range maps, external databases, and experts, including scientists from natural heritage member programs. While centrally NatureServe maintains range maps and/or data representing all native full species vertebrates and vascular plants, within individual member programs resources generally limit the tracking of specific locations of species and other elements of biodiversity within their jurisdictions to those having the highest conservation concern.

## E-4.2 Alaska blackfish (*Dallia pectoralis*)

**Classification/Taxonomic Information:** The relationship of *Dallia* to other esociforms is not settled. Most classifications place *Dallia* in the Umbridae, but it has at times been classified in a separate family, the Dalliidae. External morphometry suggests that *Dallia* is more similar to pikes (genus *Esox*). Evidence from a phylogenic analysis using DNA sequencing (Lopez et al. 2000) suggests *Dallia* should be classified in the family Esocidae (AKNHP BIOTICS 2011a).

**Geography/Location:** Alaska blackfish can be found from the Arctic coast south to Bering Sea drainages and to the Alaska Peninsula and upstream in the Yukon-Tanana drainage (Mecklenburg 2002, Morrow 1980), and are plentiful in interconnected waterways and lowland lakes, particularly in the Yukon-Kuskokwim delta (NatureServe 2011).

**Reproduction Ecology:** Little is known about the Alaska blackfish, relative to other fish species. They spawn from May to August, beginning shortly after ice breakup (Morrow 1980). Spawning habitat includes swampy potholes, bottoms of quiet streams and shallow ponds, and in aquatic vegetation (Morrow 1980, NatureServe 2011). Eggs stick to vegetation and hatch in about 10 days when water temperature is between 12°-13° C (Morrow 1980). Young live off their yolk sac for another 10 days after hatching (ADF&G 2011).

**Migration Ecology:** Migrations of the Alaska blackfish are short; they move upstream or inshore to spawn, and reverse the migration to overwinter in deeper waters (Morrow 1980). Upstream spawning migration is initiated when water temperatures rise to 10°-15° C (Morrow 1980).

**Habitat Description:** Adult Alaska blackfish are freshwater fish, and inhabit densely vegetated portions of lakes, rivers, ponds, lowland swamps, and interconnected waterways and low-lying lakes typical of river deltas (ADF&G 2011, NatureServe 2011). These fish can live in forested areas, although they are most commonly found in tundra regions in northern and western Alaska (NatureServe 2011). Alaska blackfish are unique in that they are capable of living in low-oxygen environments during dry spells, in habitats that are unsuitable for other species of fish, such as small stagnant tundra or muskeg pools, or moist tundra mosses (ADF&G 2011). They have a modified esophagus that allows gas absorption, enabling them to live off atmospheric oxygen (ADF&G 2011). They can also inhabit lakes where water conditions lead to winterkill; specifically, lakes with a maximum depth less than three meters, low flood probability, and no river connections (Glesne 1986). Eats almost exclusively small invertebrates. Small individuals eat mostly copepods and Cladocera, shifting as they grow larger to insect larvae, snails, and rarely small fishes (Scott and Crossman 1973, Morrow 1980).

**Threats/Stressors:** (See Figure E-42.) Few threats affect this species, as it occurs in relatively pristine and remote environments. Five PAHs (toxic hydrocarbons) and the PCB Aroclor were found in blackfish tissues from St. Lawrence Island near Northeast Cape, where in 1969 180,000 gallons of diesel fuel were spilled at a formerly used Defense Site (Houston et al. 2000). It is currently harvested in subsistence fisheries throughout its Alaskan range. Fall et al. (1996) found blackfish utilized in several communities of Bristol Bay, AK and estimated low harvest rates. Used as human or dog food and as bait for Pike *(Esox* *lucius*) fishing. During the winter, shrews and minks feed on blackfish that come to the surface at holes in frozen-over lakes. Also known prey of yellow-billed loon (*Gavia adamsii*) (North 1994). Subjected to strong competition for food where it co-occurs with char (*Salvelinus* spp.) (Gudkov 1998) AKNHP BIOTICS 2011a.

**Indicators of Ecological Status:** The stressor-based indicators identified for this CE (Table E-30, Figure E-42) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling (e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5th-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-41. Alaska Blackfish Conceptual Model/Diagram**

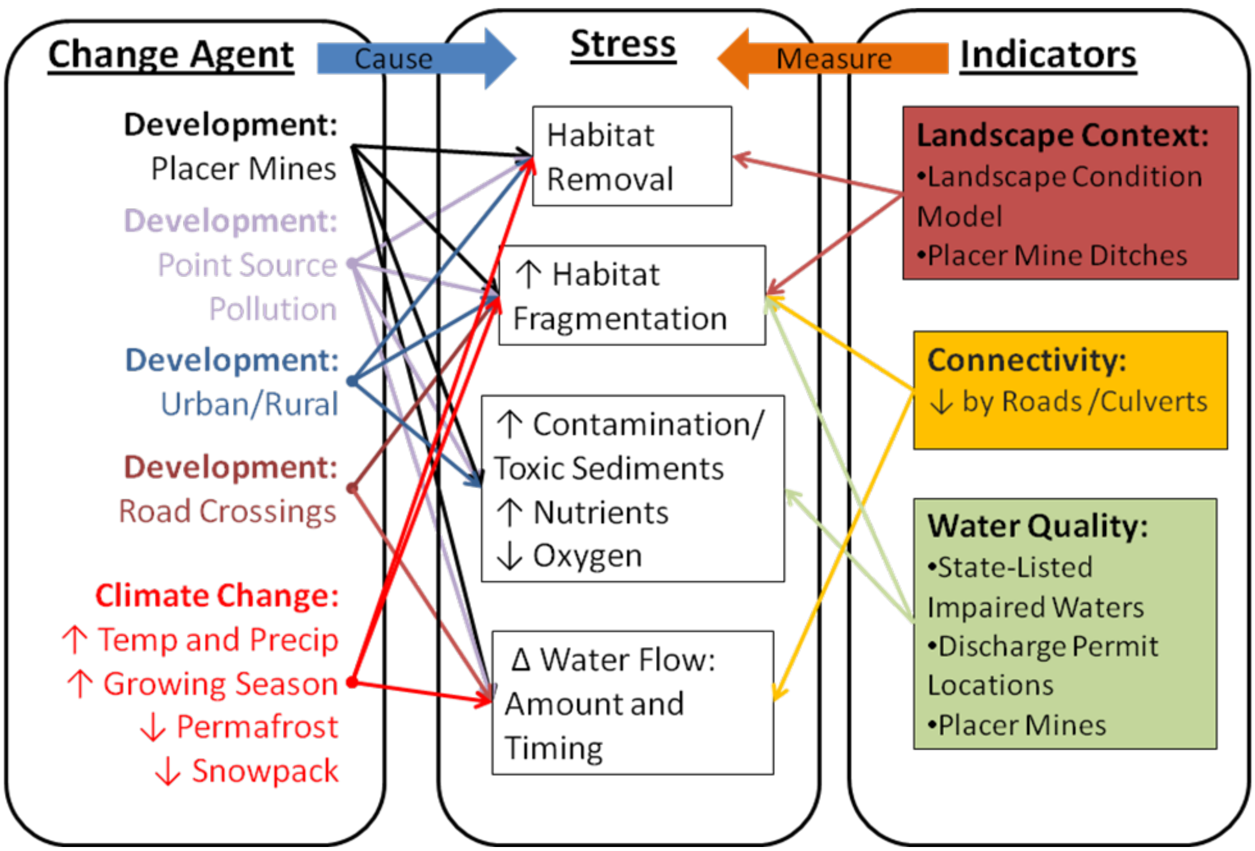

**Table E-30. Ecological status indicators for Alaska blackfish.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |
| **Key Ecological Attribute: Connectivity** | | |
| Index of Fish Passage (culverts) | This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

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## E-4.3 Arctic grayling (*Thymallus arcticus*)

**Classification/Taxonomic Information:** Once there were four isolated stocks in North America, considered separate species: *Thymallus signifer, T. montanus, T. tricolor*, and *T. ontariensis*. *Thymallus signifer* now is considered synonymous with *T. arcticus*, and others as subspecies (Lee et al. 1980). The genus includes four species: one in Europe, two in Mongolia, and probably one widespread cross Asia and North America (Nelson 1984) (AKNHP BIOTICS 2011b).

**Geography/Location:** Grayling occur throughout the arctic as far west as the Kara River in Russia and east to the western shores of Hudson Bay in Canada (ADF&G 2011). Arctic grayling are common through mainland Alaska (Mecklenburg et al. 2002, Morrow 1980), including the Selawik River delta (Brown 2004).

**Reproduction Ecology:** Spawning occurs just after ice breakup in the spring, usually between May and June (Morrow 1980). Most often spawning occurs in creek riffles; spawning in lakes may occur but is rare (NatureServe 2011). Arctic grayling prefer clean streams, and seem to have no substrate preference, but often spawn over gravel (Morrow 1980, NAB 2006). Eggs hatch after 11-21 days, depending on water temperature (Morrow 1980). Juveniles remain in quiet water close to where they hatch and in late spring move upstream to feeding areas for the summer (ADF&G 2011, NAB 2006).

**Migration Ecology:** Long migrations between feeding, spawning, and overwintering habitats are common, although some individuals may spend their entire life in a single short section of lake or stream (ADF&G 2011, NAB 2006). Some may return to the same feeding and spawning grounds every year, while others may not (ADF&G 2011). In April, Arctic grayling congregate at mouths of tributaries and move upstream through channels in the ice, and some travel over 160 km (Morrow 1980). Some adults stay in streams after spawning to feed, or leave the area when through spawning, to move upstream or into tributaries to spend the summer in pools (Morrow 1980, NAB 2006). In mid-September migration to overwintering habitat commences, which is often downstream from summer feeding areas (Morrow 1980). Both adults and juveniles overwinter in deep, large lakes or rivers, or sometimes in smaller streams where there is sufficient in-stream flow and good water quality (NAB 2006). Lakes or deep pools of clear water streams and medium-sized rivers are preferred; large glacial rivers like the Yukon are also utilized (ADF&G 2011, Morrow 1980).

**Habitat Description:** Arctic grayling are freshwater fish that prefer clear water streams and deep lakes, water temperatures from 8.3°-11.1° C, and are tolerant of low dissolved oxygen levels (ADF&G 2011, NAB 2006, NatureServe 2011). Often older and larger adults are more abundant in upper reaches of streams and rivers, sub-adults are found in middle reaches, and juveniles are at lower reaches (ADF&G 2011). Fish feed at the water's surface, or at mid-depth, and may feed on the bottom in the fall (Morrow 1980).

**Threats/Stressors:** (See Figure E-43.) Once as common as far south as Michigan and Montana, the Arctic grayling has almost disappeared from the northern United States because of overfishing, competition from introduced species, and habitat loss (ADF&G 2011). Predators probably include other fishes and predatory birds (osprey, gulls, eagles) and mammals (mink, otter) (AKNHP BIOTICS 2011b).

**Indicators of Ecological Status:** The stressor-based indicators identified for this CE (Table E-31, Figure E-43) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling (e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by

Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5th-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-42. Arctic grayling Conceptual Model/Diagram**

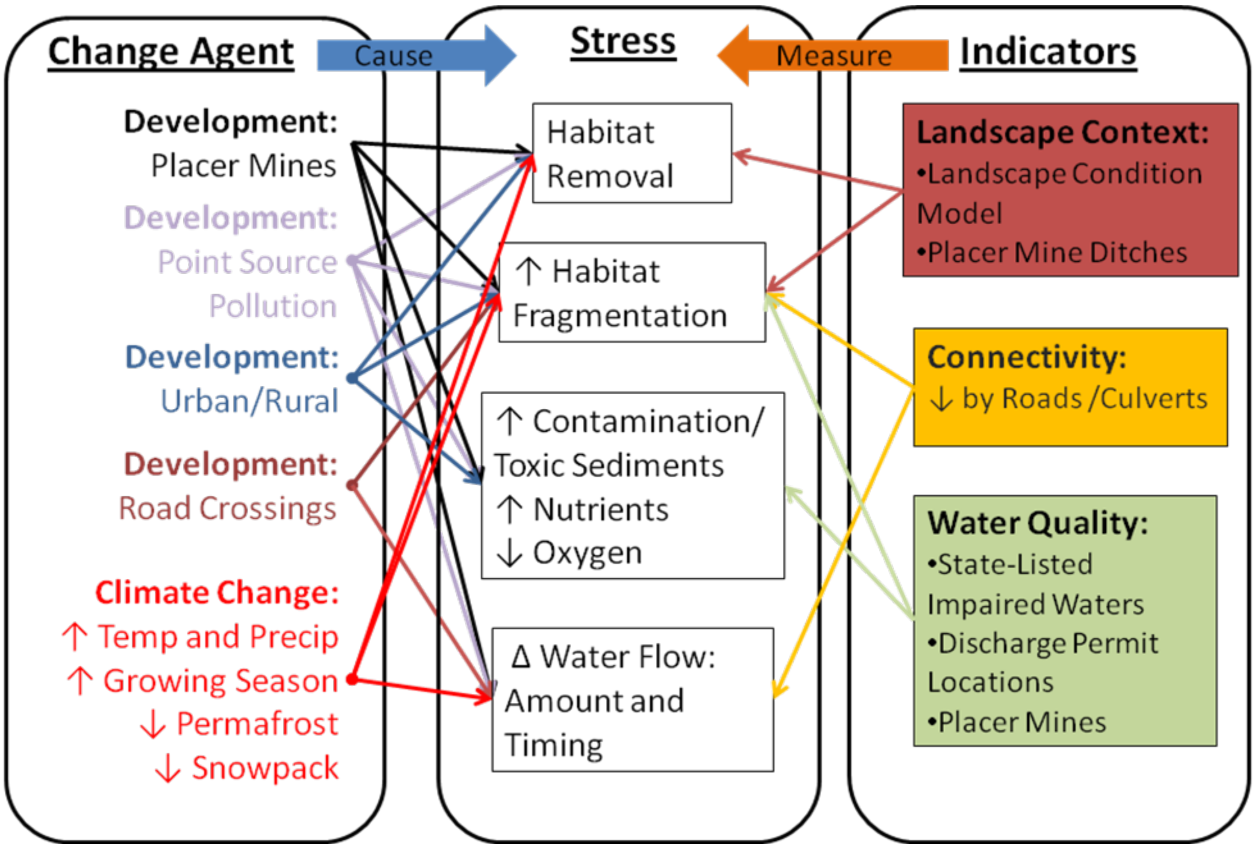


**Table E-31. Ecological status indicators for Arctic grayling.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |
| **Key Ecological Attribute: Connectivity** | | |
| Index of Fish Passage (culverts) | This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

**REFERENCES:**

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## E-4.4 Chinook salmon (*Oncorhynchus tshawytscha*)

**Classification/Taxonomic Information:** There are two behavioral forms of Chinook salmon: 1) the "ocean-type" in the southern part of their range, and 2) the "stream-type" found in Alaska and elsewhere. Stream-type Chinook spend one or more years as fry in fresh water, undertake extensive oceanic migrations, and move to natal rivers several months before spawning in the spring and summer. Infrequently, males may mature without ever migrating to the sea (NatureServe 2011).

**Geography/Location:** The northernmost North American populations of Chinook can be found at Point Hope, Alaska, just north of the Kotzebue Sound. The species continues south to California, with the greatest abundance in North America found between the Yukon River and Sacramento River in California (Morrow 1980). North of Point Hope, strays occur along the Beaufort and Chukchi coasts, as far north as the Coppermine River draining into the Arctic Ocean (Mecklenburg et al. 2002, Morrow 1980). In the sea, they are found throughout the northern Pacific Ocean, Bering Sea, and Chukchi Sea (ADF&G 2011, Morrow 1980). There are major populations in the Kuskokwim and Yukon rivers (ADF&G 2011). The Andreafsky River and its East Fork are tributary to the lower Yukon River and provide important rearing and spawning habitat for this species (Maschmann 2010), as is the Gisasa River in the Koyukuk National Wildlife Refuge (Melegari 2010).

**Reproduction Ecology:** Overall, spawns at 2-7 years old, in spring, summer, or fall, depending on population. Eggs hatch in about 2 months young remain in gravel 2-3 weeks juveniles stay in fresh water for a few days or up to 3 years; adults die soon after spawning (AKNHP BIOTICS 2011c). In the Yukon drainage, spawning occurs in July to early September, while farther south it may extend to November or December (Morrow 1980). Very few streams are used for spawning; preferred habitat are large rivers, with deep, fast moving water, and gravel riffles (ADF&G 2011, Mecklenburg et al. 2002, Morrow 1980). Spawning can occur from anywhere near to the coast to 3200 km upstream (Mecklenburg et al. 2002). Normal development of eggs requires salinity less than 8 ppt, and temperature less than 25° C (AKNHP BIOTICS 2011c).

Eggs hatch after seven to nine weeks in southern areas, and may take up to three months in colder regions (Morrow 1980). Alevins stay in gravel for two to three weeks after hatching, and remain in streams and rivers for anywhere from a few days to three years (Morrow 1980). In the Yukon River, young remain in fresh water for two to three years, but most often for one year, while young move to the sea earlier farther south (Morrow 1980). Before migrating to the ocean, Chinook smolt move to deeper water, avoiding light (Morrow 1980). Juveniles thrive in clear, cool streams and are not successful in shallow, warm lakes (Morrow 1980).

**Migration Ecology:** Upon reaching the ocean, Chinook initially remain near shore, and some stay near shore throughout their life (Mecklenburg et al. 2002, Morrow 1980). However, others migrate long distances and may move over 1600 km out to sea and can be found more than 200 m deep (Mecklenburg et al. 2002, Morrow 1980). In the spring, Chinook are scattered across the Bering Sea and northern Pacific Ocean, and in summer, populations increase around the western Gulf of Alaska and Aleutian Islands (Morrow 1980).

After one to five years in salt water Chinook return to their natal river to spawn (Mecklenburg et al. 2002, Morrow 1980). Migration toward freshwater begins in the winter, with fish arriving at river mouths in the spring (Morrow 1980). Rivers in Alaska, including the Yukon, typically have only a single run of Chinook occurring from May through July, but farther south there may be two runs (ADF&G 2011, Morrow 1980). Some fish have long migrations, and are known to travel over 3200 km in 60 days up the Yukon River (ADF&G 2011). Adults die shortly after spawning (Mecklenburg et al. 2002, Morrow 1980).

**Habitat Description:** Preferred habitats are large rivers, with deep, fast moving water, and gravel riffles (ADF&G 2011, Mecklenburg et al. 2002, Morrow 1980). Nonspawning habitat: mainly oceanic. Most spawning occurs in gravel riffles in main streams where the female forms a redd, or nest, in the gravel. Salinity of 8 ppt is the upper limit for the normal development of chinook eggs and alevins (Morgan et al. 1992). Streams with temperatures near the upper tolerance level (25 c) during spawning migrations may be able to provide habitat for chinook salmon if a patchwork of thermal refugia is present (Torgersen et al. 1999) (ANHP BIOTICS 2011c). In fresh water juveniles feed opportunistically on terrestrial and aquatic insects. In salt water they eat crustaceans as well as other bottom invertebrates. Adults eat mostly fishes (ANHP BIOTICS 2011c).

**Threats/Stressors:** (See Figure E-44.) Currently few threats are identified in Alaska, however in the Yukon and Kuskokwim rivers were there are stocks listed as special concern by the Alaska Department of Fish and Game (Augerot and Foley 2005). In the southern parts of its range, Chinook are threatened by habitat alteration, mining practices, water diversions and hatchery practices (Augerot and Foley 2005). In addition, their large individual sizes limits their habitat to larger rivers, so dams can have a greater detrimental effect, as this species has less small tributary refugia available.

**Indicators of Ecological Status:** The stressor-based indicators identified for this CE (Table E-32, Figure E-44) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling (e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5th-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-43. Chinook salmon Conceptual Model/Diagram**

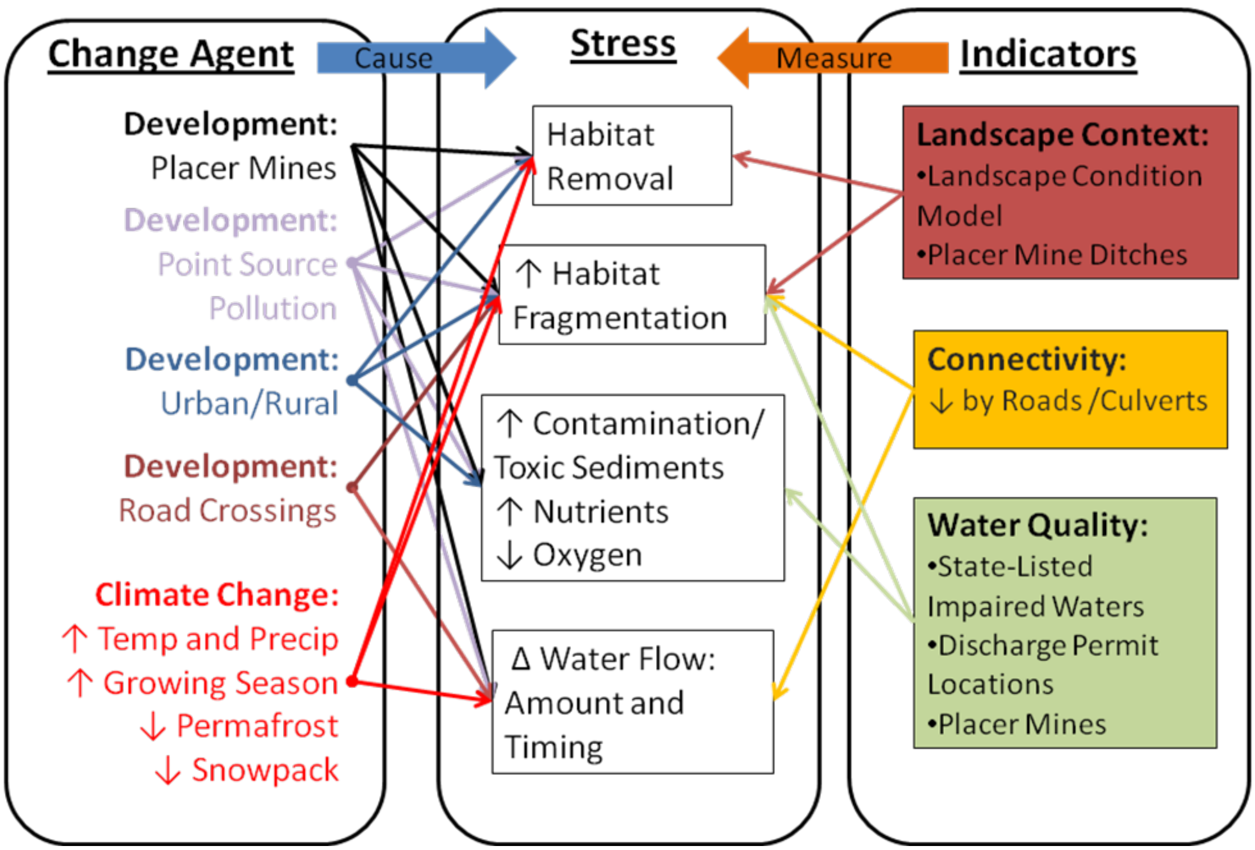


**Table E-32. Ecological status indicators for Chinook salmon.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |
| **Key Ecological Attribute: Connectivity** | | |
| Index of Fish Passage (culverts) | This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

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## E-4.5 Chum salmon (*Oncorhynchus keta*)

**Classification/Taxonomic Information:** The Yukon River hosts two runs of Chum, and may be the only location that supports a true summer run (Mecklenburg et al. 2002).

**Geography/Location:** Summer run chum enter the river around June and spawn in run-off streams that are tributaries to the lower portion of the Yukon River, primarily downstream from the Koyukuk River mouth. Fall-run chum enter the river around July and spawn in spring-fed streams, often in ground-water seeps and springs (Morrow 1980).

**Reproduction Ecology:** Most often, chums spawn in the fall in a single run and travel short distances (<160 km), although some will migrate up to 3200 km from sea to the Yukon Territory or British Columbia (Morrow 1980). Chum generally spawn in riffles with a substrate of sand (NAB 2006) or gravel with a diameter of 2-3 cm (Morrow 1980). Less frequently chums may use coarser gravel or small boulders over bedrock (Morrow 1980). Spawning streams vary in size and typically have a water temperature range from 12° to 14° C (BIOTICS 2011). Spawning may also occasionally occur in intertidal zones (ADF&G 2011, Mecklenburg et al. 2002).

Eggs hatch while streams are still covered in ice, and young proceed to sea shortly after emergence (Mecklenburg et al. 2002, Morrow 1980). Seaward migration occurs at night, and chum hide in the stream bottom throughout the day. Fry absorb yolk sac in 30-50 days (Wydoski and Whitney 1979). For those with long migrations, daytime travel may occur, and they may school in freshwater (Morrow 1980). Young chum can tolerate temperatures up to 23.8° C, but are not resistant to prolonged exposure to warm waters (Morrow 1980).

**Migration Ecology:** Chum will school and feed in nearshore waters and estuaries during the summer, and spend several months close to shore before dispersing into the ocean to feed, usually around mid-August (Mecklenburg et al. 2002, Morrow 1980). In fall, chum move into the Gulf of Alaska, the Bering Sea (ADF&G 2011), and the Chukchi Sea (Morrow 1980) where they reside for 2-7 years (NatureServe 2011). In the Yukon River, chum are most often 4 to 5 years old when they return to spawn in their natal stream and die shortly thereafter (Mecklenburg 2002, Morrow 1980). The Gisasa River in the Koyukuk National Wildlife Refuge is a tributary to the Koyukuk River and serves as rearing and spawning habitat for this species (Melegari 2010). The Andreafsky River and its East Fork are tributary to the lower Yukon River are important rearing and spawning habitat for summer chum (Maschmann 2010).

**Habitat Description:** Spends most of its life (2-7 years) in the ocean. Chum salmon spawn in rivers and streams but usually not far from salt water. Athough adults return to spawn in areas where they were hatched and may move up to 2000 km upstream to spawn in rivers lacking major barriers (Lee et al. 1980) (AKNHP BIOTICS 2011d). No freshwater residents or land-locked forms have been reported (in captivity, has been reared to maturity in fresh water). Spawns usually in streams of various sizes where temperature is 12-14 C. Spawning occurs in gravel riffles. The female digs a redd, or nest, by displacing gravel and making depressions in an area of about 2.25 sq meters (Moyle 1976). Fry migrate directly to the sea soon after emergence (AKNHP BIOTICS 2011d).

**Threats/Stressors:** (See Figure E-45.) Currently few threats are identified in Alaska (however chum stocks in the Yukon and Kuskokwim Rivers have been listed as "of concern" by Alaskan fisheries managers). In the southern parts of its range, chum are threatened by habitat alteration, mining practices, water diversions and hatchery practices with two endangered or possibly extirpated stocks in Puget Sound and lower Columbia Rivier populations and widespread extirpation in northern and central California (Augerot and Foley 2005). In addition, their large individual sizes limits their habitat to larger rivers, so dams can have a greater detrimental effect, as this species has less small tributary refugia available.

**Indicators of Ecological Status:** The stressor-based indicators identified for this CE (Table E-33, Figure E-45) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling (e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5$^{th}$-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-44. Chum salmon Conceptual Model/Diagram**

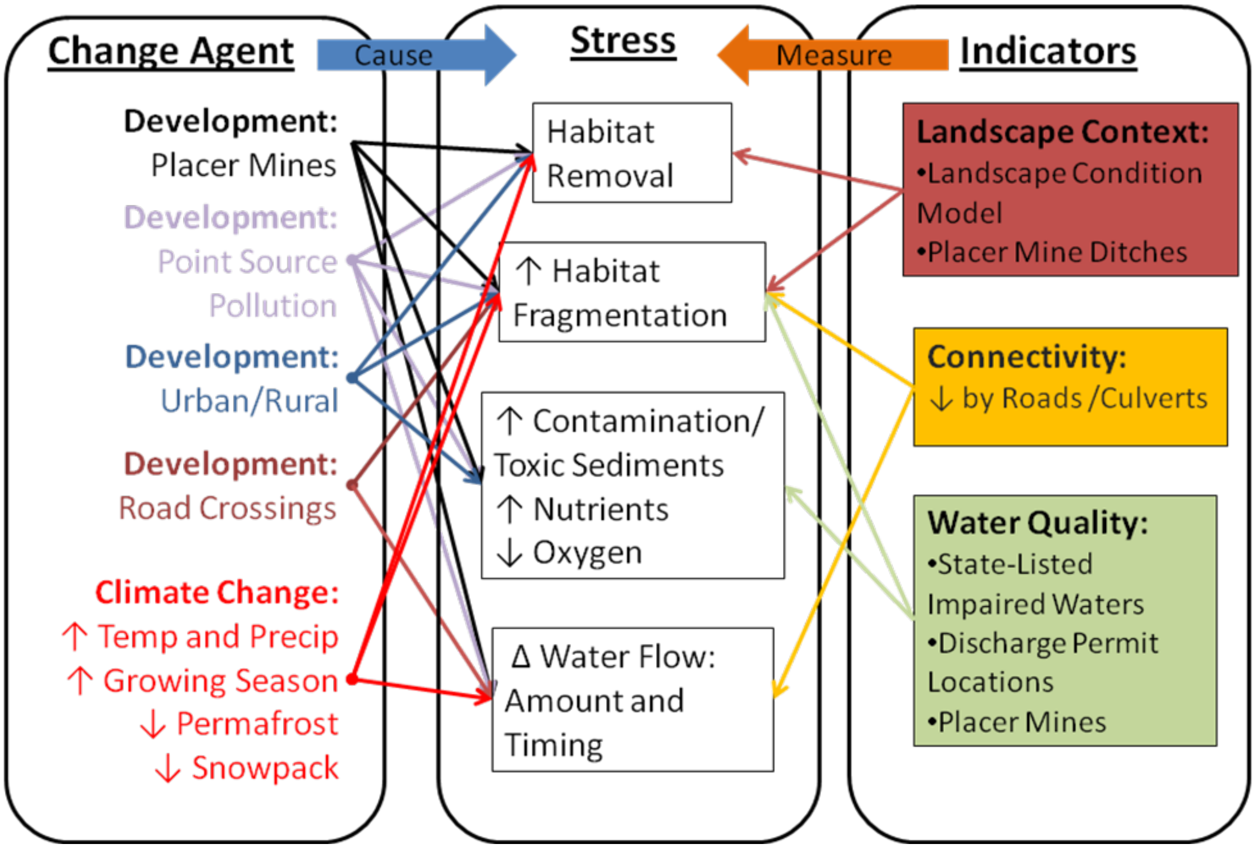


**Table E-33. Ecological status indicators for Chum salmon.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Key Ecological Attribute: Connectivity** | | |
| Index of Fish Passage (culverts) | This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

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## E-4.6 Coho salmon (*Oncorhynchus kisutch*)

**Classification/Taxonomic Information:** Apparently does not comprise genetically distinct, temporally segregated runs within a single river drainage, such as those that characterize the Chinook salmon and steelhead trout however, each coastal stream probably has a distinctive strain adapted to local conditions (Moyle et al. 1989). NMFS (1995) determined that there are six major stock groupings in the region extending from southern British Columbia to southern California (AKNHP BIOTICS 2011e).

**Geography/Location:** Coho salmon can be found from California north to Point Hope, Alaska; strays occur north along the Beaufort and Chukchi coasts (Mecklenburg et al. 2002, Morrow 1980). In freshwater coho are highly adaptable, occupying almost any accessible body of water, and occurring in the Yukon River far upstream to the Alaska-Yukon border (ADF&G 2011). The Andreafsky River and its East Fork are tributary to the lower Yukon River and provide important rearing and spawning habitat for this species (Maschmann 2010).

**Reproduction Ecology:** Coho will spawn in any accessible coastal stream, with a preference for forested regions (NatureServe 2011). Spawning occurs in heads of riffles or tails of pools, with loose, coarse gravel, a water depth of 10-54 cm, and water temperature of 6°-12° C (NatureServe 2011). Eggs take six to seven weeks to develop, although up to 115 days until hatching has been recorded (Morrow 1980).

Eggs hatch in spring, and alevins stay in gravel two to ten weeks to emerge in May or June (ADF&G 2011, NatureServe 2011). Juvenile habitats include: pools at least one meter deep in rivers and streams; submerged woody debris in runs and pools; shallow stream margins, lakes, ponds, and quiet areas without current, good cover, high dissolved oxygen levels, and plentiful invertebrate food sources

(ADF&G 2011, NatureServe 2011). At the age of one to two years coho smolt avoid light and move to deeper water (Morrow 1980). In the fall, young coho may travel long distances to locate off-channel habitat for overwintering (ADF&G 2011). Some enter brackish water their first spring and rear in estuarine ponds, then return to freshwater in the fall (ADF&G 2011). The duration of time spent in freshwater varies, with northerly populations remaining in freshwater longer (NatureServe 2011). Young may stay in freshwater for anywhere from a few weeks to five years before moving to sea (ADF&G 2011, NatureServe 2011). The young travel downstream at night and enter the ocean in spring or early summer (Morrow 1980). They remain close to shore initially, then gradually move out and school in the ocean (Mecklenburg et al. 2002, Morrow 1980).

**Migration Ecology:** Once at sea, Alaskan coho spread throughout the northern Pacific Ocean and Bering Sea, and remain at sea for one to three years (Mecklenburg et al. 2002, Morrow 1980). The spawning run occurs between midsummer and winter, and happens earlier to the north and later in the south (Morrow 1980). Fish enter spawning streams during times of high runoff and migration to spawning grounds can take several weeks or months (ADF&G 2011). Adults remain in pools and avoid riffles until they are ready to spawn; spawning occurs at night, and adults die shortly thereafter (Mecklenburg et al. 2002, Morrow 1980).

Eighty-five percent of coho return to natal streams to spawn, while others will colonize newly accessible streams rather than return to their natal stream (Mecklenburg et al. 2002, Morrow 1980, NatureServe 2011). In the Yukon River, spawning occurs in spring-fed tributaries as far upriver as Tanana, but is more common in short coastal streams (Mecklenburg et al. 2002, Morrow 1980).

**Habitat Description:** Usually spends 2 (range 1-3) growing seasons in the ocean before spawning. In ocean, generally stays within 30 km of natal stream (but up to several hundred kilometers away), remains over continental shelf. Young spend a few weeks to 2 years (varies geographically) in freshwater before migrating to sea (spends longer time in fresh water in the north than in the south) (AKNHP BIOTICS 2011e). Juveniles prefer pools at least 1 m deep with plenty of overhead cover and temperatures of 10-15 C most numerous among woody debris in pools and runs, where oxygen and invertebrate populations remain high (Moyle et al. 1989). Hatchlings that have left the spawning site seek shallow water, usually along stream margins juveniles move into stream pools. Fry may summer in brackish water in southeastern Alaska. Fry initially form schools, later become territorial after attaining parr stage. Fry feed on a variety of small invertebrates. Parr feed on aquatic insects and their larvae, terrestrial insects, and some small fishes. At sea, they to form schools and prey primarily on other fishes (Moyle 1976), also invertebrates (AKNHP BIOTICS 2011e). Stocked populations occur in lakes and reservoirs.

**Threats/Stressors:** (See Figure E-46.) Currently few threats are identified in Alaska. In the southern parts of its range, coho are threatened by habitat alteration, mining practices, water diversions and hatchery practices. Coho have been largely extirpated from the upper Columbia River system (Augerot and Foley 2005). Damming and coastal development continue to threaten remaining stocks in northern and central California (Augerot and Foley 2005). In addition, their large individual sizes limits their habitat to larger rivers, so dams can have a greater detrimental effect, as this species has less small tributary refugia available.

**Indicators of Ecological Status:** The stressor-based indicators identified for this CE (Table E-34, Figure E-46) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling (e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent).  KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5th-level watersheds (10-digit hydrologic catalog units, or HUC10).  The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-45. Coho salmon Conceptual Model/Diagram**

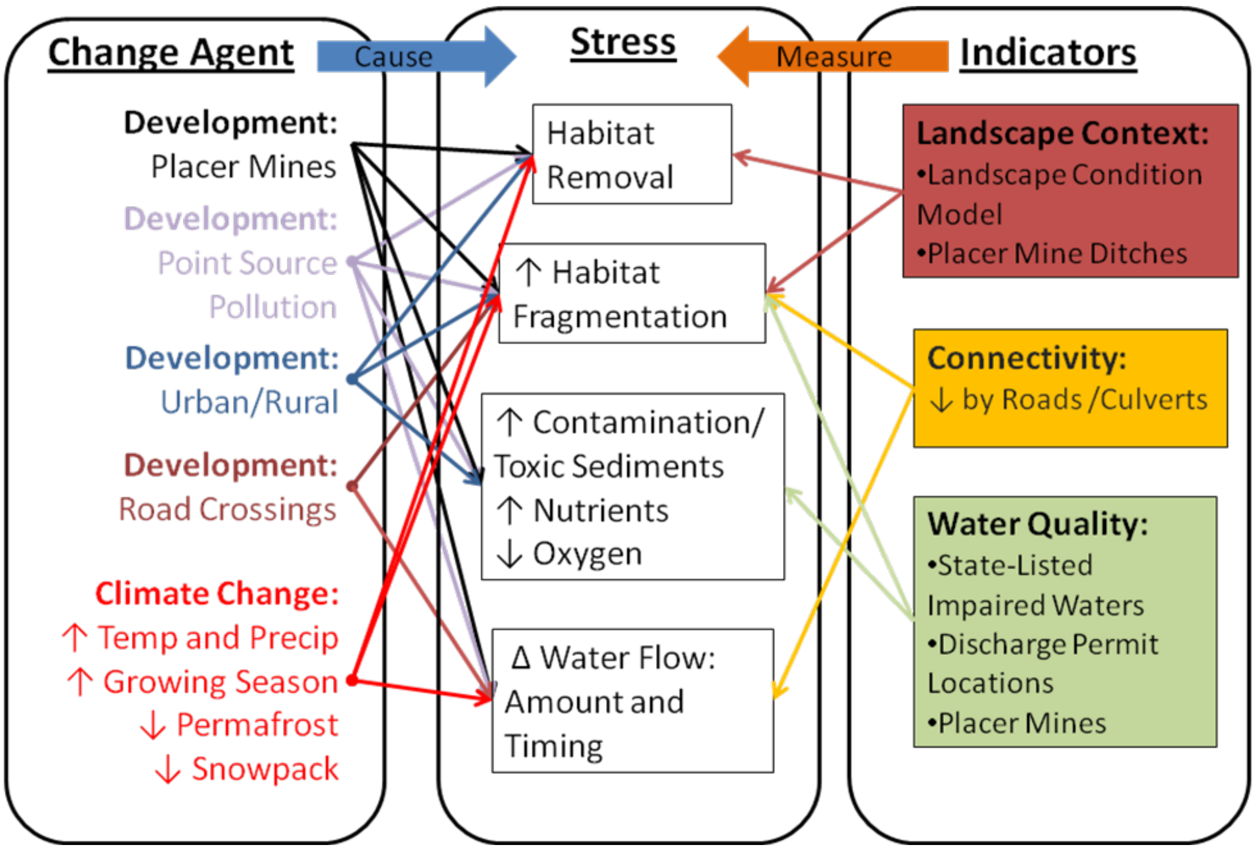


**Table E-34. Ecological status indicators for Coho salmon.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |
| **Key Ecological Attribute: Connectivity** | | |
| Index of Fish Passage (culverts) | This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

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Pentz, S.B. and R.A. Kostaschuk. 1999. Effect of placer mining on suspended sediment in reaches of sensitive fish habitat. Environmental Geology 37: 78-89.

## E-4.7 Dolly Varden (*Salvelinus malma*)

**Classification/Taxonomic Information:** Previously considered a subspecies of *Salvelinus alpinus* by some authors. Includes *S. anaktuvukensis*, which was described as a distinct species by Morrow (1980) but was included in *S. malma* in the 1980 and 1991 AFS checklists (Robins et al. 1980, 1991). Page and Burr (1991) recognized *S. anaktuvukensis* as specifically distinct from *S. malma* (AKNHP BIOTICS 2011f).

**Geography/Location:** In the vicinity of Alaska, Dolly Varden range from arctic Alaska to Washington and British Columbia, and west to Russia (Mecklenburg et al. 2002, Morrow 1980). The northern form (*Salvelinus malma malma*) are found from the Mackenzie River to the south side of the Alaska Peninsula, and the southern form (*Salvelinus malma lordi*) are found south of the Alaska Peninsula to the Puget Sound (Crane et al. 2005). Dolly Varden have spawning and rearing habitat in the Kivalina River; springs in the upper drainage possibly provide habitat for spawning, but have yet to be inventoried (BLM 2006). These fish are also present in Norton and Kotzebue Sound drainages in isolated mountain streams (NAB 2006). Fish tagged while overwintering in the Wulik River were recovered in the Kivalina, Wulik, Noatak, Kobuk, and Pilgrim rivers, as well as on Saint Lawrence Island and as far away as Russia (Crane et al. 2005).

**Reproduction Ecology:** Spawning often occurs from September through November, with eggs hatching in spring (Morrow 1980), although some populations may spawn in the spring (NatureServe 2011). Spawning typically occurs in tributaries to lakes where Dolly Varden overwinter (Mecklenburg et al. 2002), often in small headwater streams (ADF&G 2011). However, some Dolly Varden may overwinter in river systems not connected to their natal stream (Crane et al. 2005). Spawning also occurs at spring areas, or just downstream from spring areas (BLM 2006). The fish prefer sites toward the center of a stream, where there is a strong current, water is at least 0.3 m deep, water temperature is 5.5°-6.5° C, and there is clean gravel 0.6-5 cm in diameter (Morrow 1980).

Fry spend approximately their first 18 days in gravel (NatureServe 2011), then emerge to stay on the bottom of eddies or pools, spending a total of three to four years in a creek before traveling to the sea (Morrow 1980), or in some instances, up to six years (ADF&G 2011).

**Migration Ecology:** Patterns of movement differ between Kotzebue Sound and Norton Sound populations. Norton Sound Dolly Varden follow the movement of salmon; they delay seaward migration in the spring to feed on salmon fry, and reenter freshwater throughout the summer to feed on salmon eggs (Crane et al. 2005). The majority of Kotzebue Sound Dolly Varden move upstream to spawning habitat in the summer, spawn in the summer, move downstream to overwinter lower in their natal stream - although some overwinter in other streams - and in the spring move out to sea (Crane et al. 2005). Most Norton Sound fish and some Kotzebue Sound fish enter spawning streams in the fall, spawn in the fall in headwater springs, and overwinter near spawning grounds (Crane et al. 2005).

In anadromous populations, seaward migration typically occurs in May or June, while September and October migrations have also been documented (ADF&G 2011, NatureServe 2011). Dolly Varden will remain in coastal seas for two to three years before returning to freshwater (NatureServe 2011). When in fresh water, they inhabit clear water streams, springs or spring-fed parts of streams, and deep pools and runs of creeks and rivers of various sizes (Morrow 1980, NatureServe 2011). Young may overwinter farther upstream and in smaller springs than adult Dolly Varden (Morrow 1980). Fish may also overwinter in lakes (Mecklenburg et al. 2002), and although few populations are landlocked, those that are reside in lakes and tributary streams (NatureServe 2011). The northern form of Dolly Varden often overwinter in the river from which they spawned (ADF&G 2011) and move seaward directly after ice break up (Morrow 1980). It is typically spawners that return to their natal stream, a migration that begins in August, while non-spawners do not necessarily return to the stream from which they were hatched (Morrow 1980). For example, in the Wulik River of Kotzebue Sound it has been observed that overwintering Dolly Varden have been comprised almost entirely of non-spawners from other drainages (Morrow 1980).

**Habitat Description:** Habitat preferences, behavior, and traits of Dolly Varden vary between anadromous and non-anadromous (landlocked) populations and between locations. They are typically anadromous, but many resident populations also exist (NatureServe 2011). Anadromous individuals occur in coastal seas (2-3 years) and in deep runs and pools of creeks and small to large rivers. Most dwarfed race populations seem to spend their lives in rivers and streams. Some landlocked populations inhabit lakes and tributary streams (AKNHP BIOTICS 2011f). Non-anadromous habitats include cold headwaters near springs in lake bottoms (Page and Burr 1991). Spawning usually occurs in gravelly sections of streams. The female constructs a redd, or nest, that is usually 30-60 cm in diameter and about 30 cm deep (AKNHP BIOTICS 2011f).

**Threats/Stressors:** (See Figure E-47.) Currently few threats are identified in Alaska, however, future habitat alteration, mining practices, water diversions and hatchery practices could threaten Dolly Varden stocks. Dolly Varden is an important resource for residents of Western and Arctic Alaska (over 80% subsistence fishery catch in some communities) (USFWS 2010). Assessment population and management are challenging for anadromous Dolly Varden because they home to spawn in their natal streams, overwinter in freshwater lakes and rivers in mixed aggregates, and are harvested in subsistence fisheries when populations are mixed for overwintering or migrating between marine and freshwater environments (USFWS 2010). Identification and conservation of local reproductive units are essential to the long-term sustainability of a resource (USFWS 2010).

**Indicators of Ecological Status:** The stressor-based indicators identified for this CE (Table E-35, Figure E-47) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling (e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5th-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-46. Dolly Varden Conceptual Model/Diagram**

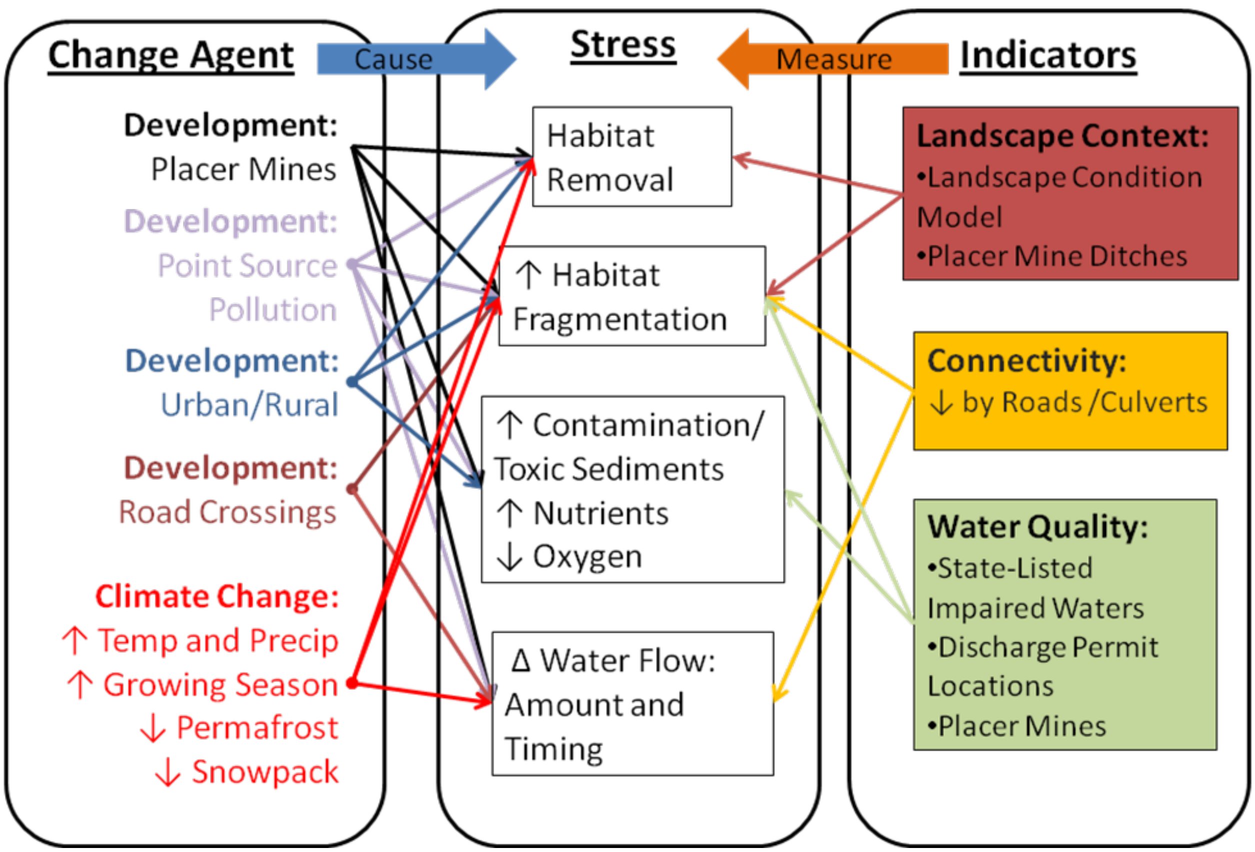

**Table E-35. Ecological status indicators for Dolly Varden.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |
| **Key Ecological Attribute: Connectivity** | | |
| Index of Fish Passage (culverts) | This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

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Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brookeri, E.A. Lackner, R.N. Lea, and W.K. Scott. 1980. A List of Common and Scientific Names of Fishes from the US and Canada (4th Ed). American Fisheries Soc., Special Publication No. 12, 174 pp.

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## E-4.8 Pink salmon (*Oncorhynchus gorbuscha*)

**Classification/Taxonomic Information:** Because of the fixed two-year life cycle, individuals spawning in a particular river system in odd and even years are reproductively isolated from each other and have developed into genetically different lines in some river systems, such as the Fraser River in British Columbia, only the odd-year line exists in significant numbers in Bristol Bay, Alaska, the major runs occur in even years (areas in between have runs in both even and odd years) (AKNHP BIOTICS 2011g, Heard 1991). An electrophoretic study by Varnavskaya and Beacham (1992) found that pink salmon from the Fraser River and southern British Columbia were distinct from more northerly spawning populations in British Columbia, Alaska, and Kamchatka (AKNHP BIOTICS 2011g). The concept of a 'fluctuating stock' population structure of pink salmon or random mixing during spawning over a large geographic area was not supported by observed patterns of genetic variation. In Russia, in contrast, lack of distinct stocks in different areas has been inferred from the lack of biochemical genetic differentiation detected in some surveys (see Varnavskaya and Beacham 1992).

**Geography/Location:** In the ocean, pinks can be found in the Bering Sea and North Pacific Ocean north of 40° N latitude (Mecklenburg et al. 2002). Ocean ranges may shift south in the winter and north in the summer (NatureServe 2011), and overall range extends from the Beaufort Sea to the California coast (Mecklenburg et al. 2002). Along with chum, pinks are the only salmon to regularly maintain populations along Beaufort coast drainages (Mecklenburg et al. 2002). Pink salmon have been observed spawning in the main portion of Squirrel River, below the mouth of the Omar River (BLM 2006), as well in the lower Yukon River as far upstream as Grayling (Morrow 1980). The Andreafsky River and its East Fork are tributary to the lower Yukon River and provide important rearing and spawning habitat for this species (Maschmann 2010).

**Reproduction Ecology:** In the Yukon River spawning happens in mid-July, but occurs later in areas farther south (Morrow 1980), and has been reported to occur as late as November (NatureServe 2011). Spawning most often occurs at natal streams within a few kilometers of the sea (ADF&G 2011, NatureServe 2011). Intertidal areas are also used for spawning, as alevins and eggs can tolerate exposure to salt water for a day or more (Morrow 1980). Favored spawning areas include downstream ends of pools and shallow riffles with cobble-size rock or coarse gravel (ADF&G 2011, NatureServe 2011). However, in the absence of gravel, pink salmon are very adaptable and can spawn even in fractured bedrock (NAB 2006). Water temperature needs to be above 4.5° C for eggs to develop, as colder temperatures cause high mortality and deformities (Morrow 1980).

Eggs hatch between December and February and emerge from gravel in April or May, at which time they proceed almost immediately downstream to estuaries (Morrow 1980). Young fish typically travel at night along the water surface, can cover up to 16 km a night, and hide in gravel throughout the day

(Morrow 1980). For juveniles with longer migrations that may take several days, fry may school and travel during daylight hours (Morrow 1980). Once they reach the sea juvenile pink salmon spend one to several months schooling in nearshore waters and feeding in estuaries before moving offshore (Morrow 1980). Juveniles form dense schools and move along the water surface near beaches (ADF&G 2011).

Pink salmon have a unique two-year life cycle, which makes the odd and even year runs genetically distinct (Morrow 1980). Abundance of spawning populations may differ greatly between years. For example, in the Fraser River in British Columbia, the odd-year run includes nearly 20 million adults whereas the even-year run is virtually nonexistent (Beacham et al. 1994). However, this pattern is not evident in all river systems (AKNHP BIOTICS 2011g).

**Migration Ecology:** Adult pinks spend the majority of their life, about 18 months, at sea and return to spawning streams between June and October in a series of runs (Morrow 1980, ADF&G 2011). Most often pink salmon return to their natal streams to spawn, although some have been found up to 640 km away from their stream of origin (Morrow 1980). Migration is short compared to other types of Pacific salmon (NatureServe 2011), although in the Yukon and Kuskokwim rivers pinks are known to travel 160 km upstream (Morrow 1980). Pink salmon die after spawning.

**Habitat Description:** Adults spend most of their lives at sea. Spawning occurs in rivers and tributary streams, in lower tidal areas in some rivers. After juveniles emerge from gravel (in April-May), they immediately move downstream to estuary. Young fish may be found in inshore waters for several months before they move to sea (Scott and Crossman 1973). Migratory fry usually do not feed, but if they are traveling long distances they eat aquatic insect larvae. Young form schools in estuaries before moving out to sea. These juveniles in estuaries feed on zooplankton. Predators of young salmon include: cutthroat and rainbow trout, Dolly Varden, kingfishers, mergansers, etc. (AKNHP BIOTICS 2011g). At sea, juveniles eat small crustaceans and other invertebrates. Adult diet includes mainly fishes, squid, euphausiids, amphipods, and copepods (AKNHP BIOTICS 2011g, Moyle et al. 1989).

**Threats/Stressors:** (See Figure E-48.) Currently few threats are identified in Alaska. In the southern parts of its range, pink salmon are threatened by habitat alteration, mining practices, water diversions and hatchery practices. Most populations are robust in Canada, although have been large runs reduction in Fraser River compared to historic averages (Augerot and Foley 2005). Even though pink salmon are the least dependant of salmon on freshwater they are the most dependant on lowlands /coastal estuary areas and have been extirpated from agriculture areas (Augerot and Foley 2005).

**Indicators of Ecological Status:** The stressor-based indicators identified for this CE (Table E-36, Figure E-48) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling (e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5$^{th}$-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-47. Pink salmon Conceptual Model/Diagram**

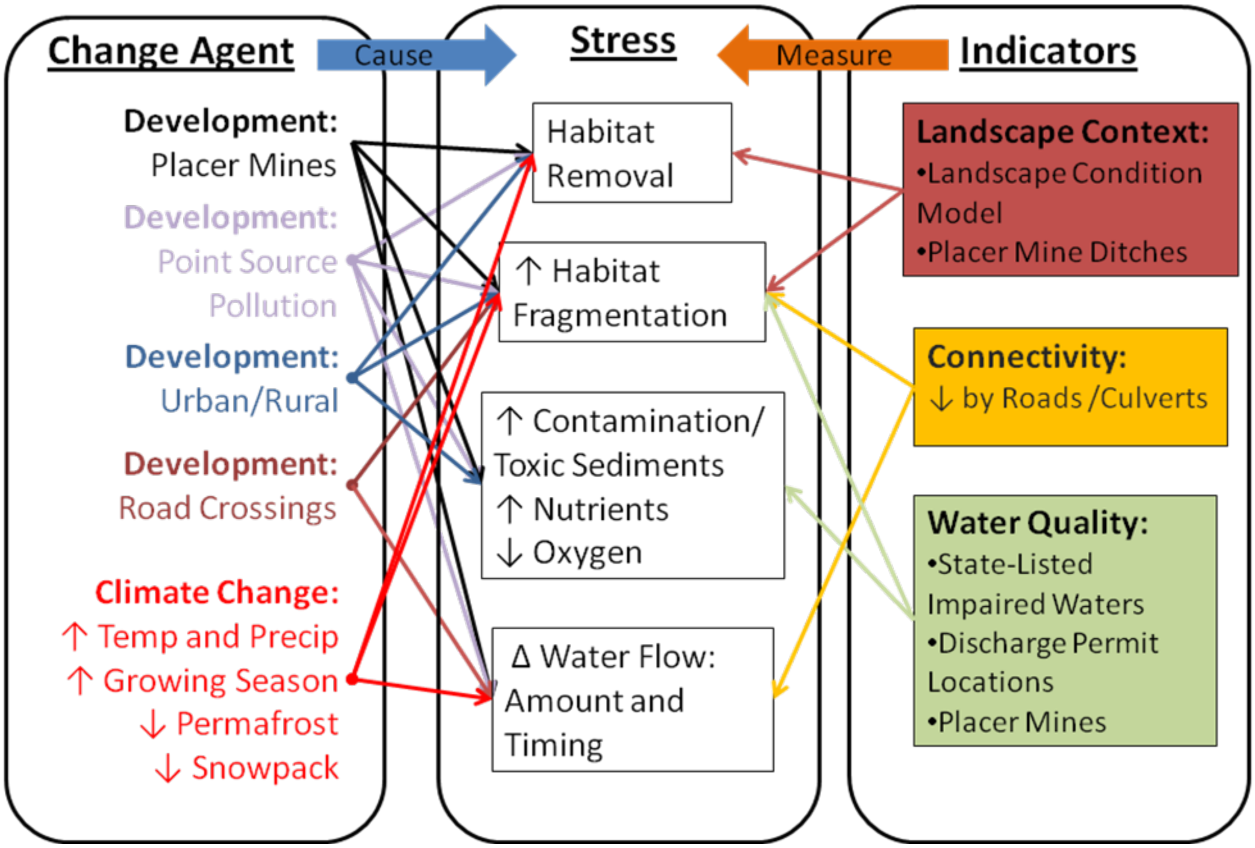


**Table E-36. Ecological status indicators for Pink salmon.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Key Ecological Attribute: Connectivity** | | |
| Index of Fish Passage (culverts) | This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

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## E-4.9 Sheefish (Inconnu) (*Stendous leucichthys*)

**Classification/Taxonomic Information:** In Alaska, sheefish exist in five distinct populations that do not mix: Minto Flats, upper Yukon River, lower Yukon River, Kuskokwim River, and Kobuk-Selawik (Morrow 1980). Two of these populations occur in the REA study area, and are anadromous, while the populations farther inland are landlocked. Sheefish spend their entire life in a single estuary and river system. There is minimal interbreeding between populations, as they do not migrate between different drainages, and populations only mix in feeding and overwintering habitat (Brown 2004, Hander et al. 2008, Underwood et al. 1998)

**Geography/Location:** The sheefish is found only in arctic and subarctic North America and Asia. In Alaska, it is most abundant in the Kuskokwim and Yukon river drainages and in the Selawik and Kobuk drainages of Kotzebue Sound. A few are found in the smaller rivers of Norton Sound (ADF&G 2011).

**Reproduction Ecology:** In Alaska, spawns late September-early October at water temperatures of 1.4-4.6 C. Individuals may spawn at intervals of 2-4 years. Young hatch sometime from late February to April. Sheefish become sexually mature in 7-10 years in Great Slave Lake (AKNHP BIOTICS 2011h).

The Kuskokwim River population likely spawns in clear tributaries (Morrow 1980) and is known to spawn specifically between Big River and Highpower Creek (Mecklenburg et al. 2002). The lower Yukon River population travels 1600 km upstream to spawn in the Alatna River (Morrow 1980), or in the main Yukon River between Circle and Beaver (Mecklenburg et al. 2002). The Kobuk-Selawik population may spawn up to 670 km up the Kobuk River (Morrow 1980).

More specifically, sheefish are known to spawn in the upper reaches of the Selawik and Kobuk rivers (NAB 2006), and spawn evenings through September and early October (Morrow 1980). They prefer clear, fast moving streams one to three meters deep, with water temperatures around 1.4°-6° C (Morrow 1980). Females do not dig a redd, and instead drop eggs in the water and depend on a substrate of different-sized gravel and cobble to catch the eggs before they are carried away by the current (Morrow 1980). Eggs take about six months to develop and hatch between late February and April (ADF&G 2011, Morrow 1980). In the Selawik and Kobuk rivers, and possibly elsewhere, young fish are carried downstream in spring floods (Morrow 1980).

**Migration Ecology:** Anadromous near coasts, landlocked in inland lakes (Page and Burr 1991). Upstream migration from wintering areas begins at ice breakup. An initial upstream migration leads both spawners and non-spawners to feeding grounds, which also serve as holding areas in the early summer (Hander et al. 2008, Underwood et al. 1998). For spawning adults, increased discharge caused by summer rain appears to encourage further upstream movement to spawning areas in mid to late August and September (Underwood 1998). Fish may stay in runs and deep holes for a period of time before spawning (Underwood et al. 1998). Migration can take anywhere from a few weeks to four months and can be as long as 1600 km for populations traveling far upstream (Morrow 1980). Spawning grounds in the upper reaches of rivers are reached in the late summer or fall and spawning occurs from late September through early October (Hander et al. 2008, Underwood et al. 1998). Sheefish spawn several times throughout their life, in some cases annually, or only once every few years (Morrow 1980). After spawning, sheefish return downstream immediately to overwintering areas (Morrow 1980, NAB 2006).

The Kuskokwim and lower Yukon River populations overwinter in deltas (Morrow 1980). The Kobuk-Selawik population overwinters in the brackish water of Hotham Inlet and Selawik Lake and their associated waterways, and can be found as far out as the village of Kotzebue, although they avoid moving fully into sea water (Hander et al. 2008). Sheefish cannot withstand marine water winter temperatures, which can be as low as -2° C (Hander et al. 2008). It is also reported that overwintering occurs in the Kotzebue Sound, and lower portions of the Selawik and Kobuk rivers (NAB 2006).

**Habitat Description:** Anadromous in coastal areas ascends streams from the sea to spawn. When ice goes out in the spring, sheefish can be found feeding in large lakes, inlets, and river deltas (Underwood et al. 1998). Some stay in sloughs, lower lakes, estuaries, or lower reaches of a river system, while others migrate up tributary streams in summer, returning in fall. (Hander et al. 2008, Underwood et al. 1998). Very young postlarvae eat plankton, soon change to insect larvae and larger zooplankton. Adults feed mostly on fishes, especially least cisco also isopods and mysids. Adoption of fish diet may occur in first to fourth year (AKNHP BIOTICS 2011h).

**Threats/Stressors:** (See Figure E-49.) Currently few threats are identified in Alaska, however, future habitat alteration, mining practices, water diversions and hatchery practices could threaten sheefish. Because sheefish spend their entire life in a single estuary and river system and do not migrate between different drainages, some five distinct populations may be susceptible to local stressors. In addition, sheefish sport fishing is becoming more popular especially in summer feeding grounds such as Minto Flats, the Holitna River, or the Selawik-Kobuk areas and in September the Koyukuk River at Hughes and Allakaket (ADF&G 2011). In past years, the major use of the sheefish has been as a subsistence food for Alaska Natives and their dogs so impacts from sport fishing need to be monitored.

**Indicators of Ecological Status:** The stressor-based indicators identified for this CE (Table E-37, Figure E-49) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling (e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by

Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5th-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-48. Sheefish Conceptual Model/Diagram**

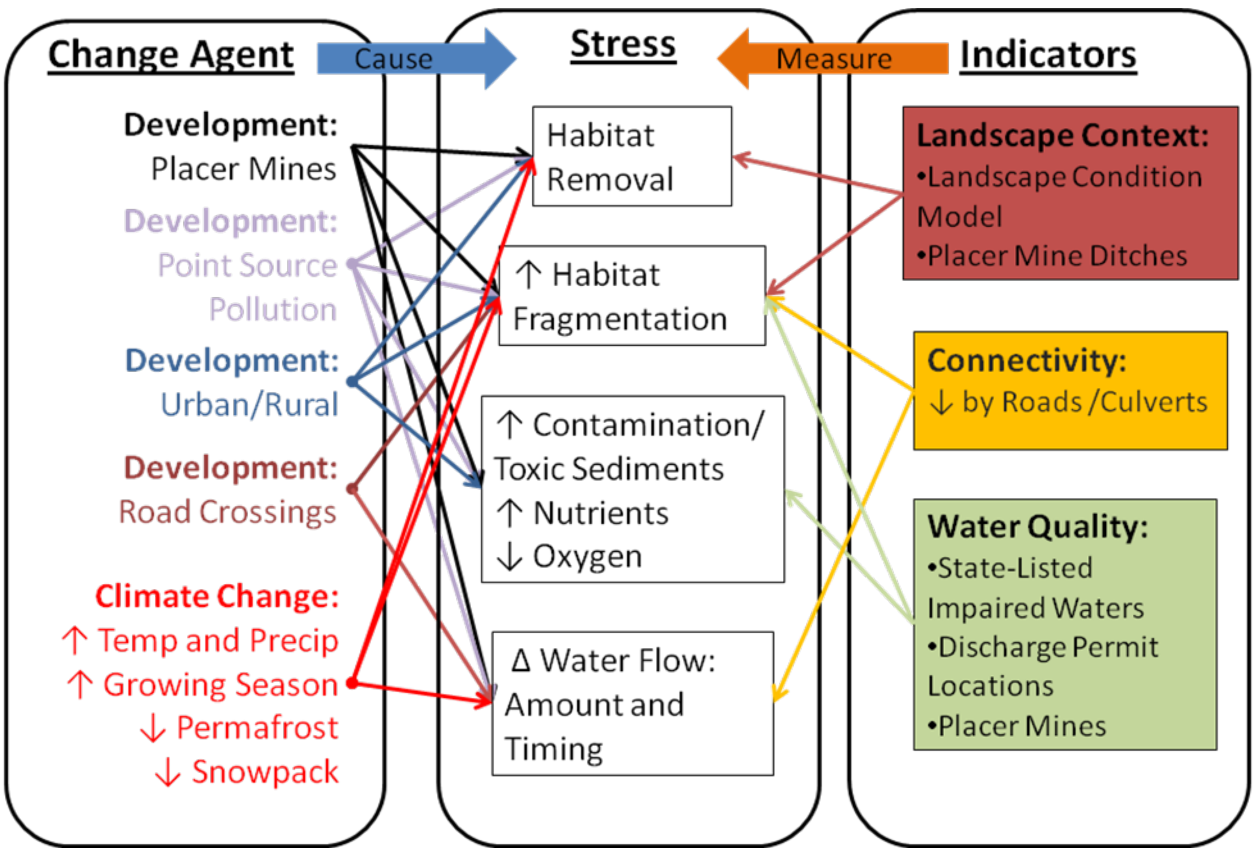


**Table E-37. Ecological status indicators for Sheefish.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |
| **Key Ecological Attribute: Connectivity** | | |
| Index of Fish Passage (culverts) | This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

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## E-4.10 Sockeye salmon (*Oncorhynchus nerka*)

**Geography/Location:** In eastern Pacific, sockeye salmon are abundant from Bristal Bay south to Fraser River. They occur from Point Hope south to California, with a few strays north of Point Hope (Mecklenburg et al. 2002, Morrow 1980). In the Yukon River they are found as far upstream as Rampart (Mecklenburg et al. 2002, Morrow 1980). The Andreafsky River and its East Fork are tributary to the lower Yukon River are important rearing and spawning habitat for this species (Maschmann 2010). In saltwater they are found in nutrient-rich waters throughout the Bering Sea, north Pacific Ocean, and Arctic Ocean, with a range that shifts southward in the winter and north in the summer (ADF&G 2011, NatureServe 2011).

**Reproduction Ecology:** Sockeyes spawn between July and December, while kokanee spawn August to February (NatureServe 2011). Most often spawning occurs in fall, and timing is dependent on location (NatureServe 2011). After spawning it takes six to nine weeks for eggs to develop, or up to five months, depending on water temperature (Morrow 1980). Eggs hatch between mid-winter and early spring, and larvae emerge two to three weeks later (Morrow 1980, NatureServe 2011). Alevins typically emerge from gravel between April and June, depending on water temperature (Morrow 1980, NatureServe 2011). Young fry initially avoid light and hide in gravel and stones in stream bottoms throughout the day, only to emerge at night (Morrow 1980). In the absence of a lake, fry move to the ocean soon after emergence from gravel (ADF&G 2011). However, it is more common for fish to spend one to four years in freshwater before going to sea (Mecklenburg et al. 2002, Morrow 1980). Regardless of whether young were hatched in an inlet or outlet stream, the fry move toward a lake to rear, and rear in lakes more so than other types of salmon (Mecklenburg et al. 2002, Morrow 1980). The initial few weeks in a lake are spent near shore, then fish move offshore to occupy about the upper 20 m of water (Morrow 1980).

Although kokanee never move to the ocean, their general behavior is similar to sockeye (Morrow 1980). Water temperatures above 15.5° C cause mortality, particularly in juveniles, but kokanee thrive in cold, large mountain lakes with well oxygenated water (NatureServe 2011). They travel in large schools which disperse at dusk and reform after dawn (NatureServe 2011). Small barriers may inhibit migration and spawning takes place in outlet or inlet streams, or along lake shores (Morrow 1980). Spawn takes place in late spring to midsummer, and all kokanee die shortly thereafter (Morrow 1980, NatureServe 2011).

**Migration Ecology:** Migration to sea occurs in the spring or summer, when water reaches about 4° C (Morrow 1980, NatureServe 2011). Upon reaching the sea, fish stay close to shore initially, then spread throughout the North Pacific, north of 40°N latitude (Mecklenburg et al. 2002, Morrow 1980). In late winter, sockeye can be found spread out in a band across the north Pacific, south of 50°N latitude, and their range shifts north in late spring as they move to summer feeding areas (Morrow 1980). Some sockeye remain in the ocean for up to four years, while others return to their natal stream in the spring (Mecklenburg et al. 2002, Morrow 1980).

Spawning migration takes place from July to October, or into December farther south (Morrow 1980). Sockeyes may migrate thousands of miles between the ocean and their natal stream (ADF&G 2011). Adults die after spawning (Mecklenburg et al. 2002, Morrow 1980).

**Habitat Description:** Sockeye salmon spawning and rearing is habitat needs are complex (Augerot and Foley 2005). They spawn almost entirely in rivers or streams connected to lakes, although they occasionally spawn directly in a lake, or in streams without lakes (Morrow 1980). Kokanee, the landlocked form of sockeye salmon, spawn in lakes or tributaries (NatureServe 2011).

When spawning in a lake, the preferred location is along shores with springs, seepage outflow, wind-induced waves, or upwellings (ADF&G 2011, NatureServe 2011). The preferred substrate for a spawning site is gravel, particularly with the following ratios: 40% of rock less than 2.5 cm diameter, 50% of rock 2.5 to 7.5 cm diameter, and 10% or less of rock greater than 7.5 cm diameter (Morrow 1980). Both sockeye and kokanee will spawn over gravel riffles or shore, but they have a difference in temperature requirements; kokanee require a water temperature of 4.4°-12.8° C, and sockeye prefer temperatures around 2.7°-7.3° C (NatureServe 2011). Developing sockeyes require adequate water flow for aeration and survival; silt deposition can reduce water flow through a redd and cause high mortality of eggs and alevins (Morrow 1980). Spawning in lakes generally occurs later than spawning in streams (Morrow 1980).

**Threats/Stressors:** (See Figure E-50.) Sockeye salmon are the third most abundant salmon in the North Pacific (Augerot and Foley 2005). Currently few threats are identified in Alaska, but in the southern parts of its range, sockeye salmon are threatened by habitat alteration, mining practices, water diversions and hatchery practices (Augerot and Foley 2005). Because sockeye spend more time in freshwater than other salmon species rearing in rivers and lakes (Mecklenburg et al. 2002, Morrow 1980); they are more susceptible to inland impacts to water flows from diversions and water pollution from mining practices (Augerot and Foley 2005). Sockeye might be more vulnerable to threats than other salmon because most stocks in British Columbia are assess as either high or low risk of extinction (Augerot and Foley 2005).

Sockeye are one of the best studied of all Pacific fish species because of high economic value. Alaska sockeye is noted for a highly variable catch – from a high of 35 million in 1938 to a low of 6 million in 1958, to a new record of 64 million in 1993 (Augerot and Foley 2005). Bristol Bay sockeye runs are currently declining (Augerot and Foley 2005).

**Indicators of Ecological Status:** The stressor-based indicators identified for this CE (Table E-38, Figure E-50) provide a link between the ecological requirements of the CE and CA effects on the CE; they serve as an indication of the ecological status based on the effects of CAs on the CE. The indicators are assessed or measured through spatial modeling (e.g., calculating index of culverts intersecting with a CE within a HUC) to provide a measure of status. The indicators are organized hierarchically, grouped by Key Ecological Attributes (e.g., Water Quality), which reflect primary ecological drivers of integrity, and then by Rank Factors (Condition, Landscape Context, Size/Extent). KEAs are assessed using indicators that can be evaluated and reported at spatial scales and units that are supportable with existing information. For aquatic conservation elements, the reporting unit is 5th-level watersheds (10-digit hydrologic catalog units, or HUC10). The score for each indicator is normalized between 0 and 1, with 1 being highest ecological status and 0 being lowest.

**Figure E-49. Sockeye salmon Conceptual Model/Diagram**

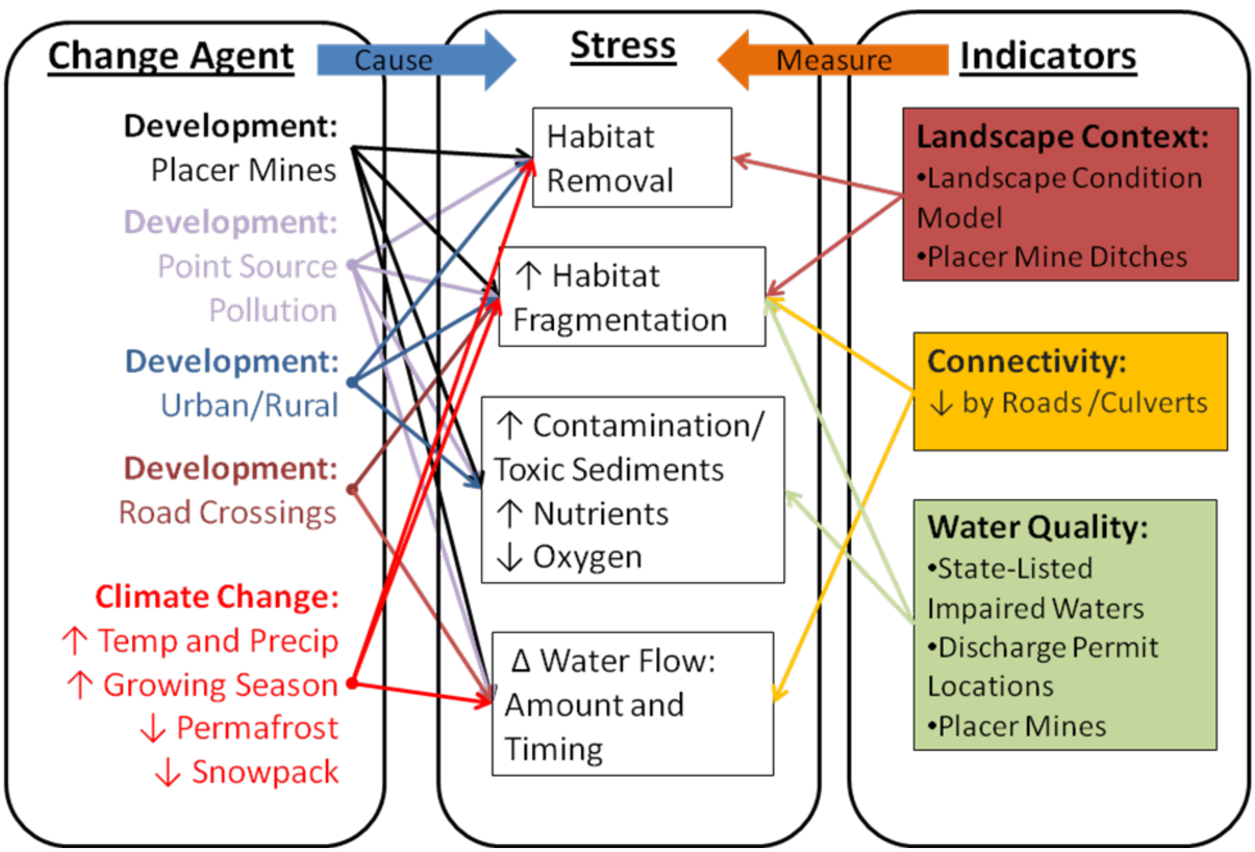

**Table E-38. Ecological status indicators for Sockeye salmon.**

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| **Rank Factor: Landscape Context** | | |
| **Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context** | | |
| Landscape Condition Index | Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. Landscape condition scores range from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition. | Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance. |
| Index of Placer Mine Ditches | This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC. The total ditch length per watershed is converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs. |
| **Key Ecological Attribute: Connectivity** | | |
| Index of Fish Passage (culverts) | This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources. |
| **Rank Factor: Condition** | | |
| **Key Ecological Attribute: Water Quality** | | |
| Index of Placer Mines | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of placer mines intersecting the aquatic CE. The number of CE-mine intersections per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream. |

| Indicator | Definition and Scoring | Justification |
|---|---|---|
| Pollution Permits | This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The number of permits per watershed was converted to a normalized score where 0 = worst or highest degree of impact and 1 = best or least impacted score. | Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants. |

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# *E-5 Additional Terrestrial Animal CEs*

## E-5.1 Introduction

This section contains descriptive information for additional species conservation elements: 1) animal species being treated with the "local" approach, and 2) species that were not treated individually, but instead treated within coarse-filter CEs or species assemblages. Unlike plants and fish treated with the "local" approach, bird species in this category did receive predictive habitat models. (This was because models of predicted habitat were being developed for these species, among many other vertebrate species, by the Alaska GAP program.) Per memo 3 and the work plan, local species had not been intended to receive ecological status assessments; therefore, a list of indicators of ecological status was not developed. However, the tool used for assessing the landscape condition indicator for individual CEs can be set to run for entire groups of CEs (assuming they have a distribution model). The development-related features comprising the landscape condition indicator are assumed to have some impact on the six local bird species; therefore, when the landscape condition surface was adjusted and re-assessed for other terrestrial CEs, the six local bird species were included. The brief descriptive text includes information on the species' habitat and geographic range.

The descriptive information was provided by the Alaska Natural Heritage Program for the SNK REA. The species information included in the AKNHP's documents was obtained from the Alaska Heritage Program's installation of Biotics, a biodiversity database developed centrally at NatureServe and maintained through the combined efforts of the member heritage programs and NatureServe. The member program biodiversity databases are coordinated with the central NatureServe database; these databases are dynamic, maintained and refined through updates made to reflect current changes to taxonomy, and by the periodic import of new records that are developed according to standard methodology by natural heritage member program scientists and other collaborators, including government agencies, universities, natural history museums and botanical gardens, and additional conservation organizations. This ongoing process of adding and revising information and records helps to maintain currentness and enhance completeness of the data.

NatureServe member programs' biodiversity databases contain an array of information about elements of biodiversity, with particular emphasis on those that are more threatened across their range. Tracked data includes taxonomy, conservation status, ecological and life history, habitat requirements, and distribution, with primary sources of this information consisting of scientific literature, museum specimen records, reliably documented observation records, species lists, range maps, external databases, and experts, including scientists from natural heritage member programs. While centrally NatureServe maintains range maps and/or data representing all native full species vertebrates and vascular plants, within individual member programs resources generally limit the tracking of specific locations of species and other elements of biodiversity within their jurisdictions to those having the highest conservation concern.

## E-5.2 Emperor Goose (*Chen canagica*)

**Assessment:** Local

**Geographic Range and Habitat Description:** Considered an uncommon breeder on the Seward Peninsula. Documented breeding range includes the coastal lowlands from Lopp Lagoon around the coast to Cape Espenberg and the Nugnugaluktuk-Lane-Pish river region. Also considered an uncommon migrant in the Bering Strait region and a rare migrant and summer visitant along the northern coastline of Norton Sound (Kessel 1989).

According to Kessel (1989), on the Seward Peninsula this species breeds primarily in pond-studded lowlands at the lower extremities of rivers that drain into large lagoons, such as the Mint, Arctic and Shishmaref Rivers, or lagoons that drain directly into the sea, such as the Kitluk and Pish rivers. Nesting has also been observed in wetlands on coastal barrier strips, such as those located off of Lopp Lagoon and at Cape Espenberg. Frequently feeds on salt grass meadows and mudflats and in shallow brackish and salt water.

On the Yukon-Kuskokwim Delta, typically breeds within 15 km of the coast on flat tidally influenced salt marsh habitats. This area is characterized by tidal rivers and sloughs, as well as brackish and freshwater ponds and lakes with halophytic plants and graminoid meadows (Petersen et al. 1994). Also nests on shore (e.g., among driftwood) or on low coastal or estuarine islands (Harrison 1978). Nests on high ground in areas subject to flooding. Typical brood rearing areas in Alaska (Kokechik River area): insides of bends of major sloughs and rivers that supported stands of *Carex rariflora* (Eisenhauer and Kirkpatrick 1977).

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## E-5.3 Hudsonian Godwit (*Limosa haemastica*)

**Assessment:** Local

**Geographic Range and Habitat Description:** Considered an uncommon summer visitant and possibly a rare breeder on the Seward Peninsula, where it is present from mid-May through August. It occurs primarily at the base of the Peninsula, in the wetlands surrounding the Buckland River estuary and also around Norton Bay. Also occurs as far west as the Fish River delta. In general, these birds are found in wet meadows and tidal flats while on the Seward Peninsula (Kessel 1989).

Elsewhere in Alaska, breeding habitat includes sedge-grass marshes, wet tundra, and taiga bogs (Armstrong 1995). Nesting habitat open sedge meadows intermixed with forest within Alaska. In western Alaska, species breeds in spruce or spruce-deciduous forests interspersed with open bogs or wet meadows (Elphick and Klima 2002).

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## E-5.4 Kittlitz's Murrelet (*Brachyramphus brevirostris*)

**Assessment:** Local

**Geographic Range and Habitat Description:** Nests on coastal cliffs, and barren ground, rock ledges, and talus above timberline in coastal mountains, generally near glaciers (AOU 1983), 0.25 to 75 kilometers inland (Piatt et al. 1999). Nests generally on ground on barren scree slopes, short distance below peak or ridge (Day et al. 1983, Day 1995, Piatt et al. 1999). Breeding generally occurs in high elevation alpine areas, with little or no vegetative cover. When present, vegetation is primarily comprised of lichens and mosses (Day et al. 1993).

Kittlitz's Murrelets nest at widely separate localities along the Bering and Chukchi sea coasts. Considered a rare breeder in the mountains of the western half of the Seward Peninsula, where it nests in isolated pairs high on talus slopes, generally more than 25 km from the coast, often at the base of a rock with north facing exposure, near the top of a ridge or mountain (Kessel 1989).

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Piatt, J. F., N. L. Naslund and T. I. van Pelt. 1999. Discovery of a new Kittlitz's Murrelet nest: clues to habitat selection and nest-site fidelity. Northwest Nat. 80:8-13.

## E-5.5 McKay's Bunting (*Plectrophenax hyperboreus*)

**Assessment:** Local

**Geographic Range and Habitat Description:** Considered a rare winter visitant on the Seward Peninsula during winter, where it feeds along the windblown coast (Kessel 1989). Winters on coastal marshes, shingle beaches, and agricultural fields with exposed vegetation on the mainland bordering the Bering Sea (Lyon and Montgomerie 1995).

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## E-5.6 Red Knot (*Calidris canutus*)

**Assessment:** Local

**Geographic Range and Habitat Description:** Breeding and foraging habitat characterized by well drained moist alpine tundra habitats near Arctic coasts (Cramp and Simmons 1983). Often nests on ridges or slopes dominated by stunted willow or dryas (Harrington 2001). During migration uses marine habitats, primarily tidal flats and beaches, including sandy coastal habitats near tidal inlets or mouths of estuaries and bays (Harrington 2001).

Considered an uncommon breeder and fall migrant on the Seward Peninsula. During the breeding season, the species is found widely dispersed along most of the length of the northern uplands, where it utilizes high, exposed domes and ridges in open dwarf shrub mat habitat for nesting (Kessel 1989).

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## E-5.7 Spectacled Eider (*Somateria fischeri*)

**Assessment:** Local

**Geographic Range and Habitat Description:** Breeding range in western Alaska consists of coastal salt marshes that grade into thousands of wetlands and lakes. Sedges, grasses with higher areas containing shrubs. Islands in river deltas and wetlands characterize habitat on the north slope. Apparently prefers coastal areas with shallow muddy water, river deltas. Nests on drier sites, small islets, or ridges or tussocks by water, mainly within 15 km of the coast.

Distribution is restricted on the Seward Peninsula, where it is considered a rare local breeder and a summer visitant. The only confirmed breeding sites are the salt grass meadow-pond complex west of the mouth of the Arctic River at the edge of Shishmaref Inlet, and at Cape Espenberg. May also breed along the inner margins of Lopp and Arctic Lagoons (Kessel 1989).

**REFERENCES**

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## E-5.8 Willow Ptarmigan (*Lagopus lagopus*)

**Assessment:** Treated within coarse-filter CEs relating to wet willow shrubland habitats

**Geographic Range and Habitat Description:** Primarily inhabits subarctic and subalpine zones, particularly shrubby habitats in relatively low, moist areas. Common in areas with patches of dense vegetation, especially where willow or birch shrubs are abundant (shrub height of 0.3 to 2.0 m; Weeden 1965, Moss 1972a, Johnsgard 1983, Martin and Hannon 1987). Also found in sedge-willow marshes, in meadows, along road and forest edges, and on open tundra (Campbell et al. 1990). In winter, typically moves to areas with greater vegetation cover, such as muskegs, river and lake margins, and forest openings (Bent 1932, Godfrey 1986, Campbell et al. 1990).

Considered a common resident to the Seward Peninsula, although populations may fluctuate from year to year from uncommon to common. Widely distributed across the Seward Peninsula in summer across the northern and southern uplands and interior and coastal lowlands, where it's presence is closely correlated with the presence of low shrub thicket. During winter, Willow Ptarmigan withdraw from the western and northern coastal portions of the Seward Peninsula, where shrubs are low, becoming snow covered and unavailable as winter food (Kessel 1989).

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Weeden, R.B. 1965. Further notes on Wandering Tattlers in central Alaska. Condor 67:87–89.

Moss, R. 1972. Social organization of Willow Ptarmigan on their breeding grounds in interior Alaska. Condor 74: 144-151.


## E-5.9 Polar bear (*Ursus maritimus*)

**Assessment: Not assessed.** Originally to be treated as part of coarse-filter sea ice habitats; marine habitats not addressed in SNK REA. However, Alaska GAP provided a model of predicted habitat for polar bear for this REA.

**Geographic Range and Habitat Description:** Polar bears are closely tied to the Arctic pack ice. They prefer areas with ice that is periodically active, such as at the interface of landfast ice and drifting pack ice along the Arctic coasts or near polynyas. Polar bears are most commonly observed in or near nearshore zones where ice is constantly moving, opening up and reconsolidating, rather than pelagic areas which are of lower productivity (Stirling and Smith 1975; Pomeroy 1997; Stirling 1997). Sometimes they wander inland as much as 150 km from the coast. In the Bering and Chukchi Seas, Alaska, where sea ice melts in summer, bears migrate up to 1000 km to remain with the southern ice boundary

(Amstrup 2003). Pregnant females remain on or near land in dens through winter while males and non-breeders winter on sea ice (Derocher and Stirling 1990). In Alaska, polar bears den most commonly on offshore islands and associated heavy, stable ice from the mouth of Colville River to Brownlow Point (MacDonald and Cook 2009). Occasionally den on shorefast ice and river bottoms from Kuparuk River to Point Hope (ADFG 1973).

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# *E-6 Local Terrestrial Plant CEs*

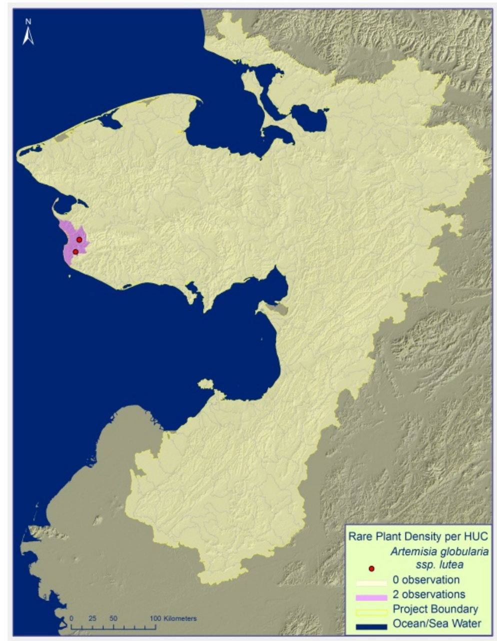
## E-6.1 Introduction

This section contains descriptive information for a subset of species conservation elements: rare plants, all of which are treated with the “local” approach. Ecological status was not assessed for local plant species. The descriptive text includes information on the species’ conservation status, habitat, geographic range, and relationships to change agents.

The descriptive information was provided by the Alaska Natural Heritage Program for the SNK REA. The species information included in the AKNHP’s documents was obtained from the Alaska Heritage Program’s installation of Biotics, a biodiversity database developed centrally at NatureServe and maintained through the combined efforts of the member heritage programs and NatureServe. The member program biodiversity databases are coordinated with the central NatureServe database; these databases are dynamic, maintained and refined through updates made to reflect current changes to taxonomy, and by the periodic import of new records that are developed according to standard methodology by natural heritage member program scientists and other collaborators, including government agencies, universities, natural history museums and botanical gardens, and additional conservation organizations. This ongoing process of adding and revising information and records helps to maintain currentness and enhance completeness of the data.

NatureServe member programs’ biodiversity databases contain an array of information about elements of biodiversity, with particular emphasis on those that are more threatened across their range. Tracked data includes taxonomy, conservation status, ecological and life history, habitat requirements, and distribution, with primary sources of this information consisting of scientific literature, museum specimen records, reliably documented observation records, species lists, range maps, external databases, and experts, including scientists from natural heritage member programs. While centrally NatureServe maintains range maps and/or data representing all native full species vertebrates and vascular plants, within individual member programs resources generally limit the tracking of specific locations of species and other elements of biodiversity within their jurisdictions to those having the highest conservation concern.

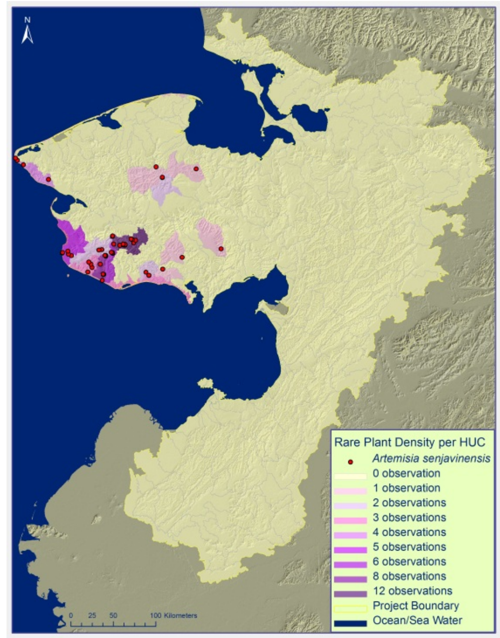
## E-6.2 *Artemisia globularia* Bess ssp. *lutea* Hultén (a Boreal Wormwood subspecies)




**Global rank:** G4T1T2
**State rank:** S1S2
**Distribution:** *Global:* Chukotka, Russia; Bering Sea Islands and western Seward Peninsula, Alaska, USA.
*State:* St. Matthew, St. Lawrence, and St. Paul Islands and western Seward Peninsula (Crete Creek, Kigluaik Mountains)
**Associated Parent Material:** Cretaceous Kigluaik granites and/or high-grade metasedimentary and metaigneous rocks (see Till et al. 2010) on the Seward Peninsula
**Landforms:** Mountain and hill sides, 50 – 1,500 ft in elevation
**Soil type:** acidic tundra soils, granitic boulders, talus, gravel, sandy substrates
**Moisture regime:** Moist to dry, often well-drained
**Slope:** Flat to steeply sloping
**Aspect:** Variable
**Vegetation type:** Alpine tundra, willow-herbaceous fellfields
**Population sizes:** Known from approximately 20 locations in the Bering Strait region with just a single area in the REA in the western Kigluaik Mountains, near Crete Creek. Population size of the Crete Creek complex was estimated at a few hundred plants (Carlson et al. 2007).
**Association with Change Agents:** No known impacts of CAs on this taxon. Direct perturbations by development, or establishment of significant numbers of invasive plants in these areas seem unlikely. The population complex in the Kigluaiks may be vulnerable to climate change, as very few populations are known and migration corridors are likely limited.

**Figure E-50. Habitat of *Artemisia globular* var. *lutea*, western Kigluaik Mountains, Seward Peninsula.**

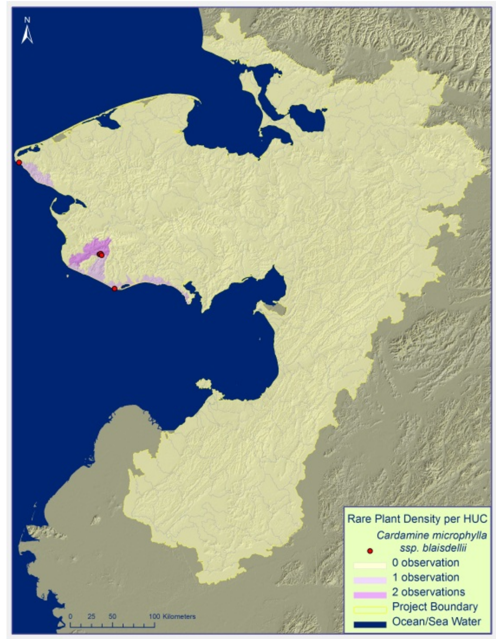
## E-6.3 *Artemisia senjavinensis* Bess (Arctic Sage)




**Global rank:** G3
**State rank:** S2S3
**Distribution:** *Global:* Eastern Chukotka, Russia; Seward Peninsula, Alaska, USA.
*State:* Seward Peninsula
**Associated Parent Material:** Mixed marble, graphitic metasiliceous rock, and schist of Devonian-Ordovician; Limestone and dolomitic limestone; Metacarbonate rocks, Paleozoic Marble of the Moon Mountains (see Till et al. 2010)
**Landforms:** Mountain ridges, benches, slopes, knolls, outcrops, cliffs
**Soil type:** Limestone and marble talus, gravel, and finer mineral substrates
**Moisture regime:** Mesic to dry, well-drained
**Slope:** Flat to steeply sloping
**Aspect:** Variable
**Vegetation type:** Barren to dry dwarf shrub herbaceous barrens, moister dwarf shrub herbaceous meadows
**Population sizes:** Known from 59 records in Alaska, 45 of which occur in the REA in a number of locations associated with barren limestone habitats. Population sizes for most populations are not known, however it is known to be locally abundant in some populations (Carlson et al. 2007). One population along Stewart River had approximately 300 plants and another population had approximately 50 plants (Carlson et al. 2007).
**Association with Change Agents:** No known impacts of CAs on this taxon. Direct perturbations by development could be considered a threat; however, this species has been observed colonizing anthropogenically disturbed areas such as barrow pits. Migration corridors to track climate envelopes are limited for this taxon if physiological limits are surpassed due to climate change.

**Figure E-51. Habitat of *Artemisia senjavinensis* (Arctic Sage), Stewart River area, Seward Peninsula.**

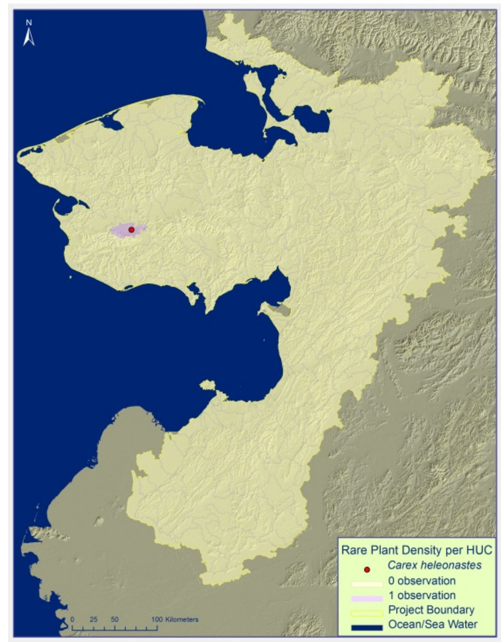
## E-6.4 *Cardamine microphylla* ssp. *blaisdellii* (Eastw.) D.F Murray & S. Kelso (Littleleaf Bittercress)




**Global rank:** G5T4T3
**State rank:** S3S4
**Distribution:** *Global:* Chukotka, Russia; Seward Peninsula to western Brooks Range, Alaska, USA.
*State:* Cape Prince of Wales west through the hills and mountains of the southern Seward Peninsula to the headwaters of the Unalakleet River in the Nulato Hills. Isolated populations are found on the Lisburne Peninsula and scattered to the east in the Brooks Range to the Angayucham Mountains.
**Associated Parent Material:** Generally associated with Quaternary surficial deposits of moist acidic, organic substrates
**Landforms:** Creek and lake edges, solifluction lobes, hillslopes, toeslopes, alpine ridges
**Soil type:** Moist tundra soil, scree
**Moisture regime:** Mesic to wet, often associated with snowbed and snowmelt
**Slope:** Flat to moderately sloping
**Aspect:** Variable, often north and west-facing
**Vegetation type:** Herbaceous meadows, wet graminoid-forb or graminoid-Dryas slopes, or mossy areas, and occasionally found in scree habitats.
**Population sizes:** Known from approximately 40 records in Alaska, which occur in three areas of the REA in the Seward Peninsula Highlands and Kigluaik Mountains. Sizes for most populations are not known, however at three sites near Stewart River, populations were estimated at approximately 50 individuals and another site with 500 individuals (Carlson et al. 2006).
**Association with Change Agents:** No known impacts of CAs on this taxon. Populations are relatively widespread and not uncommon and direct perturbations by development are unlikely to be a significant threat. One site near Jensen's Camp was growing along a stream impacted by historic placer mining (Carlson pers. obs.). Climate change could be considered a threat; however, suitable habitat would be expected to track to the north and east and to higher elevations.

**Figure E-52. *Cardamine microphylla* ssp. *blaisdellii* (Littleleaf Bittercress) and wet graminoid-forb habitats on the Seward Peninsula.**

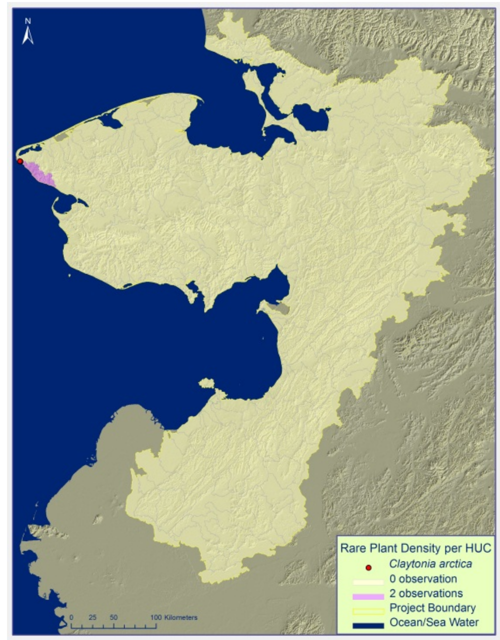
## E-6.5 *Carex heleonastes* Ehrh. (Hudson Bay Sedge)




**Global rank:** G4
**State rank:** S2S3
**Distribution:** *Global:* Circumarctic/boreal.
*State:* Isolated collections in the Brooks Range, Alaska Range, Kenai Peninsula and Seward Peninsula.
**Associated Parent Material:** Quaternary-derived wet organic and mucky substrates.
**Landforms:** Bogs, mires, damp meadows.
**Soil type:** Saturated peat
**Moisture regime:** Wet
**Slope:** Flat to moderately sloping
**Aspect:** Generally associated with flat ground.
**Vegetation type:** Well-developed oligotrophic bogs, low tussocks, wet meadows, sedge bogs, wet-sandy roadsides.
**Population sizes:** Known from seven records in Alaska, one of which occurs in the REA at Pilgrim Hot Springs along a wet-sandy roadside near the airstrip. Population sizes are not known.
**Association with Change Agents:** No known impacts of CAs on this taxon.

**Figure E-53. *Carex heleonastes* (Hudson Bay Sedge) specimen from the western Brook Range (UAM 2011).**

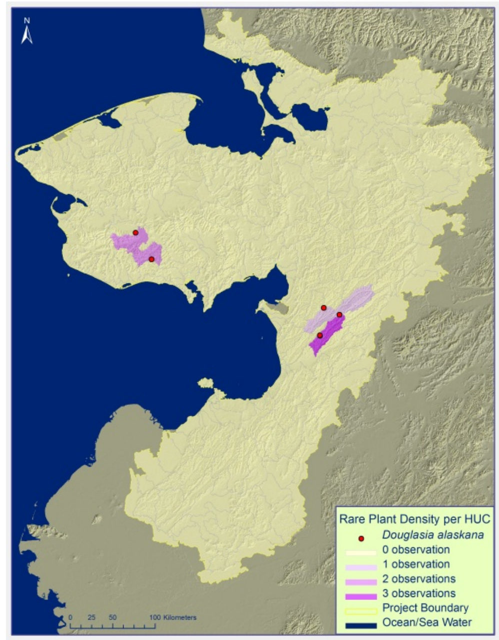
## E-6.6 *Claytonia arctica* Adams (Arctic Springbeauty)




**Global rank:** G3
**State rank:** S1
**Distribution:** *Global:* Western Alaska, Northeast Asia including arctic Russia (Klein and Morse 1994, Miller 2004, Elven 2011) *State:* Aleutian Islands, St. Lawrence Island, Seward Peninsula (Hultén 1968, Carlson et al. 2006, Elven 2011, UAM 2011)
**Associated Parent Material:** Mississippian Limestone, dolomitic limestone, marble, and potentially tin-bearing granitic stocks on the Seward Peninsula (see Till et al. 2010)
**Landforms:** Slopes; alpine tundra; riverbeds on Wrangel Island (Lozhkin et al. 2001); 180 ft m to 1920 ft in Alaska
**Soil type:** Scree, talus, sand (Lozhkin et al. 2001), calcareous substrates
**Moisture regime:** Dry
**Slope:** Sloping
**Aspect:** Variable
**Vegetation type:** Sparsely vegetated, fellfields
**Population sizes:** Seven occurrences known from Alaska, one of which is located within the REA; occasional to locally common (Carlson et al. 2006)
**Association with Change Agents:** The population in the REA is in the immediate vicinity of the Tin City Radar Station Tram. The radar station is inactive, but maintained out of Elmendorf AFB. Clean-up and other activities in this area could impact the population. Additionally, this taxon is known from only a single population on the Seward Peninsula on an isolated limestone bedrock intrusion and migration corridors to track climate envelopes are limited for this taxon if physiological limits are surpassed due to climate change

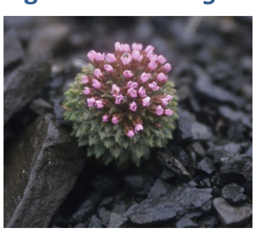
**Figure E-54. *Claytonia arctica* (Arctic Springbeauty) – Tin City (R. Lipkin).**

## E-6.7 *Douglasia alaskana* (Coville & Standl. ex Hultén) S. Kelso (Alaska Rockjasmine)

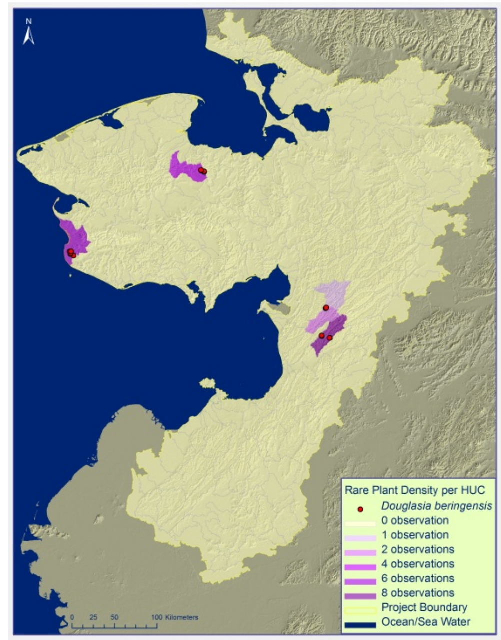



**Global rank:** G3
**State rank:** S2S3
**Distribution:** *Global:* Endemic to Alaska and southwestern Yukon (Cody 1996, Kelso 2009)
*State:* Western Alaska including Seward Peninsula, Nulato Hills, Kuskokwim mountains, Ahklun Mountains; Alaska Range, Aleutian Range, Chugach Mountains, St. Elias Mountians, Wrangell Mountains; Afognak Island (AKNHP 2011, UAM 2011)
**Associated Parent Material:** High-grade metasedamentary and metaigneous and Orovician Casadepaga schist of the Seward Peninsula (see Till et al. 2010). Parent material of the Nulato Hills complex of populations is not known.
**Landforms:** Alpine slopes, ridges, glacial moraines, rock ledges, rock outcrops; floodplains; 60 ft to 5800 ft
**Soil type:** Scree, talus, rock, gravel, glacial till, sand; sometimes associated with shale or calcareous substrates
**Moisture regime:** Moist, well-drained
**Slope:** Gentle to steep
**Aspect:** Various
**Vegetation type:** Sparsely vegetated; heath, dwarf shrub tundra, alpine dwarf scrub, alpine sedge – scrub, *Dryas*-lichen mat
**Population sizes:** Approximately 40 occurrences are known from Alaska, including two from the Seward Peninsula and three from the Nulato Hills; rare to occasional, usually found in small numbers as isolated individuals (Lipkin and Gravuer 2009)
**Association with Change Agents:** No known impacts of CAs on this taxon. Direct perturbations by development seem unlikely. Migration corridors to track climate envelopes are limited for this taxon if physiological limits are surpassed due to climate change.

**Figure E-55. *Douglasia alaskensis* (Alaska Rockjasmine) (R. Lipkin, A. Miller).**

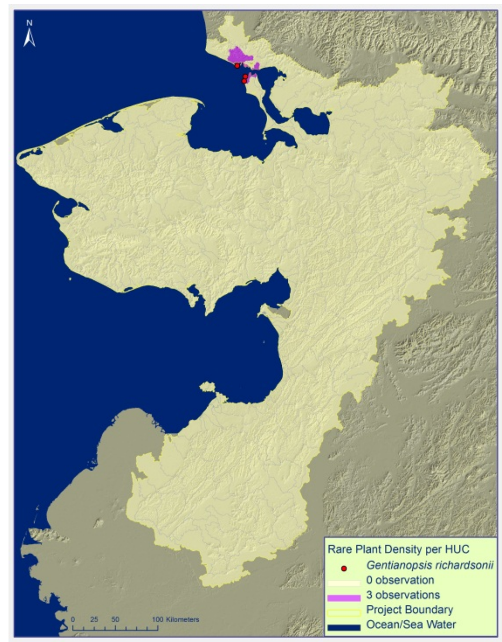
## E-6.8 *Douglasia beringensis* S. Kelso, Jurtz., & D. F. Murray (Arctic Dwarf-primrose)




**Global rank:** G2
**State rank:** S2
**Distribution:** *Global:* Endemic to western Alaska (Kelso 2009)
*State:* Seward Peninsula, Nulato Hills; Lime Hills west of Lake Clark National Park (ALA, BCD)
**Associated Parent Material:** Paleozoic marble of the Moon Mountains, impure chlorite marble (see Till et al. 2010). Parent material of the Nulato Hills complex was identified in one record as "non-calcareous".
**Landforms:** Rock outcrops, rock ledges, and slopes in Seward Peninsula; alpine slopes and ridges in Nulato Hills; slopes and outcrops in Lime Hills; 45 ft to 3170 m
**Soil type:** Scree, rock, gravel, grus on calcareous substrates in Seward Peninsula, non-calcareous substrates including shale and slate in Nulato Hills, and limestone in Lime Hills (Lipkin and Tomaino 2007)
**Moisture regime:** Moist to mesic and well-drained
**Slope:** Often steep
**Aspect:** Various
**Vegetation type:** Sparsely vegetated; scattered forbs, *Dryas* heath, moss
**Population sizes:** Approximately 8 occurrences are known from Alaska, including 4 from the Seward Peninsula and 3 from the Nulato Hills; scattered to abundant (UAM 2011); most populations are small but at least two have several thousand ramets (Lipkin and Tomaino 2007)
**Association with Change Agents:** No known impacts of CAs on this species. Few populations and its close association with marble substrates that are scattered on the Seward Peninsula make this species susceptible to direct perturbations by development, such as use of the substrate as a materials source, as well as climate change. Establishment of significant numbers of invasive plants in relatively remote is unlikely.

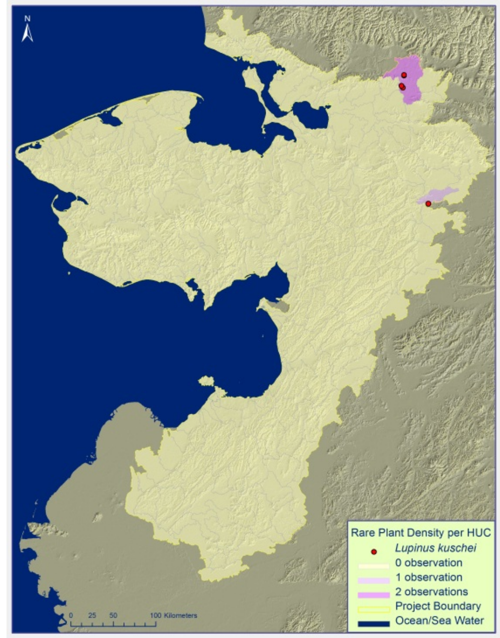
**Figure E-56. *Douglasia beringensis* (Arctic Dwarf-primrose), Seward Peninsula (R. Lipkin).**

## E-6.9 *Gentianopsis richardsonii* (A. E. Porsild) (= *Gentianopsis detonsa* ssp. *detonsa* in part) (Sheared Gentian)



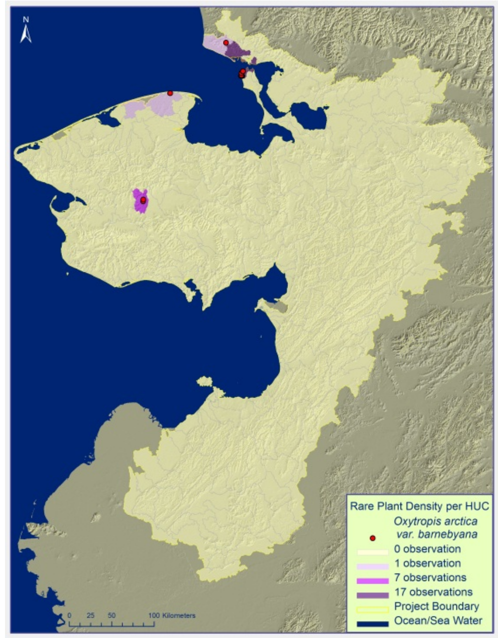

**Global rank:** G3G5T3T5?
**State rank:** S1
**Distribution:** *Global:* Endemic to arctic coast of the District of Mackenzie and Kotzbue Sound, Alaska (Porsild and Cody 1980)
*State:* Kotzbue Sound (Porsild and Cody 1980)
**Taxonomic note:** *Gentianopsis* have recently been reviewed in the Panarctic Flora Checklist and the plants from coastal arctic regions of Alaska (Kotzebue Sound and Mackenzie River District) are considered distinct from the plants of interior Alaska and Yukon. The coastal plants are referred to as *G. richardsonii* (see Elven 2011).
**Associated Parent Material:** Surficial marine deposits of estuaries, imported gravels
**Landforms:** Estuary shores, beaches, coastal marshes
**Soil type:** Loam, gravel; also occurs on mud (McJannet et al. 1995) and sand (Porsild and Cody 1980) in District of Mackenzie
**Moisture regime:** Moist to wet; often in brackish or semi-brackish water
**Slope:** Flat
**Aspect:** None
**Vegetation type:** Coastal meadow, heath
**Population sizes:** Known from seven records in two locations in the Kotzbue Sound area; scattered, population from Baldwin Peninsula consists of 60 plants along 2 mile beach
**Association with Change Agents:** No known impacts of CAs on this species. Populations of this species are associated with estuaries in Kotzebue Sound and therefore any alterations to coastal habitats are potential threats. Coastal habitats could be impacted by climate change related effects, such as sea-level rise or increased erosion, and by development. This species is absent from other estuaries between Kotzebue Sound and the Mackenzie River, suggesting that it is a restricted habitat specialist.

## E-6.10 *Lupinus kuschei* Eastw. (Yukon Lupine)




**Global rank:** G3
**State rank:** S2
**Distribution:** *Global:* Endemic to Northern British Columbia, Yukon, and Alaska (Cody 1996, Douglas et al. 1999)
*State:* East-central Alaska in Wrangell Mountains, Nabesna River Valley, Nutzotin Mountains; disjunct in northwest Alaska along Kobuk River and Kugarak River and in the Koyukuk National Wildlife Refuge (ALA, BCD)
**Associated Parent Material:** Active surficial alluvial and aeolian sands, Kobuk and Nogohabara Dunes
**Landforms:** Active sand areas including dunes, blowouts, and sand sheets; river terraces, river bars, floodplains; roadsides (Hultén 1968); 180 ft to 2640 ft
**Soil type:** Most commonly in sand; also silt and cobbles
**Moisture regime:** Moist to dry
**Slope:** Flat to sloping
**Aspect:** No information available
**Vegetation type:** Sparsely vegetated; open poplar floodplain, scattered willows
**Population sizes:** Approximately ten occurrences are known from Alaska (Lipkin and Gravuer 2008, UAM 2011), including three from Kobuk River Valley; infrequent to locally common (Lipkin and Gravuer 2008)
**Association with Change Agents:** No known impacts of CAs on this species. This species is a narrow habitat specialist of active sand dunes, which are isolated and therefore migration corridors to track climate envelopes are limited for this taxon if physiological limits are surpassed due to climate change.

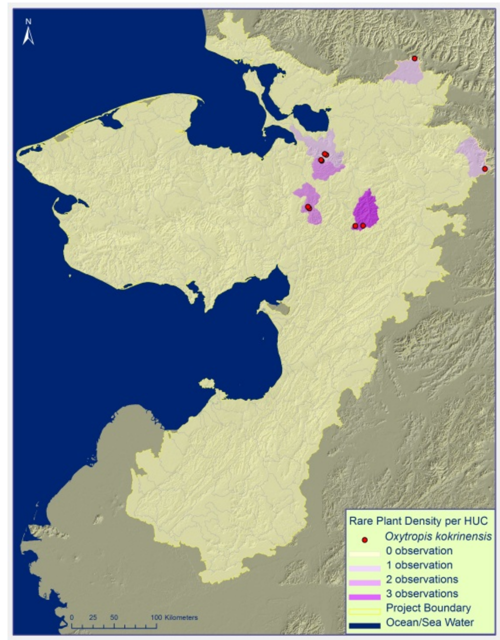
## E-6.11 *Oxytropis arctica* R. Br. var. *barnebyana* S. L. Welsh (Barneby's Locoweed)




**Global rank:** G4?T2Q
**State rank:** S2
**Distribution:** *Global:* Northwestern and North Slope Alaska, USA
*State:* Baldwin Peninsula, western Seward Peninsula, western Brooks Range, central North Slope
**Taxonomic note:** This taxon has recently been reviewed (Elven 2011 and references therein) and is believed to represent a white color-phase of *O. arctica*, making the retention of this entity as a separate questionable.
**Associated Parent Material:** Quaternary surficial deposits, roadside fill
**Landforms:** Floodplains, beach ridges, roadsides, gravel pads, pingos from sea level to 2000 ft (Lipkin and Murray 1997)
**Soil type:** Mineral soil, gravel, and sand, sometimes with an organic layer, rocky silt loam, scree, rocky outcrops
**Moisture regime:** Mesic to dry, well-drained
**Slope:** Flat to sloping
**Aspect:** Often flat or south-facing
**Vegetation type:** Dry to mesic dryas-herb tundra, herbaceous shrub tundra, barrens, open floodplains, tundra vegetation, willow heath, mixed herbaceous meadows, and dryas fellfields
**Population sizes:** Known from nearly 50 records in Alaska, 12 of which occur in the REA. Most populations are concentrated on gravel pads near Kotzebue. Additional populations are known from the central Seward Peninsula on the Kougarok and Kitluk rivers. Population sizes are unknown, but it is reported as “abundant on sparsely vegetated gravel pads near buildings” of the Air Force installation (AKNHP 2011).
**Association with Change Agents:** This plant is often associated with substrate disturbance and is likely merely a color-form of a more widespread taxon and therefore is of minor conservation concern.

**Figure E-57. *Oxytropis arctica var. barnebyana* (Barneby's Locoweed) specimen (UAM 2011).**

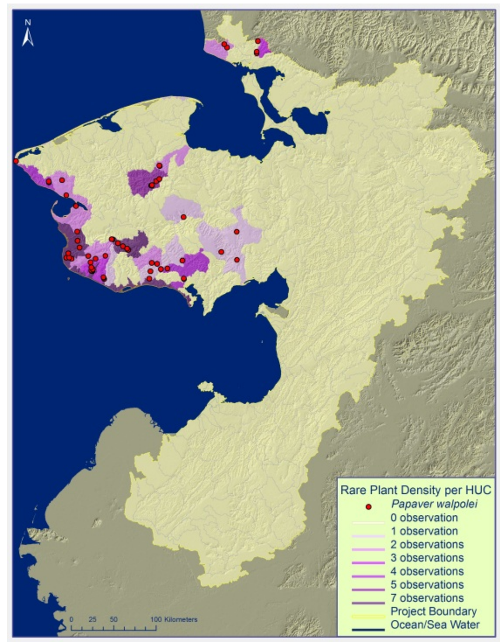
## E-6.12 *Oxytropis kokrinensis* A.E. Porsild (Kokrines Oxytrope)




**Global rank:** G3
**State rank:** S3
**Distribution:** *Global:* Northwestern Alaska, USA
*State:* Ray Mountains in the east, north to the DeLong Mountains and southwest to the northern edge of the Nulato Hills
**Associated Parent Material:** Sand, gravel, granites, acidic substrates, limestone-igneous contact zones, phyllite
**Landforms:** Ridges, sideslopes, hills
**Soil type:** Sand, gravel, scree
**Moisture regime:** Mesic to dry, well-drained
**Slope:** Flat to sloping
**Aspect:** Variable, a number of collections note south-facing and a few note west-facing
**Vegetation type:** Dryas meadows, fellfields, scree slopes
**Population sizes:** Known from approximately 30 records in Alaska, 8 of which occur in the REA. Populations in the REA are clustered in three areas: the Selawik Hills, Buckland Hills, and upper Tagagwik Basin. The sizes of populations are unknown.
**Association with Change Agents:** No known impacts of CAs on this taxon. Direct perturbations by development seem unlikely to populations in the REA. With numerous populations east and north of the region in mountainous areas, climate change is not likely as serious a concern as it is for other species. Establishment of non-natives in these remote areas seems unlikely.

**Figure E-58. *Oxytropis kokrinensis* (Kokrines Oxytrope) specimen (UAM 2011).**

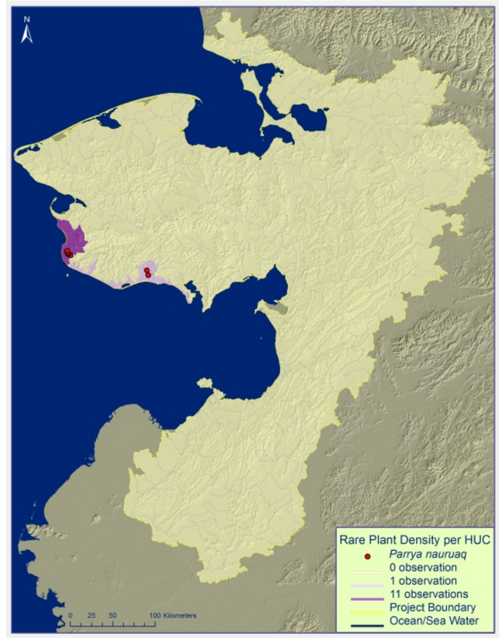
## E-6.13 *Papaver walpolei* A.E. Porsild (Walpole's Poppy)




**Global rank:** G3
**State rank:** S3
**Distribution:** *Global:* Russian Far East to western Alaska and the Ogilvie Mountains, Yukon *State:*Seward Peninsula, Baird Mountains, western Brooks Range
**Associated Parent Material:** Range of calcareous substrates. Mixed marble, graphitic metasiliceous rock, and schist of Devonian-Ordovician; Limestone and dolomitic limestone; Metacarbonate rocks, Paleozoic Marble of the Moon Mountains; pelitic, calcareous, and graphitic schist; phyllite and argillite; impure chlorite marble (see Till et al. 2010).
**Landforms:** Ridges, sideslopes, hills, barrens
**Soil type:** Dry limestone outcrops, screes, gravels, gravelly loam, grus
**Moisture regime:** Moist to xeric, well-drained
**Slope:** Flat to steeply sloping
**Aspect:** Variable
**Vegetation type:** Mesic tundra, fellfields, barren scree slopes, willow-heath.
**Population sizes:** Known from approximately 70 records in Alaska, 48 of which occur in the REA. Populations in the REA are associated with calcareous substrates on the southern half of the Seward Peninsula. Population sizes appear to generally be small and plants are often widely scattered; two populations were estimated at 100 individuals along the upper Sinuk River (Carlson et al. 2007.), and approximately 50 individuals were estimated for a population near the Solomon River (M. L. Carlson pers. obs.).
**Association with Change Agents:** No known impacts of CAs on this taxon. Direct perturbations by development could threaten individual populations; however, this species is quite widely distributed in the REA and often occurs in remote areas. This species has also been observed growing on gravel pull-out and as a whole is not particularly vulnerable to development. Shrub or other native species encroachment is likely a greater risk than non-native species for *P. walpolei*.

**Figure E-59. *Papaver walpolei* (Walpole's Poppy) habitats on weathered marble outcrop (A) and fellfield (B). White-flowered (C) and yellow-flowered (D) plants.**

## E-6.14 *Parrya nauruaq* Al-Shehbaz, J. R. Grant, R. Lipkin, D. F. Murray & C. L. Parker (Naked-stemmed Wallflower)




**Global rank:** G2
**State rank:** S2
**Distribution:** *Global:* Seward Peninsula, northwestern Alaska, USA *State:* Moon Mountains and Solomon River highlands, Seward Peninsula
**Associated Parent Material:** Metacarbonate rocks, Paleozoic Marble of the Moon Mountains; layered, mixed marble, graphitic metasiliceous rock and schist (Devonian to Ordovician – area of a distinctive belt of dolostone and marble of Silurian-Devonian age (Till et al. 2010)
**Landforms:** Outcrops, hogback ridges, weathered 'badlands', floodplains, slopes, bluffs
**Soil type:** Eroding marble, scree, platy rock, shallow grus, gravel
**Moisture regime:** Moist, well-drained
**Slope:** Flat to sloping
**Aspect:** Variable
**Vegetation type:** Barrens, grading into shrub tundra, open dryas mats and dryas fellfields
**Population sizes:** Known from only one large site in the Moon Mountains, with several sub-populations, and a population that is over 10,000 ramets. Ca. 25 plants are known from the Solomon River population.
**Association with Change Agents:** No known impacts of CAs on this species. Few populations and its close association with marble substrates that are scattered on the Seward Peninsula make this species susceptible to direct perturbations by development, such as use of the substrate as a materials source, as well as climate change. Establishment of significant numbers of invasive plants in relatively remote marble barrens is unlikely.

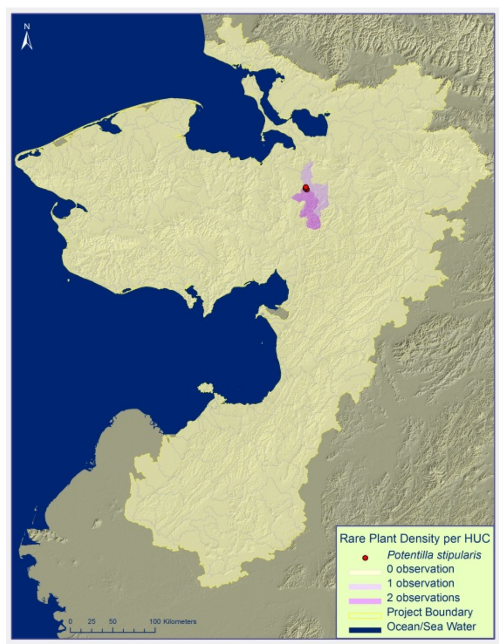
**Figure E-60. *Parrya nauruaq* (Naked-stemmed Wallflower) plants and habitats along the Solomon River and the Moon Mountains, Seward Peninsula (center and right photos by R. Lipkin).**

## E-6.15 *Potentilla rubricaulis* Lehm. (Rocky Mountain Cinquefoil)

**Global rank:** G4
**State rank:** S2?
**Distribution:** *Global:* Alaska, Yukon, Northwest Territories; western U.S. and Canada; Greenland (Aiken et al. 2007)
*State:* Keele Range and Noatak National Preserve; determinations of additional specimens from interior and south-central Alaska are tentative (UAM 2011)
**Taxonomic note:** Specimens from Alaska have recently been reviewed by R. Elven and D. F. Murray, and many of the previously identified "*P. rubricaulis*" are in fact the more widespread *P. hookeriana*. This includes all specimens from the REA area. **As this taxon is not believed to be present within the SNK REA project boundary, it is not treated in this REA.**

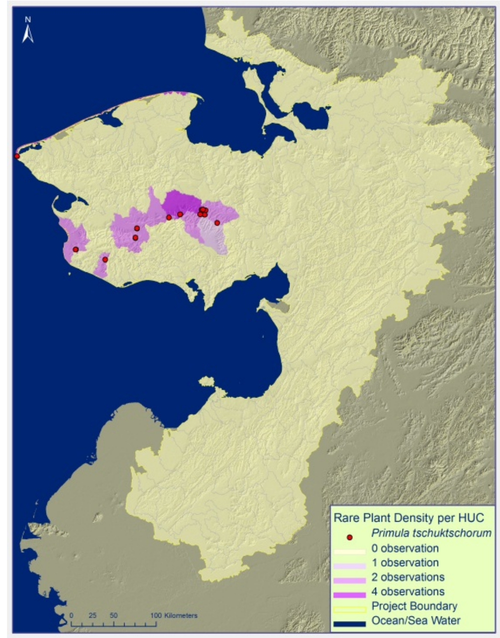
## E-6.16 *Potentilla stipularis* L. (Circumpolar Cinquefoil)

**Global rank:** G5
**State rank:** S1
**Distribution:** *Global:* Widespread and abundant in northern Asia, extending into northwestern Alaska; disjunct in Greenland (Cortés-Burns et al. 2009)
*State:* Seward Peninsula, De Long Mountains, upper Noatak River area, Colville River (Cortés-Burns et al. 2009)




**Associated Parent Material:** Appears to be associated with surficial deposits
**Landforms:** Sideslopes and valleys, stream banks, river banks, river terraces, cutbanks, bluffs, draws, floodplains (ALA, Cortés-Burns et al. 2009); 45 ft to 2100 ft
**Soil type:** Silty loam, gravel, mud, sand, cobbles, chert
**Moisture regime:** Wet to mesic
**Slope:** Moderate
**Aspect:** Predominantly south-facing
**Vegetation type:** Grassy meadow enclosed by tall willow and alder, graminoid-*Salix-Dryas* tundra, *Dryas*-heath hummock tundra, sedge tussock
**Population sizes:** Known from six occurrences in Alaska, including one from within the REA; abundant in Seward Peninsula population
**Association with Change Agents:** No known impacts of CAs on this species.

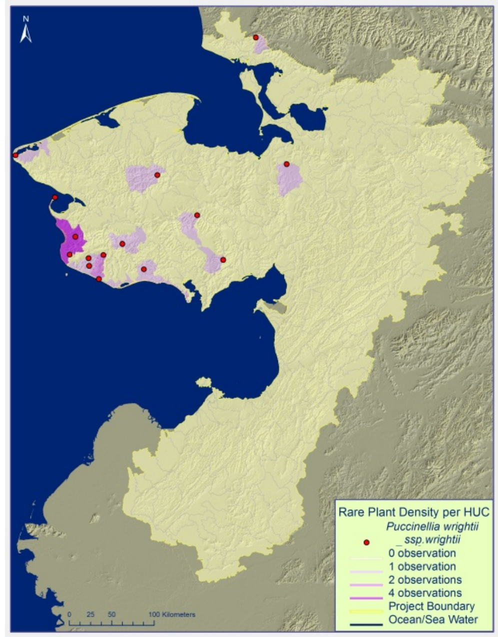
## E-6.17 *Primula tschuktshorum* Kjellm. (Chukchi Primrose)




**Global rank:** G2G3
**State rank:** S2S3
**Distribution:** *Global:* Russian Far East, western Alaska, USA
*State:* Walatka, Ahklun, and Kilbuck mountains, St. Lawrence Island, Seward Peninsula
**Associated Parent Material:** Bendeleben and Kuzitrin plutons (Cretaceous); high-grade metasedimentary and metaigneous rocks (Paleozoic and Proterozoic); surficial Quaternary deposits on the Seward Peninsula (see Till et al. 2010)
**Landforms:** Stream edges, solifluction slopes, lake margins, mountain and hill slopes
**Soil type:** Wet organic, moist gravely loam, mud among rocks, frost boils
**Moisture regime:** Moist to wet, often associated with snowmelt areas
**Slope:** Flat to sloping
**Aspect:** Variable
**Vegetation type:** Forb-graminoid tundra, mixed herbaceous-dwarf willow tundra, moist barren tundra, occasionally in open mesic dryas tundra
**Population sizes:** Most known populations in the REA are clustered in the Bendeleben Mountains with a few outlying collections scattered in the Kigluaik Mountains and near Cape Prince of Wales. Population sizes near Kuzitrin Lake appear to have dropped dramatically since 1995, from many thousand to less than 500 (Carlson 2006, Carlson et al. 2007, 2008). The population along Crete Creek is estimated to be composed of < 500 individuals.
**Association with Change Agents:** No known impacts of CAs on this species. Populations of this species can be impacted by goose, caribou, and reindeer herbivory as well as by reproductive interference with the more common *P. pumila* [syn =*P. eximia*] Carlson 2006, Carlson et al. 2007, 2008). Direct impacts by development are unlikely. Impacts from climate change are unknown, but as this species is often associated with snow melt areas and cryoturbation, it may be vulnerable to increases in summer and winter temperatures.

**Figure E-61. *Primula tschuktschorum* (Chukchi Primrose) plants and habitats in the Bendeleben Mountains**

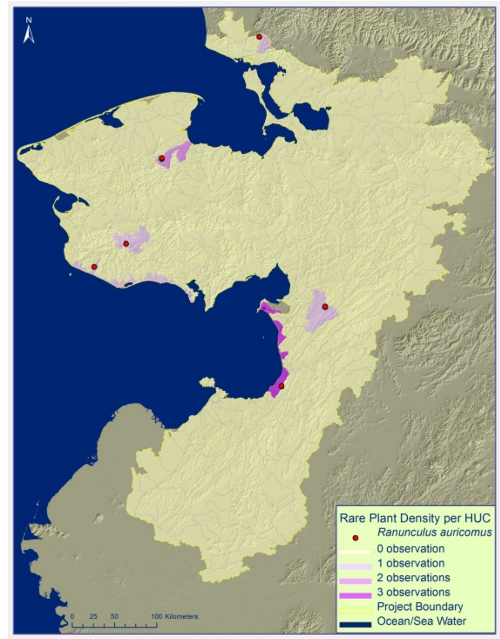
## E-6.18 *Puccinellia wrightii* ssp. *wrightii* (Scribn. & Merr.) Tzvelev (a Wright's Arctic Grass subspecies)




**Global rank:** G3G4
**State rank:** S2S3
**Distribution:** *Global:* Chukotka Peninsula and northwestern Alaska (Davis and Consaul 2007, Elven 2011)
*State:* Seward Peninsula; Noatak National Preserve, Killik River on North Slope, Cape Beaufort
**Taxonomic note:** The Panarctic Flora Checklist lists two subspecies of *Puccinellia wrightii* with all of the Alaskan material assigned to *P. wrightii* ssp. *wrightii* and *P. wrightii* ssp. *colpodioides* restricted to Wrangel Island of the Russian Arctic (Elven 2011).
**Associated Parent Material:** Limestone, marbleized carbonate rock, calcareous bedrock (Cortés-Burns et al. 2009). On the Seward Peninsula, populations appear to be associated with a range of calcareous bedrock: Mississippian Limestone, dolomitic limestone, marble; Paleozoic marble of the Moon Mountains, high-grade metasedamentary and metaigneous; peltitic, calcareous, and graphitic schists (see Till et al. 2010).
**Landforms:** Alpine slopes, valleys, seepages; 15 ft to 2800 ft
**Soil type:** Diluvium; wet organic tundra soils; calcareous substrates
**Moisture regime:** Wet to mesic
**Slope:** Sloping
**Aspect:** Various
**Vegetation type:** Dwarf shrub and herbaceous graminoid meadows
**Population sizes:** Known from 18 occurrences in Alaska, 15 of which are located within the REA; information on size of occurrences not available
**Association with Change Agents:** No known impacts of CAs on this taxon. Populations are scattered throughout the Seward Peninsula and this grass is likely overlooked. Direct perturbations to populations near roads in particular could be possible if substrates or the hydrology are disturbed.

**Figure E-62. *Puccinellia wrightii* (Wright's Arctic Grass) specimen (UAM 2011).**

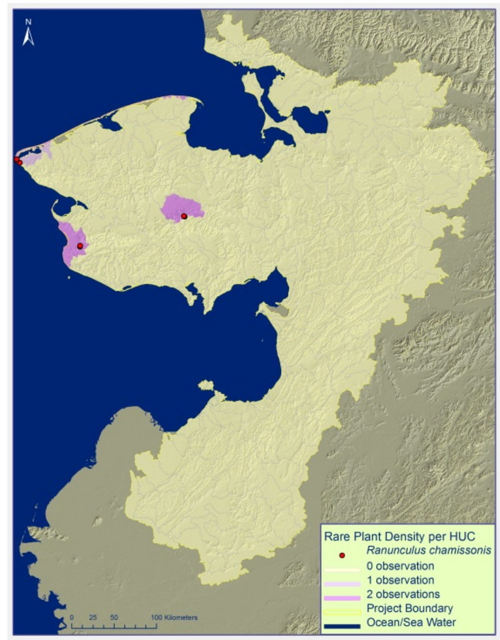
## E-6.19 *Ranunculus auricomus* L. (Goldilocks Buttercup)




**Global rank:** G5
**State rank:** S2
**Distribution:** *Global:* Greenland, Iceland, Fennoscandinavia, Russia, Siberia, western Alaska, USA
*State:* southwestern Seward Peninsula and Nulato Hills
**Associated Parent Material:** Generally associated with Quaternary surficial deposits of moist acidic, organic substrates
**Landforms:** Ridges, hill slopes, toeslopes, bluffs, streambanks
**Soil type:** Organic, loam
**Moisture regime:** Mesic to wet
**Slope:** Flat to sloping
**Aspect:** Variable
**Vegetation type:** Shrub tundra, mixed herbaceous-shrub tundra, willow thickets, lush meadows, dryas-heath meadows
**Population sizes:** In North America, known from just eight collections in the REA and one additional population to the north of the REA. The size of one population was estimated at 20 individuals (Carlson et al. 2007).
**Association with Change Agents:** No known impacts of CAs on this species.

**Figure E-63. *Ranunculus auricomus* (Goldilocks Buttercup) specimen (UAM 2011) and mixed herbaceous-shrub tundra habitat, southern Seward Peninsula**

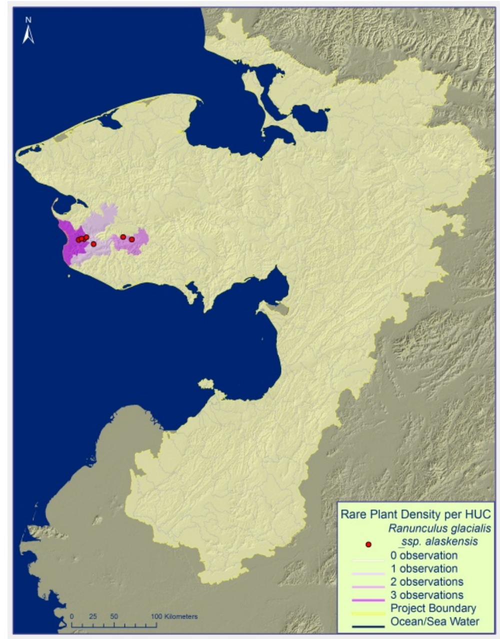

## E-6.20 *Ranunculus camissonis* Schltdl. (= *Ranunculus glacialis* var. *chamissonis* (SCHLECT.) Hult.) (Glacier Buttercup)




**Global rank:** G3G4
**State rank:** S2
**Distribution:** *Global:* Chukotka, Russia; western and northern interior Alaska USA
*State:* St. Lawrence Island, Seward Peninsula, western Brooks Range, Kokrine-Hodzana Highlands, White Mountains, Yukon-Tanana Uplands
**Associated Parent Material:** Generally the taxon is associated with basic substrates (Elven 2011), including marble, high-grade metasedimentary and metaigneous parent material of the Seward Peninsula (see Till et al. 2010); however it is also known from Tin-bearing granite stocks of Cape Mountain
**Landforms:** Alpine slopes, seeps, creek margins, snowmelt drainage, cirques, terraces, old alluvial fans, calcareous outcrops, toeslopes
**Soil type:** Turf, organic tundra soils, rocky and coarse sand, wet mud-rock pavements
**Moisture regime:** Moist to wet
**Slope:** Variable
**Aspect:** Unknown
**Vegetation type:** Graminoid meadows, mesic seep/tundra, wet marshy areas, wet sedge-grass meadows, fellfields, dryas mats
**Population sizes:** This taxon is known from just three populations on the Seward Peninsula with unknown population sizes. It has been described as locally abundant in two Alaskan sites (Carlson et al. 2007).
**Association with Change Agents:** No known impacts of CAs on this species.

**Figure E-64. *Ranunculus camissonis* (Glacier Buttercup) plant (R. Lipkin) and specimen (UAM 2011).**

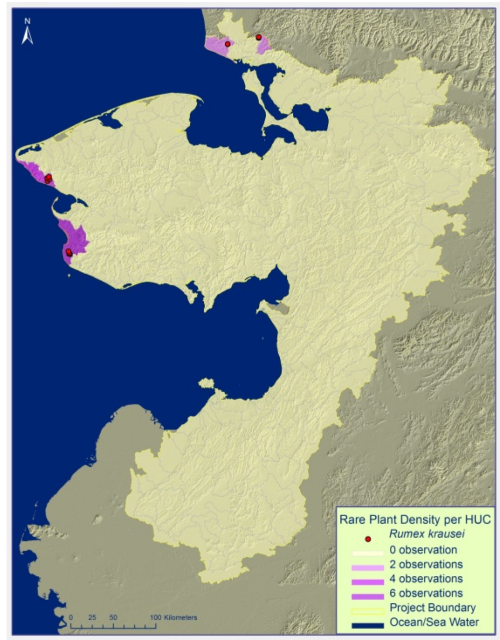
## E-6.21 *Ranunculus glacialis* ssp. *alaskensis* Jurtz. (a Glacier Buttercup subspecies)




**Global rank:** G4T2
**State rank:** S2
**Distribution:** *Global:* Seward Peninsula Alaska, USA
*State:* Kigluaik Mountains of the Seward Peninsula
**Associated Parent Material:** The known locations of this taxon appear to be associated with the Paleozoic and Proterizoic high-grade metasedimentary and metaigneous rock; and potentially Proterizoic orthogneiss (see Till et al. 2010)
**Landforms:** High-alpine rubble slopes, ridges, from 900 to 3,000 ft elevation (Lipkin and Murray 1997)
**Soil type:** Non-carbonate slopes, shattered, platey, shale-like, or schistose rock slopes (Lipkin and Murray 1997), scree with fines
**Moisture regime:** Mesic to dry
**Slope:** Flat to moderate
**Aspect:** Variable
**Vegetation type:** Barren scree
**Population sizes:** Known from just four populations within the Kigluaik Mountains. Population sizes of the Crete Creek complex appeared to be less than 50 plants in 2006; however other populations are estimated at thousands of individuals (Carlson et al. 2007).
**Association with Change Agents:** No known impacts of CAs on this taxon. Direct perturbations by development seem unlikely in the Kigluaik Mountains. Migration corridors to track climate envelopes are extremely limited for this taxon if physiological limits are surpassed due to climate change and the very few known locations for this taxon suggest high intrinsic vulnerability.

**Figure E-65. *Ranunculus glacialis ssp. alaskensis* specimen (UAM 2011).**

## E-6.22 *Rumex krausei* Jurtz. & V.V. Petrovsky. (Krause's Sorrel)




**Global rank:** G2
**State rank:** S2
**Distribution:** *Global:* Eastern Chukotka Russia to western Alaska, USA *State:* Southwestern Seward Peninsula, Igichuk Hills and Baird Mountains, Lisburne Peninsula
**Associated Parent Material:** Ordovician Limestone and Metacarbonate rocks, Paleozoic Marble of the Moon Mountains (see Till et al. 2010), silty sands, or argillaceous soil (Lipkin and Murray 1997)
**Landforms:** River terraces, flats, alpine slopes, outcrops, 60 – 1000 ft (Lipkin and Murray 1997)
**Soil type:** Gravels, solifluction soil, frost scars, grus
**Moisture regime:** Moist to wet
**Slope:** Gentle
**Aspect:** Variable
**Vegetation type:** Barrens, wet-sedge rock stripes, moist-marshy disturbed areas, grassy hummocks, open-graminoid meadows, dryas fellfields
**Population sizes:** Populations in the REA are concentrated in the York and Moon mountains of the Seward Peninsula and the Igichuk Hills. Sizes of populations are not known.
**Association with Change Agents:** No known impacts of CAs on this species. The Lost River population complex is in the immediate vicinity of an area that has been subject to intermittent placer and lode-deposit tin mining since 1903. This area harbors the largest deposits of tin in North America (see Lorain et al. 1958). One collection label indicates the plants were growing in wet area disturbed by mining activities, suggesting low to moderate levels of disturbance are unlikely to be detrimental.

**Figure E-66. *Rumex krausei* (Krause's Sorrel) plant (photo by R. Lipkin) and specimen (UAM 2011).**

## E-6.23 *Saussurea* cf. *triangulata* Trautv. & C.A. Mey. (a Saw-wort)


**Global rank:** G1
**State rank:** S1
**Distribution:** *Global:* Russian Far East, northwestern Alaska
*State:* Waring Mountains, northwestern Alaska
**Associated Parent Material:** Unknown
**Landforms:** Near ridge tops, sideslopes, hills
**Soil type:** Humic soil, cobbles
**Moisture regime:** Mesic
**Slope:** Flat to gently sloping
**Aspect:** West-facing
**Vegetation type:** Herbaceous-heath meadow and alder margins, low shrub meadows, alder scrub
**Population sizes:** This plant is only known from a single area in the Waring Mountains of Selawik National Wildlife Refuge and is outside of the REA by less than a mile. We include this taxon because it is likely that it occurs within unsurveyed areas of the REA.
**Association with Change Agents:** No known impacts of CAs on this species. With just a single population known for North America this is a species of high conservation concern, warranting additional surveys.

**Figure E-67. *Saussurea* cf. *triangularis* specimen (UAM 2011).**

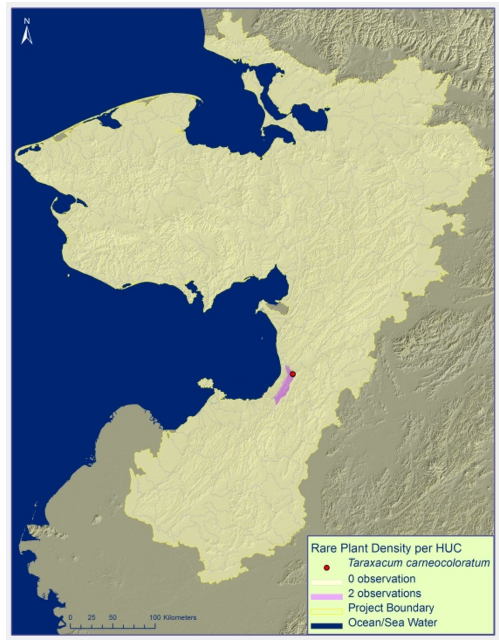
## E-6.24 *Smelowskia johnsonii* G.A. Mulligan (Johnson's False Candytuft)

**Note:** During the SNK REA process, AKNHP reviewed rare plant EOs and determined that the *Smelowskia johnsonii* population from Lost River (on the western end of the Seward Peninsula) was a misidentification (M. Carlson, pers. comm.). Therefore, no populations of this taxon are present within the SNK REA boundary. The information on this species is retained here for reference.

**Global rank:** G1
**State rank:** S1
**Distribution:** *Global:* Northwestern Alaska, USA *State:* western S
**Associated Parent Material:** Ordovician Limestone (see Till et al. 2010).
**Landforms:** Outcrops, sideslopes, 0 – 1,800 ft
**Soil type:** loose rocks, limestone rubble, talus
**Moisture regime:** Dry
**Slope:** Gently to steeply sloping
**Aspect:** unknown.
**Vegetation type:** Barrens, talus slopes, dryas fellfields
**Population sizes:** Known from just four sites in western Alaska. Three are known from the Lisburne Peninsula and one at Lost River on the York Mountains of the Seward Peninsula. No information is available on population sizes.
**Association with Change Agents:** The Lost River population is in the immediate vicinity of an area that has been subject to intermittent placer and lode-deposit tin mining since 1903. This area harbors the largest deposits of tin in North America (see Lorain et al. 1958). *Smelowskia johnsonii* may therefore be directly impacted by future mining activities. Additionally, this taxon is known from only a few populations on isolated limestone bedrock and migration corridors to track climate envelopes are limited for this taxon if physiological limits are surpassed due to climate change.

**Figure E-68. *Smelowskia johnsonii* (Johnson's False Candytuft) specimen (UAM 2011) and washing plant at the tin mine, Lost River, photograph by Len Grothe (Bundtzen et al. 1988).**

## E-6.25 *Taraxacum carneocoloratum* A. Nelson (Pink Dandelion)




**Global rank:** G3Q
**State rank:** S3
**Distribution:** *Global:* Alaska, Yukon (Brouillet 2006)
*State:* Alaska Range, Chugach Mountains, Wrangell Mountains, Neacola Mountains; Western Alaska in Kilbuck Mountains and Nulato Hills
**Associated Parent Material:** Various
**Landforms:** Alpine slopes, ridges, drumlins, rock outcrops, river terraces, floodplains; 760 to 7600 ft (Lipkin 2000) in Alaska
**Soil type:** Scree, gravel, rocky mineral soil; often found on calcareous substrates (ALA, Lipkin 2000)
**Moisture regime:** Dry to moist
**Slope:** Flat to 50° slope
**Aspect:** Various
**Vegetation type:** Sparsely vegetated
**Population sizes:** Over 30 locations are known in Alaska, including one in the Nulato Hills Ecoregion of the REA; rare at most sites (Lipkin 2000, UAM 2011); several populations numbering in the thousands (Lipkin 2000)
**Association with Change Agents:** No known impacts of CAs on this taxon. Direct perturbations by development seem unlikely to populations in the REA. With numerous populations east of the region in mountainous areas, climate change is not likely as serious a concern as it is for other species. Establishment of non-natives in these remote areas seems unlikely.

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# E-7 Additional Aquatic Species CEs

## E-7.1 Introduction

This section contains descriptive information for additional fish conservation elements lacking adequate data to develop spatial distribution models. Most are landscape species; Arctic char was placed in the "local" species category. (Because these species do not have spatial distributions, with the exception of Arctic char, ecological status could not be assessed.) The descriptive text includes information on the species' taxonomy, reproductive ecology, migration ecology, habitat, and geographic range.

The descriptive information was provided by the Alaska Natural Heritage Program for the SNK REA. The species information included in the AKNHP's documents was obtained from the Alaska Heritage Program's installation of Biotics, a biodiversity database developed centrally at NatureServe and maintained through the combined efforts of the member heritage programs and NatureServe. The member program biodiversity databases are coordinated with the central NatureServe database; these databases are dynamic, maintained and refined through updates made to reflect current changes to taxonomy, and by the periodic import of new records that are developed according to standard methodology by natural heritage member program scientists and other collaborators, including government agencies, universities, natural history museums and botanical gardens, and additional conservation organizations. This ongoing process of adding and revising information and records helps to maintain currentness and enhance completeness of the data.

NatureServe member programs' biodiversity databases contain an array of information about elements of biodiversity, with particular emphasis on those that are more threatened across their range. Tracked data includes taxonomy, conservation status, ecological and life history, habitat requirements, and distribution, with primary sources of this information consisting of scientific literature, museum specimen records, reliably documented observation records, species lists, range maps, external databases, and experts, including scientists from natural heritage member programs. While centrally NatureServe maintains range maps and/or data representing all native full species vertebrates and vascular plants, within individual member programs resources generally limit the tracking of specific locations of species and other elements of biodiversity within their jurisdictions to those having the highest conservation concern.

## E-7.2 Arctic char (*Salvelinus alpinus*)

**Assessment:** Local

**HABITAT DESCRIPTION**

Arctic char spawn in the fall, between August and October in the northern portion of their range, or around November and December farther south (Morrow 1980). Most often they spawn in lakes, but may also use quiet pools in streams or rivers (Mecklenburg 2002, Morrow 1980). Spawning occurs over rocky or gravel shoals, or over steep and broken substrates deep enough to be safe from winter ice (ADF&G 2011, Morrow 1980). Water temperature for spawning is generally between 3°-13° C, but has been reported as low as 0.5° C (Morrow 1980). Hatching possibly occurs in 60-70 days, or not until ice goes out in the spring (Morrow 1980). Young emerge in the summer, a few months after hatching (NatureServe 2011).

Alaskan Arctic char are lacustrine, although anadromous populations exist elsewhere (Mecklenburg 2002, Morrow 1980). They are often found in pools and deep runs of medium and large lakes and rivers; they are not often far inland, with the exception of populations in isolated lakes or up large rivers (NatureServe 2011). These fish can survive partial freezing of their body (Morrow 1980).

Arctic char are circumpolar in the arctic and subarctic (Morrow 1980). In Alaska, Arctic char are found from the Arctic Ocean and Bering Sea, south to Southeast Alaska (Mecklenburg et al. 2002, Morrow 1980). Within the REA study area, they are found in lakes of the Kigluaik Mountains on the Seward Peninsula (ADF&G 2011, NAB 2006).

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## E-7.3 Arctic lamprey (*Lampetra japonica* syn. *Lampetra camtschatica*)

**Assessment:** Lacks data on distribution in REA study area

**HABITAT DESCRIPTION**

Spawning takes place in spring, usually between late May and early July (Morrow 1980), in gravel runs and riffles of clear streams (Mecklenburg et al. 2002). Spawning occurs in streams with moderate flow but out of the main current, preferably where flow is between 0.16 and 0.3 meters per second (Morrow 1980, NatureServe 2011). Water needs to be from 12°-15° C and from a few centimeters to a meter deep (Morrow 1980). Eggs take from one to a few weeks to develop and hatch into ammocoetes (ADF&G 2011, Morrow 1980).

Ammocoetes burrow into mud, sand, or silt of eddies and shallow pools of clear streams (ADF&G 2011), or live in backwaters and muddy margins of lakes and rivers (Mecklenburg et al. 2002). The duration of time spent as an ammocoete varies, and are reported as either one to two years (Morrow 1980), up to four years (NatureServe 2011), or three to seven years (ADF&G 2011). Metamorphosis to adult form happens in the fall, at which time young adults move downstream to sea, lakes, or large rivers (Morrow 1980). Downstream migration occurs from August through November when the Arctic lamprey attaches itself to a variety of fish species (NatureServe 2011).

There are both freshwater and anadromous forms of the Arctic lamprey (Morrow 1980). Lower Yukon River Arctic lamprey are mostly anadromous, and have similar habitat needs as anadromous salmon (Morrow 1980, NatureServe 2011). Freshwater forms reside in large rivers or lakes (NatureServe 2011), while anadromous lampreys overwinter in freshwater but spend 1-4 years at sea and can be found at up to 50 m depth (ADF&G 2011, Mecklenburg et al. 2002).

To spawn, adults migrate to freshwater streams in the spring (NatureServe 2011) or fall (ADF&G) and may travel for several months to clear, cool headwaters (ADF&G 2011, NatureServe 2011). Adults die shortly after spawning (ADF&G 2011, BIOTICS 2011).

Arctic lamprey can be found from the Arctic coast south to the Kenai Peninsula, including the Bering Sea drainages (Mecklenburg et al. 2002, Morrow 1980). They are abundant in the lower Yukon River, and are also present far upstream, as well as in the Kuskokwim River drainage (Mecklenburg et al. 2002, Morrow 1980).

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## E-7.4 Bering cisco (Coregonus laurettae)

**Assessment:** Lacks data on distribution in REA study area

**HABITAT DESCRIPTION**

Little is known about the life history traits of the Bering cisco, but it is likely that they spawn in the fall (Morrow 1980), between late September and early October (NAB 2006). It is presumed that spawning takes place in clear water streams that are tributary to major rivers (Morrow 1980). Bering cisco spawning habitat in the Susitna River was 0.15-0.8 m deep, 3°-3.8° C, with 2.5-7.5 cm diameter gravel (BIOTICS 2011). Sand, silt, and cobble areas are also utilized (BIOTICSC 2011, NAB 2006).

Bering cisco are tolerant of high salinity and are frequently found in estuaries (ADF&G 2011). They mostly overwinter near river mouths in brackish or salt water (Mecklenburg et al. 2002), and are known to overwinter in lakes, deep rivers, or estuarine regions including Grantely Harbor and Hotham Inlet (NAB 2006). Spawning fish have also been found well up the Kuskokwim and Yukon rivers, which suggests that overwintering also occurs in freshwater (Morrow 1980). Bering cisco undertake long spawning migrations, beginning in the spring (Morrow 1980) to late summer (NatureServe 2011). Some evidence show that adults spend 15 to 20 days in spawning areas, primarily around October (BIOTICS 2011).

With the exception of an occurrence in Siberia, Bering cisco are endemic to Alaska (BIOTICS 2011). They are present in Bering Sea drainages of the Norton Sound and Seward Peninsula (ADF&G 2011), and range from the Kotzebue Sound to Bristol Bay (BIOTICS 2011). An anadromous population is known in the Kuskokwim River (BIOTICS 2011), and they also range up to 840 km away from sea on the Kuskokwim's South Fork (Morrow 1980). Along the Yukon River, they are present as far upstream as Fort Yukon (Mecklenburg et al. 2002, Morrow 1980) or Dawson (NatureServe 2011).

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## E-7.5 Broad whitefish (*Coregonus nasus*)

**Assessment:** Lacks data on distribution in REA study area

**HABITAT DESCRIPTION**

Spawning occurs between September and October, and sometimes into November (Morrow 1980). Within the Kuskokwim River, fish spawn while the river freezes (BIOTICS 2011). Eggs hatch in the spring, at which time young fish travel downstream (Morrow 1980). Spawning most often takes place on gravel-bottomed streams (Morrow 1980), although substrate may vary from mud and sand to cobble (BIOTICS 2011). Juvenile fish disperse in nearshore marine water and in small coastal drainages (Brown 2004)

Although the broad whitefish is anadromous, it spends most of its time in freshwater. When in the ocean, they remain near shore and close to brackish water (Mecklenburg et al. 2002, Morrow 1980). The coastal zone is used as an alternative feeding area and as a migration corridor (BIOTICS 2011). However, this species has a low tolerance to salinity, and populations may be isolated by barriers of salt water exceeding 20 ppt (BIOTICS 2011).

Within freshwater, broad whitefish are found most often in rivers and streams, but also occupy lakes, ponds, sloughs, and estuaries (Mecklenburg 2002, BIOTICS 2011). Overwintering occurs in deep sections of rivers or in estuaries (Morrow 1980), or sometimes in lakes (NatureServe 2011).

Upstream migration to spawning grounds takes place between June and September, or possibly later (Morrow 1980). Migration upstream can be hindered by water velocities >40 cm/second in stream reaches longer than 100 m (BIOTICS 2011). After spawning, adults move downstream. Individuals may travel several hundred miles between overwintering, spawning, and feeding habitats (BIOTICS 2011).

Broad whitefish are found from the Arctic coast south to the Kuskokwim River (Mecklenburg 2002, Morrow 1980). They are present in the Bering, Chukchi, Beaufort, and Arctic Ocean drainages, possibly in every river (Mecklenburg et al. 2002, Morrow 1980). Broad whitefish are present in the Yukon River from its mouth to its headwaters in British Columbia (Mecklenburg et al. 2002, Morrow 1980), and throughout the entirety of the Kuskokwim River system and near shore waters of Kuskokwim Bay (BIOTICS 2011, Mecklenburg et al. 2002). Deep, calm pools of the Omar River host whitefish in large schools (BLM 2006), and they are commonly found in the slow-moving water of interconnected lakes and sloughs of Selawik Flats (NAB 2006).

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## E-7.6 Humpback whitefish (*Coregonus pidschian*)

**Assessment:** Lacks data on distribution in REA study area

**HABITAT DESCRIPTION**

Spawning usually occurs in October, but on the Kuskokwim River, humpback whitefish are known to spawn as late as mid-November under ice (Morrow 1980). Gravel substrate in rivers' upper reaches is preferred spawning habitat (ADF&G 2011). Eggs presumably hatch in late winter or spring, at which time juvenile fish move downstream (Morrow 1980) and disperse in nearshore marine water and in small coastal drainages (Brown 2004).

Humpback whitefish are anadromous, although some upstream populations may never visit the ocean (Mecklenburg et al. 2002, Morrow 1980). While at sea, fish are found relatively close to shore (Mecklenburg et al. 2002). The exact distances humpback whitefish travel are unknown, but they have been caught several miles off Kotzebue Sound, around the Kuskokwim and Yukon River mouths (Morrow 1980). In freshwater, fish are most often found in lakes, but also inhabit large rivers and brackish water (NatureServe 2011). Overwintering occurs in close proximity to river mouths (Mecklenburg et al. 2002).

Upstream spawning migration begins around June and can be over 1280 km long (Mecklenburg et al. 2002, Morrow 1980). Humpback whitefish are found in high concentrations during spawning, but fish are dispersed the rest of the year (Morrow 1980).

Most rivers that drain into the Bering, Chukchi, and western Beaufort seas host humpback whitefish (Mecklenburg et al. 2002, Morrow 1980). They are also found throughout the Kuskokwim River drainage, the lower reaches of the Yukon River (Mecklenburg et al. 2002, Morrow 1980), and in all drainages north of the Alaska Range (ADF&G 2011). Deep, calm pools of the Omar River host whitefish in large schools (BLM 2006), and they are commonly found in the slow-moving water of interconnected lakes and sloughs of Selawik Flats (NAB 2006). These fish are abundant throughout the Selawik River delta, which serves as an important feeding habitat for mature populations, although immature fish are not found in the delta (Brown 2004).

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## E-7.7 Pacific lamprey (*Lampetra tridentata*)

**Assessment:** Lacks data on distribution in REA study area

**HABITAT DESCRIPTION**

Spawning takes place in spring, often in upper reaches of clear streams in riffles and runs with a substrate of sand, gravel, or rock (Morrow 1980, NatureServe 2011). Eggs hatch after one or two weeks, depending on water temperature, and produce ammocoetes (Morrow 1980). Ammocoetes spend several years buried in sand, mud, and silt, in backwaters or bottoms of streams and shallow eddies or pools (Mecklenburg et al. 2002, Morrow 1980). In Alaska this stage typically lasts four or five years; lampreys metamorphose and move to sea at the age of five or six and remain at sea for 12-14 months (Mecklenburg et al. 2002, BIOTICS 2011). Non-anadromous landlocked populations also exist (Morrow 1980).

Most Pacific lampreys are parasitic and anadromous, with exceptions occurring in California and Oregon (Mecklenburg et al. 2002). Pacific lampreys have similar habitat requirements as salmonids, and anadromous populations spend one to four years at sea (ADF&G 2011, BIOTICS 2011). In the ocean, they are usually found at a depth of less than 250 m, but have also been reported up to 1463 m deep (Mecklenburg et al. 2002).

Upstream migration occurs in spring and summer, when lampreys are not yet sexually mature, and in Alaska lamprey may make a four month migration to headwaters (BIOTICS 2011, Morrow 1980). Lampreys have the ability to move above obstructions like waterfalls and dams (Morrow 1980). The subsequent fall and winter are spent in streams, where lampreys burrow into the stream bottom, and spawning takes place the following spring (Mecklenburg et al. 2002, Morrow 1980). Pacific lamprey die after spawning (ADF&G 2011).

Pacific lampreys can be found from the northern Bering Sea to California (Mecklenburg et al. 2002, Morrow 1980), and have a wide range throughout the Pacific Ocean (NatureServe 2011). North of the Alaska Peninsula they are rare, and are primarily found from Nome southward in the Bering Sea and coastal rivers (NatureServe 2011). They are harvested from the lower Kuskokwim and Yukon Rivers (BIOTICS 2011).

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## E-7.8 Northern pike (*Esox lucius*)

**Assessment:** Lacks data on distribution in REA study area

**HABITAT DESCRIPTION**

Prime spawning habitats include shallow and quiet water, plentiful emergent vegetation, nearby lakes, and early ice breakup (Mecklenburg et al. 2002, NAB 2006). Pike deposit their eggs over sedges and short grasses when water is <51 cm deep, often along the edges of lake shores, sloughs, marshes, bays, and slow-moving streams (ADF&G 2011, Morrow 1980). They spawn in the spring when ice starts breaking up, or when water temperature in shallow areas reaches 6 to 9° C, and hatch in about two weeks (Morrow 1980). Pike only spawn in full daylight, and light reduction caused by clouds or ripples on the water surface reduce spawning activity; extremely cold nights will also decrease spawning activity (Morrow 1980). Adults remain in spawning areas for up to 14 weeks, but often leave within six (Morrow 1980).

Juvenile pike leave their spawning grounds when they reach about two cm in length and travel during the day (Morrow 1980). In early summer and fall pike can be found in clear small lakes, vegetated shallows of lakes, relatively warm ponds, rivers of various sizes, slow-moving sloughs, marshes and creeks (Morrow 1980, NAB 2006, NatureServe 2011). In the winter, pike move to deep rivers and lakes (Morrow 1980). Just before to shortly after ice breaks up in the spring, pike move inshore to spawning areas, and movement mostly occurs at night (Morrow 1980). Migrations between overwintering, spawning, and summer feeding grounds are short (ADF&G 2011); pike do not engage in long migrations, although individuals may occasionally travel long distances (Morrow 1980).

Pike generally do not thrive in water bodies with low water or widely fluctuating water levels (Morrow 1980). Additionally, pike are sensitive to carbonate and bicarbonate concentrations and to extremes of pH (Morrow 1980). However, another source reports that northern pike can inhabit lakes that are unsuitable habitat for other fish because water conditions lead to winterkill; specifically, lakes with a maximum depth less than three meters, low flood probability, and no river connections (Glesne 1986).

Pike naturally occur in Alaska from the Arctic coasts to the Alaska Peninsula draining into the Bristol Bay, into western Alaska and east to Canada (Morrow 1980). They are present up the Squirrel River to the mouth of the Omar River (BLM 2006), and are commonly found in the interconnected lakes and sloughs of Selawik Flats in slow-moving water (NAB 2006).

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## E-7.9 Rainbow smelt (*Osmerus mordax*)

**Assessment:** Lacks data on distribution in REA study area

**HABITAT DESCRIPTION**

Little is known about Pacific coast rainbow smelt; most of what is known has been extrapolated from Great Lakes and east coast populations (Morrow 1980). Spawning occurs in spring and can last several weeks or months (Morrow 1980) with individuals spawning in multiple streams in a single season (NatureServe 2011). Rainbow smelt often spawn in streams but have also been observed spawning along shallows of lake shores (Morrow 1980). Preferred water temperature is 4.4° C or warmer (BIOTICS 2011), and substrate can vary between small boulders, rocks, pebbles, gravel, sand, and aquatic vegetation (BIOTICS 2011, Morrow 1980). Eggs settle to the bottom, stick to anything they touch, and hatch in 10-29 days depending on water temperature (Morrow 1980). Eggs cannot survive salinities greater than 12-14 ppt (NatureServe 2011).

After hatching, larvae become concentrated near the surface while carried by the current to a downstream estuary or lake (Morrow 1980, NatureServe 2011). Juveniles school at the bottom of deep channels during the day, and move to the surface or into shallow water at night to feed (NatureServe 2011).

There are both anadromous and lacustrine populations of rainbow smelt (NatureServe 2011). Those that travel to sea remain within eight to ten kilometers of the coast and are found at up to 150 m depth and occasionally deeper (Mecklenburg et al. 2002, Morrow 1980). They inhabit estuaries and coastal waters, and in freshwater can be found in rivers and midwaters of lakes, often close to the surface, and where water is less than six meters deep (NatureServe 2011).

Prior to the spawning run, rainbow smelt congregate near stream mouths before ice goes out in the spring (Morrow 1980). Spawning migration is encouraged by cold nights and warm days, and fish move into streams when the water temperature is at least 2°-4° C or warmer (Morrow 1980). Most often migration to spawning grounds takes place at night but occasionally happens during the day (Morrow 1980). Some fish return to natal streams, while others may spawn behind barrier beaches in brackish water, or in the tidal zone of an estuary (Morrow 1980). For those that do move upstream migration is short, often between a few hundred meters to a few kilometers (Mecklenburg et al. 2002, Morrow 1980). After each evening of spawning most adults drift downstream to the body of water they had previously occupied, but some males stay in the spawning stream throughout the day, avoiding light (Morrow 1980).

Rainbow smelt are present along almost the entirety of the Alaskan coast: from the Beaufort Sea to British Columbia and Bristol Bay to the Arctic coast (Mecklenburg et al. 2002, Morrow 1980).

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## E-7.10 Round whitefish (*Prosopium cylindraceum*)

**Assessment:** Lacks data on distribution in REA study area

**HABITAT DESCRIPTION**

Spawning takes place in the fall, generally at the end of September through October, although may occur later farther south (Morrow 1980). Habitats used for spawning include lake shores or shallows, and river mouths or shallows (Morrow 1980). Fish spawn over gravel and eggs settle to the bottom and rest on gravel or in rock crevices (Morrow 1980). Young hatch in the spring and leave spawning grounds after two to three weeks (Morrow 1980).

In the southern part of its range the round whitefish inhabits shallow sections of deep lakes, and farther north it tends to inhabit rivers or streams; it is infrequently found in brackish water (NatureServe 2011). Fish are most commonly found in lakes and streams (NAB 2006). Populations in lakes will move inshore to spawn and offshore when not spawning, or may travel over three kilometers to spawn in upstream waters (Morrow 1980, NatureServe 2011).

Round whitefish can be found in Alaska from Juneau north to the Arctic coast, in Arctic and Pacific drainages, and throughout mainland Alaska (Mecklenburg et al. 2002, Morrow 1980).

Round whitefish can be found in upper reaches of the Selawik River, but are not common in the Selawik River delta (Brown 2004).

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# E-8 Species Assemblage CEs

## E-8.1 Introduction

Descriptive summaries for the three species assemblages (Table E-39) were provided by AKNHP and NatureServe significantly expanded on these through additional literature review, including adding detailed information on stressors impacting these assemblages. Per memo 3 and the work plan, species assemblages had not been intended to receive ecological status assessments; therefore, a list of indicators of ecological status was not developed. However, the tool used for assessing the landscape condition indicator for individual CEs can be set to run for entire groups of CEs. The development-related features comprising the landscape condition indicator are assumed to have some impact on these assemblages; therefore, when the landscape condition surface was adjusted and re-assessed for other terrestrial CEs, the species assemblages were included.

The descriptions include a short summary of the concept of the assemblage, its general range within the ecoregion, its environmental setting, and the "habitat" or the ecosystem setting for it. Common names of species are generally used throughout the descriptions.

In another section the primary change agents (threats/stressors) and current knowledge of their effects on the assemblage are characterized. In most cases, this information was derived through additional literature review of stressors to species within the assemblage.

Literature is listed that is relevant to the component species, distribution, ecological processes, threats, stressors, or management of the CE. These are not exhaustive literature surveys, but rather a brief accumulation of known references. Some documents may be listed that are not cited in the narrative text.

**Table E-39. Ecologically-based assemblage CEs and the species which are addressed by them. Subsistence species are italicized.**

| Model Group | Ecologically-based Assemblage | Taxonomic Group | Fine-filter CEs Addressed By this Assemblage |
|---|---|---|---|
| Lowland and Coastal | Waterfowl Breeding Areas* (Migratory Bird Habitats) | Birds | *Yellow-billed Loon*, King Eider, Common Eider, Emperor Goose |
| Coastal | Seabird Colony Sites | Birds | Aleutian Tern |
| Coastal | Marine Mammal Haul-out Sites | Mammals | Pacific walrus, bearded seal, ringed seal, spotted seal |

*The original assemblage concept of migratory bird habitat was limited by available data to waterfowl concentration or breeding areas.

## E-8.2 Waterfowl Breeding Areas

### SUMMARY/CONCEPT

The Seward Peninsula is an important and productive area for breeding and nesting waterfowl. Waterfowl breed in lacustrine waters, including freshwater and brackish lakes and ponds in low lying wetlands. Lacustrine habitats include all fresh or brackish waters and lakes and ponds and their immediate shorelines. This is the primary breeding habitat for loons, waterfowl and phalaropes.

Waterfowl also use nearshore waters extensively. This includes protected marine waters such as inlets, lagoons and bays. Important areas on the Seward Peninsula include Shishmaref Lagoon, Lopp and Arctic Lagoons, Port Clarence, Grantley Harbor, Safety Sound, Golovin Lagoon and Bay, and the open mouths of rivers such as the Buckland. Nearshore waters are especially critical habitat during spring for migrating waterfowl that arrive when most other habitat types are covered with ice and snow. Open water is usually first available at river mouths and early migratory concentrations are often found at these restricted locations. Nearshore water habitats are primarily used by loons, waterfowl and gulls (Kessel 1989).

Waterfowl are also commonly associated with coastal lowlands. Coastal lowlands along the coastline of the Seward Peninsula are composed of wetlands less than 30 meters in elevation with river deltas, lagoons, spits and strips, beaches, and tidal flats. Brant and Emperor Geese nest in salt grass meadows, which are interspersed with pond habitats just above tidal flats in lagoons and at the head of shallow bays and inlets (Kessel 1989).

**THREATS/STRESSORS**

Most of the SNK ecoregion is in near-pristine condition so current threats to waterfowl breeding habitat are generally restricted to local impacts from human settlements and mining sites, especially placer mining. However, increases in human infrastructure, placer mining, roads, and water diversions to areas may pose a threat depending on location of these developments.

Waterfowl breeding areas are threatened by climate change. Climate change in Arctic over the past 50 years has been significant and climate models indicate continued warming in future (Kittel et al. 2010). In addition to changes in temperature and precipitation, other weather elements such as changes in frequency and intensity of storms (Kittel et al. 2010) may become issues. Between 1949 and 1998, Alaska's Seward Peninsula region average temperature increased by3.2 degrees Centigrade (USFWS 2012, ACRC 2012). Temperature increases were largest in winter and spring and were similar throughout the state (USFWS 2012). In 1977, Alaska underwent a dramatic change in climate that produced much warmer temperatures compared to the previous 25 years with the Arctic atmosphere and ocean regime shifts (Parson et al. 1999, USFWS 2012, ). These higher temperatures have persisted over the past 30 years. Changes in climate also have complex interactions with landscapes and biotic communities and will affect sea ice, coastal erosion rates, and hydrological impacts of melting of permafrost (Kittel et al. 2010).

Shifts in Alaska's dabbling duck populations suggests the populations increases were larger after the mid-1970s when the state began experiencing warmer springs (Petrie and Reid 2012). Whether this sudden climate change is responsible for the swelling in duck and other waterfowl populations is unknown, but an earlier spring may have benefited some waterfowl species by increasing their reproductive success. Other waterfowl species such as sea ducks (eiders and scooters) have not fared as well, some declining in population for unknown reasons (Petrie and Reid. 2012).

According to researchers cited from University of Alaska – Fairbanks, there have been significant reductions in numbers and water area of the wetlands in Kenai Peninsula lowlands and Alaska's interior between 1950 and 2002 with some areas loosing up to 25% (Petrie and Reid 2012). Melting permafrost layers, which would allow ponded water to into soil instead of remaining on surface and well increased evapotranspiration in wetlands during warmer and longer growing seasons may cause this changes (Klein et al. 2005). The warming climate that may have led to larger dabbling duck populations and may also lead to less duck habitat (Petrie and Reid 2012).

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## E-8.3 Seabird Colony Sites

**SUMMARY/CONCEPT**

This Conservation Element is the diverse assemblages of sea bird species that nest in coastal colonies on sea islands, coastal cliffs, and coastal flats (for the Arctic tern) within the SNK Ecoregion. Coastal cliffs form a unique and important breeding habitat for seabirds.  Sea cliffs are formed of erosion resistant bedrock and cliffs along the mainland coast are mostly metamorphic rock (Kessel 1989). Seabird colonies are predominately present in coastal areas of Norton and Kotzebue Sounds. The bluff colonies are the largest congregation of cliff-nesting seabirds in the area, with steep cliffs extending for three kilometers along the coast of Norton Sound and gently sloping dwarf shrub tundra inland beyond the cliffs (National Audubon Society 2011).

The seabirds that nest in these colony sites are typically medium-sized to large pelagic birds that return to the coast each summer to nest and raise their young.  Cliff-nesting species associated with coastal colonies include: Pelagic Cormorant, Mew Gull, Herring Gull, Glaucous Gull, Black-legged Kittiwake, Arctic tern, Aleutian Tern, Dovekie, Parakeet Auklet, Least Auklet, Crested Auklet, Tufted Puffin, Horned Puffin, Pigeon Guillemot, Common Eider, Common Murre, Thick-billed Murre, and Black Guillemot. Detailed information on habitat requirements of individual species and their ecology is available in references such as Denlinger 2006.

**THREATS/STRESSORS**

Alaskan seabirds generally nest in areas that are inaccessible and far from human population.  This reduces many of the direct threats/stressors from human actions such as disturbing nesting birds by walking or making noise near their colony sites.  Adult seabirds, when frightened, can hurt their young chicks when they fly away in a panic.  Indirect effects of humans, however may have larger impact on bird mortality.

**Oil Spills:** Oil pollution which coats the birds' feathers and allows water to penetrate feathers and make them susceptible to the cold sea water. Both large and small spills can kill sea birds that come in contact with oil.

**Non-Native Invasive Animals:** Ground nesting bird species lack defenses against introduced predators (Norway rate and Arctic Fox) and the young are especially vulnerable. Not only do introduced predators devastate island seabirds' populations, Croll et al. (2005) found that the introduction of arctic fox to some Aleutian islands caused cascading effects to lower tropic levels. Nutrient transport form seabird guano to island soil fertility was interrupted by fox predation on seabirds causing shifts in plant community productivity and composition transforming grasslands to dwarf shrub/forb-dominated ecosystems (Croll et al. 2005, Maron et al. 2006).

**Commercial Fisheries:** Commercial fisheries are a source of indirect stress through competition for bird prey. The birds eat many of the same species that are commercially harvested by the fishing industry. Fish populations and harvests need to be monitored so fish populations are productive enough for birds and human use. Fisheries bycatch mortality can significantly affect seabird species populations. Between 14,500 and 160,000 birds are killed by commercial fishing operations each year (NPFMC 2000, Artyukhin and Burkanov 2000). Birds are usually drowned when incidentally caught in fishing gear, either on hooks or in nets (Jones and DeGange 1988). Longline gear accounted for 90 percent of seabird bycatch, trawls for 9 percent and pots for 1 percent (Whol et al 1995).

**Pollution:** from humans can directly affect seabirds. Birds can get tangled in plastic trash such as sixpack rings, fishing line, etc. and get injured or drown. Toxic chemicals such as mercury end up in the oceans and work up the food chains. We do not know how these will affect seabird populations in the future.

**Vulnerability to Climate Change:** Climate Change in the Arctic over the past 50 years has been significant and climate models indicate continued warming in future (Kittel et al. 2010). In addition to changes in temperature and precipitation, but also other weather elements such as changes in frequency and intensity of storms (Kittel et al. 2010). Changes in climate also have complex interactions with landscapes and biotic communities and will affect sea ice, coastal erosion rates, and hydrological impacts of melting of permafrost (Kittel et al. 2010).

*Possible impacts to seabird populations:* Meehan et al. (1999) lists many possible impacts to seabird populations if warming climate trend persists. Examples include:

a) If sea ice extent continued to decline, some species of seabirds may benefit (increased productivity, range extensions) by being able to feed in open water near nesting areas earlier in spring and fledge young before fall freeze-up. However species dependent on feeding at the ice edge may adversely affected. More open water could increase severity of rough seas, potentially causing increased winter mortality of birds at sea.
b) If surface sea temperatures change substantially, the distribution of seabird prey will shift. For some species and sites, the shift may be beneficial (e.g., species that feed on prey that local conditions now favor), but for others it could be detrimental (e.g., surface feeders whose prey has been driven too deep for them to access). Initially, productivity of seabirds would be affected and ultimately population change would occur.
c) Earlier snow melt in spring will make nesting sites available sooner. This could be beneficial for some species at locations where productivity, particularly survival of young, has been reduced due to the shortness of the available nesting period. In contrast, it is possible that enhanced vegetation growth during extended growing seasons could cover crevices used by auklets.

d) If average spring air temperatures continue to increase, coastal permafrost could thaw, potentially making new areas available to burrow-nesting seabirds.
e) If warming causes increased storminess (duration and/or frequency), mortality of seabird chicks at nest sites could occur and adult mortality in winter might also result due to rough seas interfering with feeding and dispersing prey.
f) If precipitation in summer were to increase, burrow nesting seabirds may experience increased chick mortality from flooding and
g) If warming causes significant increases in sea level, low-lying nest sites on barrier islands and nearshore scree nesters might be lost.

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## E-8.4 Marine Mammal Haul-out Sites

**SUMMARY/CONCEPT**

Three species of seals (spotted, bearded, and ringed) and Pacific walrus utilize waters adjacent to the Seward Peninsula and haul-out sites on ice and land along the coast during some part of their annual migration. Terrestrial haul-outs are islands, points, spits, and headlands protected from strong winds and surf. Several thousands of individuals can occupy haul-outs at any one time. Choice of haul-out is influenced by a combination of social factors, learned behavior and proximity to prey (USFWS 1994).

The most abundant seals are spotted seals, which haul out at several locations along the Seward Peninsula and concentrate in large numbers on inlets and lagoons; they are generally present from June to December. Spotted Seals are highly concentrated in Golovin Bay (Smith 2011). Seals are littoral in summer when shorefast ice has melted, occurring in estuaries and embayments in late summer and fall. During open-water season, they haul out on sandbars and beaches (NatureServe 2011). Ringed seals concentrate on the shore in spring and early summer (February to June). Large numbers of bearded seals can be found in Shishmaref Inlet and associated lagoons during winter (approximately October to April). Ringed and bearded seals are concentrated in the Kotzebue Sound in October and November.

Pacific walrus are typically found in waters 100 m deep or less. They use moving pack ice for resting, pupping and molting and secluded rocky shores and islands for haul-outs. They migrate northward to the Chukchi Sea from their Bering Sea wintering grounds as pack ice loosens, following the southern edge of the Chukchi pack ice. Several thousand Pacific walrus haul out on Sledge Island adjacent to the Seward Peninsula (Smith 2011). In October, large herds move southward as pack ice develops and many come ashore on haul-outs in the Bering Strait region. Haul-out sites continue to be occupied until mid-December, when most move south of St. Lawrence Island (USFWS 1994).

**THREATS/STRESSORS**

Current direct threats are few in the SNK ecoregion. Ice haul-out sites, while critically important for many mammal species, are limited within the SNK ecoregion. Terrestrial haul-out sites are restricted to narrow coastal and island habitats and are currently generally inaccessible and far from human population. This reduces many of the direct threats/stressors from human actions such as disturbing mammals by walking or making noise near their haul-out sites. Adult marine mammals may trample or abandon their young when they are frightened or otherwise disturbed (2004). However, outside the SNK ecoregion the human activity with the greatest threat on walrus populations is hunting (Fay 1982, Fay et al. 1989). Walrus are hunted on both sides of the Bering Strait by natives from the Bering and Chukchi Seas for thousands of years before the 19th century and probably had little effect on the population (Fay 1982). Walrus populations have been drastically by past commercial exploitation at least three times since the mid-1800's, but each time it recovered when protected (Fay et al. 1989). Recent harvest rates are much lower than historic highs but lack of information about population size and trends precludes a meaningful assessment of the impact of the harvest (Garlich-Miller and Jay 2000).

**Commercial fisheries** impact marine mammals through direct competition for prey and by mortality through entanglement in fishing gear, incidental take and directed catch (WWF-TNC 2004).

**Direct competition for prey***:* In the North Pacific Ocean and eastern Bering Sea, commercial fishing remove millions of metric tons of fish and shellfish that are potential prey for seal and walrus each year;

however, the effect on these marine mammals is unknown (NMFS 1993). Several important fur seal prey species are the target of commercial fisheries, however, for the most part, these fisheries target larger fish than are preferred by fur seals (Sinclair 1988; Wespestad and Dawson 1992). The complexity of ecosystem interactions and limitations of data and models make it difficult to determine how fishery removals have influenced fur seals and other marine mammals (Lowry et al. 1982; Loughlin and Merrick 1989).

**Mortality**: It has been well documented that fur seals become entangled and die from marine debris, principally trawl webbing, packing bands and monofilament nets (Fowler et al. 1989) and that these same items litter the beaches fur seals use for breeding. The survival of young seals is known to be negatively correlated with entanglement rates (Fowler 1985) and it is clear that entanglement has contributed to mortality and possibly decline of fur seal populations (NMFS 1993). While at sea, northern fur seals are sometimes unintentionally caught and killed by commercial fishing gear. The number of fur seals taken incidental to commercial fisheries has been relatively low and declines with a drop in overall fishery effort. It is unlikely that the effect of incidental take by domestic fisheries during the period of the greatest decline of fur seals was significant (Fowler 1982).

**Increased coastal development** will increase disturbance from direct human contact with breeding rookeries through increased vessel traffic close to shore and low flying aircraft. These may affect the long-term use of a rookery area (NMFS 1993). Although there are few data on the effects of human activities (such as harbor development) on fur seals, some short term studies suggest little or no effect from brief disturbance episodes (Gentry et al. 1990). However, the effect of chronic, long-term disturbance is unknown.

**Petroleum transport/ oil spills:** Oil spills impact marine mammals by contaminating the fur, making them vulnerable to the physiological effects and subsequent loss of control of thermal conductance (Wolfe 1980). Oil spills near areas where fur seals concentrate to breed or migrate may cause significant direct morality (Reed et al. 1987).

**Climate change:** Climate change in Arctic over the past 50 years has been significant and climate models indicate continued warming in future (Kittel et al. 2010). In addition to changes in temperature and precipitation, other weather elements such as changes in frequency and intensity of storms may occur in future (Kittel et al. 2010). Changes in climate also have complex interactions with landscapes and biotic communities and will likely reduce sea ice and therefore increase coastal erosion rates (Kittel et al. 2010).

Sea ice is important habitat for walrus and seal to haul out on (Stroeve et al. 2007). The sea ice extent has significantly declined over the last 50 years. September Arctic sea ice extent declined 7.8% per each decade from 1953 to 2006 and by 11.7% each decade from 1979 to 2008 (Stroeve et al. 2007). Arctic sea ice reached its lowest extent during the 2007 melt season since satellite measurements began in 1979 (USFWS 2008). The extent of thin, first-year ice which is prone to rapid melting the following summer was high in 2008 (USFWS 2008). Interesting, first year sea ice is used more often than the thicker multi-year ice because of easier access to the sea (USFWS 2008).

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**SEWARD PENINSULA – NULATO HILLS – KOTZEBUE LOWLANDS**
**RAPID ECOREGIONAL ASSESSMENT**
**FINAL REPORT II-3-c**

# Appendix F: Community Meetings Detailed Summary

**REA Final Report for:**
Department of the Interior
Bureau of Land Management
Rapid Ecoregional Assessments

Version Date: 22 October 2012

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# F Community Meetings Detailed Summary

## November 2010

**Organization of Summary**
A general overview of the community meetings structure is presented on this page. The second section is input by theme, which constitutes the bulk of this summary and is found on pages 3-16. On pages 16-17 is input about concerns and considerations on the REA research project. On pages 18-20 is a list of the community participants. Hand-outs provided at the community meetings are in separate documents and include an overview of the project, a map of the study area, and a listing of conservation elements and other items that provide the organizational structure for this study.

**Community Meetings Structure**
Four community meetings were held to provide information about and get input from various organizational representatives, that may also be using the data and information resulting from this assessment on Alaska's Seward Peninsula. The Rapid Ecoregional Assessment (REA) is structured as a collaborative effort to compile already existing data into new information sets and then to model possible changes land managers will need to consider for the future. The Seward Peninsula REA includes the Nulato Hills, Kotzebue Lowlands and the Seward Peninsula ecoregions. A map is included at the end of this document.

**Participants**
The community meetings were held the first two weeks of November 2010 in Fairbanks, Kotzebue, Nome and Anchorage. Thirty-three people attended these meetings ranging from various federal and state agency representatives, university researchers, local government and native village, regional non- and for-profit organizations. A full list of participants is included at the end of this summary.

**Community Meeting Format**
All meetings except the Anchorage meeting were conducted in conjunction with a complementary initiative, the Landscape Conservation Cooperative (LCC). The REA provided a brief overview after the LCC presentation and discussion, to re-ground those participating about the purpose of the REA. The vast majority of the meeting time was spent reviewing draft or proposed management questions the research/assessment team should address. The management questions were organized into the following categories:

- Subsistence
- Species
- Socio-Economic
- Development
- Fire
- Native Plants
- Invasive Species
- Aquatic Ecological Function and Structure
- Hydrology/Sea and River Ice/Permafrost/Weather/Soils

# REA DETAILED NOTES BY THEME

Discussion on the proposed questions included additional questions that should be considered, input on data sources were identified, and discussion about gaps and baseline needs. The following color coding of management questions and input comment is used throughout this document:

Black - MQs presented by REA Team
Fairbanks - Red
Kotzebue - Blue
Nome - Green
Anchorage - Purple

**Purpose of Management Questions**

At the first community meeting in Fairbanks, those participating identified a need to connect the Proposed Management Questions with land managers' roles and their decision making purview. They identified proposed purposes for the management questions for each theme/category, which are also included in this summary.

*Consultant's Comments about some of the proposed purposes are also included in the tables in an effort to help clarify what is within the scope of the Seward Peninsula REA and what isn't.*

## SUBSISTENCE

**Data Sources/Comments**

Fairbanks

- Project Jukebox developed/managed by UAF is a possible data source.
- Data will be difficult to obtain.

Kotzebue

- SNWR has been flying and documenting beaver activity.
- Cape Krusenstern (NPS) did a lot of research on fishing in that area, including fish behavior, migration patterns, local uses, etc.
- There was a big thaw slump near the sheefish spawning areas. SNWR has been monitoring spawning populations for a long time.
- NW Arctic Borough has their zoning plan on line, which may be a good data source.
- NANA might have some maps and information on line too.
- Bob Uhl would be a good source to learn more about white fish and local use.

Nome

- Fish and marine mammals are king for subsistence species; land mammal resources seem really important, but it's a small part - surveys show only 12% from land mammals.
- Community subsistence surveys have been conducted by subsistence unit at ADF&G.
- Blueberries are important.
- The desire for musk ox and moose in the community exceeds its availability. 150 of the 175 harvested musk ox are for subsistence—25 are permit draws.
- Stakeholder groups have recognized the importance of TEK related to the NW Arctic caribou herd, but data collection and use is in its infancy.
- Cultural can mean two things with the NPS: Anthropology and TEK

Anchorage
- Some subsistence data has been collected in communities; contact Jim Simon (Fbks ADF&G regional manager)
- Harvest use - ADF&G would be a good source.
- Clarify the term subsistence, from the Alaska standpoint.
- Subsistence data and collection should be one of the themes of the State-of-the-Science meeting.

## General Observations/Comments on Climate Change

Fairbanks
- Ice on snow surface affects caribou ability to eat.

Kotzebue

Animals:
- Beaver are expanding; considered invasive by locals. Giardia, affect fishing—dams possibly preventing fish from getting to their spawning grounds.
- Bears are becoming more numerous and create problems. Black bears and 2 yr old grizzlies are sometimes taken for subsistence. Polar bears are coming into villages.
- Most important subsistence species: Caribou, moose, fish, birds, sourdock, berries, telocki (tea).
- Coyotes have just shown up recently and should be viewed as pests.
- Wood bison are not recognized as food; we put up with musk ox—they were not introduced for subsistence.
- Moose probably got harvested more this year because of the late (and different) caribou migration.

Fish:
- 4th of July is usually when we fish for whitefish, but they came in the middle of June this year.
- Salmon were late. Also fish for sheefish and trout. Sheefish were late this year.
- Fishing occurs all year long, including pike, smelts, herring, grayling.

Utilization of Subsistence Species:
- Animals and plants that are used for clothing; e.g., furbearers, beachgrass for basket weaving.

| **Subsistence/Purposed Purpose:** Provide data for managers to make sound decisions about ensuring 1) abundance of harvestable resources, 2) distribution of harvestable resources, and 3) harvester access. (Based on ANILCA Section 810 these are the three factors regularly mentioned that Federal Agencies are required to support.) |
|---|
| **Proposed Management Questions - Additions and Comments**<br>Fairbanks Red, Kotzebue Blue, Nome Green, Anchorage Purple |

Management Questions from REA Team

- What is the current distribution of subsistence species?
- How will climate change affect their range?
- How will range and use change?

Additional Comments and Questions from Fairbanks

- Comment: There's high variability and may not be easy to identify.
- Are peoples' subsistence needs being met? How, where, how many, etc.? and how will change affect?
- How do we adequately provide for subsistence needs (e.g. with Special seasons, restrictions)?
- Do use authorizations impact access, availability and/or distribution of harvestable resources?
- Comment: Assumes climate change will affect their range.

Additional Questions from Anchorage

- We need to know more about what the species are and their use patterns. And how is this changing? How could **access** to subsistence resources change?

## SPECIES

### General Observations/Comments on Climate Change

Fairbanks

- In Nulato Hills more shrubs have been seen.
- Ice on snow surface is affecting caribou's ability to eat.
- In Selawik and Arctic Refuges - sightings of polar bears along the coast are more frequent.
- Fish runs are a concern.

Kotzebue

- One potential indicator of change is that hunters have found seal blubber in walrus stomachs.

Nome

- An extreme event that has big impacts is rain on snow. Impacts caribou, ptarmigan--starvation. These events are happening more frequently. What will the impacts be on nesting birds?
- Shrub invasion is poorly documented. Increasing shrubs could increase fire frequency which would decrease caribou forage. Need to find a flagship species or iconic images or concepts in the beginning of the process that highlights the importance and urgency of the issue.

### Data Sources/Comments

Kotzebue

- Western Arctic Caribou Herd Working Group is a credible source for data
- TEK projects concerning whitefish; Alex should have this type of community harvest data with a 3-year harvest survey. This is about implementing TK, not gathering TK; practical application of TK is what we try to focus on.

Nome

- Charlie Lee works for Norton Sound and would have good information on the fish resources here/Nome.
- Dave Ryland at F&G would have information on perched culverts.
- NPS Arctic Inventory and Monitoring is coming up with a protocol for lagoon (bird) monitoring.
- Peter Bente has data for birds of prey and use of area.

- ADF&G has a lot of data, but may not be available electronically, e.g. caribou telemetry.

**Species: Questions and Comments**

Nome

- Burbot, sheefish, smelts, pike are other important subsistence fish.
- Ice edge location and timing can significantly affect the timing of migratory birds; fish are spawning limited.
- McKay's Buntings are showing up at restoration projects where reseeding has been done.
- Higher insect numbers (mosquitoes, gnats) are being observed.
- We know the least about predators (wolves) and how they relate to prey species.
- Brown bear numbers and harvests have increased over the years. Density reports are mostly anecdotal.
- Microtines are important and easy to monitor, but the larger megafauna gets all the attention.
- Rough-legged hawks have been surveyed and over the years there have been three events where their numbers dropped, but it was not investigated as to why.
- In 2009, short-eared owls (species of concerned) were radio-tagged, and high number of microtines led to a high density of owls.
- Moose weren't present on the Seward Peninsula 50-60 yrs ago. Within the last 10 yrs both moose and musk ox have been recognized as good subsistence food.
- Cottonwood trees at Serpentine Hot Springs weren't there before; also increasing beaver activity has been noted.
- Migratory birds would be a good flagship species as would fish or marine mammals.
- Better knowledge of use by the NW Arctic Caribou Herd and habitat change would be helpful information to have. Caribou populations run in cycles. There is a concept that caribou populations are like the tides in the oceans, there is nothing we can do about it.

**Beyond Scope of REA**

Kotzebue Comments

- Western Arctic Caribou Herd – there is disagreement about how human impacts affect the caribou herd. Need better information about behavior/migration from Traditional Knowledge. Need to take a social network approach – caribou are different, they communicate with each other, some are better feeders, etc. Do the better feeders know something about rangeland that we don't? Social Network Analysis needs to be done.
- Need a clearinghouse/coordinator for community research. Community's involvement in research efforts is very important. SNWR has been inundated with climate researchers recently. Coordination at the local level needs to be more systematic. (This might be best through the Borough, or a local organization.)

Anchorage Comments

- Health concerns of subsistence foods; How adaptive species are, and Ecosystem services are all beyond the scope of the REA.

| |
|---|
| **Species/Purposed Purpose:** (these are also applicable to the Development theme)<br>- Provide data so managers can make sound decisions about whether or not STIPs and normal mitgation measures will be effective given anticipated changes - whether from climate or other change agents.<br>- Provide data so managers can make sound decisions about harvesting for subsistence, sport and commercial uses, enabling managers to continue to provide the same level of opportunity. *REA Team Comment: the second item above is likely outside the scope of their contract as it appears to be a short-term focus.* |
| **Proposed Management Questions - Additions and Comments**<br>Fairbanks Red, Kotzebue Blue, Nome Green, Anchorage Purple |
| Management Questions from REA Team<br>- What is the current distribution and habitat of each conservation element? (should be available soon from USGS)<br>Additional Questions from Fairbanks<br>- Are the assumptions that we have about how we're impacting these accurate?<br>- Are our mitigation efforts going to become ineffective as a result of climate change?<br>- Are we striking a good balance between development activities and habitat protection? And how do we do that? |
| Management Question from REA Team<br>- How will species adapt to changing environments? |
| Management Questions from REA Team<br>- Where are change agents affecting their habitat and movement corridors?<br>- Where are potential habitat restoration areas? (Are there any? - presumes there are.)<br>- Where are habitats that may be limiting species sustainability?<br>- Where will critical wildlife habitat experience climate completely outside its normal range? Specifically, calving areas, wetlands, migratory stopover, etc.<br>Additional Question from Fairbanks<br>- Are our assumptions about how quickly a species will come back accurate?<br>Additional Question from Kotzebue<br>- What are the thresholds for some species? |
| Management Questions from REA Team<br>- How will climate change affect conservation element ranges?<br>- What areas have been surveyed and what areas have not been surveyed (i.e., data gap locations)? How does survey intensity vary across the region and where are data gaps?<br>Additional Question from Fairbanks<br>- How will extreme climate/weather events affect species? (Rain on snow) |
| Additional Questions from Kotzebue<br>Pollution:<br>- Blueberry/ptarmigan link and lead contamination?<br>- How does ocean acidification affect species?<br>- How is all the plastic on the beaches of Kobuk Lake (and elsewhere) affecting? |
| Management Questions from REA Team<br>- How does water quantity and quality change? |

## SOCIOECONOMIC

**Anchorage Comment**

- This theme isn't broad enough/emphasized enough for the changes that population demographics can bring.

**Data Sources/Comments**

Fairbanks

- UAF: Working on models that will link climate to permafrost – not complete yet – many uncertainties. They have model with a 2x2km res. on SNAP. Ground ice information is very limited.
- UAF: Recreational Sciences in SLARM maybe a good data source.
- Looks right now like disappearance of lakes under a warming scenario will outweigh increased lakes with disappearing permafrost.

Kotzebue

- NOAA
- is currently looking into coastal erosion.
- NANA has community maps that may show sewage lagoons/dump sites; Village Safe Water; ANTHC possibly; DEC-Contaminated Sites should have FUDS sites mapped.
- Selawik Lake harmful (toxic) plankton blooms; Alex at the Borough collected samples and had them identified.
- Alternative Energy: NANA, Matt Bergan, Sonny Adams, Brad Reeves (KEA), and Rich Seifert (UAF Coop Extension) who it was believed has a demonstration home in Kotzebue.

Nome

- 2 GAO reports regarding coastal erosion affecting Unalakleet, Shaktoolik, Golovin, Shishmaref are available.
- DCCED/DCRA and Office and Homeland Security have coastal erosion reports. ervin.petty@alaska.gov
- Remote sensing work may be able to show the extent of water level changes in lakes.
- Each village gets there water in different ways; Village Safe Water would be a good source of info.
- If the Coast Guard comes here there may be a housing shortage.

Anchorage

- L. Alessa (UAA) and Peter Schwietzer at UAF have been collecting information on water use in villages. (mainly perception data)

**General Observations/Comments on Climate Change**

Fairbanks

- Permafrost loss – need more information; lack data.
- Very small scientific community studying permafrost. Permafrost changes are locally specific. There is a lot of permafrost data in the North, not so much in the South for the Seward Pen region. Big data gaps regarding permafrost. Local knowledge will be very important.
- Patterns of resource use will change as conditions dry, etc. Incorporating social science is going to be key. You (already) can fly and 4-wheel to places you haven't been able to in the past.
- Hydrology around the villages—melting permafrost and associated increasing motorized access will also be important.

Kotzebue

- The land upriver from Noorvik is being eroded by the Kobuk River.
- Two lakes behind Noorvik have dried up recently, but it's hard to see other changes because they're happening slowly.
- Algae growth on fish in nets.
- Selawik Lake has had some harmful (toxic) plankton blooms.
- There used to be reindeer herders in the area, but they are all gone now. Some of the reindeer have shorter legs, and some people think they are better to eat.

Nome

- Through survey data they see evidence of drying lakes.
- Lakes across the landscape vary in clarity.

**Socio Economic Links to Species/Habitat**

Nome

- Birding is an emerging tourism industry. The first cruise ship that came through the NW passage docked here.
- Sea wall and port will have to be developed to have the coast guard here. This is the deepest port this far north.
- Harbor reconstruction efforts are underway, which affected the Sanke River estuary.
- Iditarod is a big tourism boost for the community.
- Biking, camping, and other tours are also increasing—people who spend more time and possibly $
- The reindeer industry is in a steep decline, but is cyclical.

**Beyond Scope of REA**

Kotzebue

Need for local ownership of resources and permits, some voiced the need for income and job data for tourism; leakage is high for tourism jobs.

**Socioeconomic/Proposed Purpose:** Provide data so managers can make sound decisions about balancing habitat protection with anthropormorphic activities, given climate and other change agents.
*REA Team Comment: it would be useful to know what types of acitivities and decisions.*

**Proposed Management Questions - Additions and Comments**
Fairbanks Red, Kotzebue Blue, Nome Green, Anchorage Purple

Additional Question from Kotzebue

- How will changes in fuel prices affect subsistence, tourism, guiding, development?

Management Questions from REA Team

- What are patterns of current tourism/guiding/angling (e.g., total revenue, total visitors, types of tourism)?
- Where will the tourism industry experience significant (and relevant) changes in climate?

Additional Questions from Fairbanks

- Will there be positive impacts due to climate change?
- What are potential increases in economic activities due to change agents?

Additional Question from Kotzebue

- What's the possibility of other salmon moving into the area as a draw for increased tourism?

| |
|---|
| Additional Question from Anchorage<br>- What are current/projected population demographics? |
| Management Questions from REA Team<br>- What areas will experience significant coastal and river erosion, and which of these will threaten villages?<br>- Increase or decrease to transportation corridors?<br>Additional Question from Nome<br>- How will storm surges affect infrastructure? (Road to Council significantly eroded due to surges.) |
| Management Question from REA Team<br>- Which communities/villages will experience significant permafrost melt? Over what timeframes?<br>Additional Questions from Fairbanks<br>- What are the implications for infrastructure given permafrost melt?<br>- What's the viability of rural communities, given changes? |
| Management Question from REA Team<br>- Where are lakes/ponds expected to disappear as a result of permafrost melt? (likely can't answer - p/ V. Romanovsky) |
| Management Question from REA Team<br>- Where will losses of lakes/rivers significantly affect water supply to villages?<br>Additional Question from Nome<br>- How will Moonlight springs—be affected by climate change (main water supply to Nome)? |
| Additional Question from Kotzebue<br>- How will changes in water levels affect villages (e.g., Upper river villages are having a tougher time getting fuel barges up because the water is too low.) |
| Management Question from REA Team<br>- Where will losses of lakes/rivers significantly affect important wildlife and other conservation elements? |
| Management Questions from REA Team<br>- Where are the current populations of Reindeer? (data available soon/only species need a permit for grazing)<br>- Where are areas of current overgrazing by Reindeer? (Anchorage comment: Overgrazing not an issue; perhaps, What are/ will be grazing needs?)<br>- Where are areas of current overgrazing because of the existence of other change agents, causing the potential for accelerated change?<br>- Where will current populations of Reindeer experience significant effects of change agents, including climate change, that are completely outside their normal range?<br>Additional Question from Fairbanks<br>- Will Reindeer grazing grow if caribou decline due to climate and other change agents? |
| Additional Questions from Kotzebue<br>- How do sewage lagoons, wastewater systems, dumps, FUDS/dewline, other hazardous sites, and air pollution impact species/habitats? |

## DEVELOPMENT

**Comments on REA Model/Research**

Fairbanks

- It's important to cross management boundaries to address changes.

Kotzebue

- We need to keep and consider subsistence within the context/definition of ANILCA, the Tribes and the Federal government's definition.

**Data Sources/Comments**

Kotzebue

- Land Use Plans for the agencies should indicate plans for future development.
- Unmanned aerial vehicles will soon be used to manage wildlife population, then keep an eye on my hunting practices. They are using them for fires and BP is using them to monitor species on the North Slope.

Nome

- Data layers from DNR are available; transportation - DOT may have.
- The open season for the Nome port is getting earlier in the spring and later in the fall.

**Subsistence Comments**

Kotzebue

- We're the only place in the country that has a truly subsistence lifestyle; and guides and transporters are given priority, shutting out the local interests.
- We don't want to be involved in the industry of bringing outsiders to help harvest their subsistence resources.

## FIRE

**General Observations/Comments on Climate Change**

Fairbanks

- Fire frequency and severity has changed over the recent years. Nulato Hills has seen more shrub.

Nome

- 6000 acres burned in NPS this year.

**Data Sources/Comments**

Nome

- Kyle Joly at Gates of the Arctic would be a good source on tundra fire histories.

Anchorage

- Fire management report will be coming out looking at data for the Nulato Hills

**Fire/Proposed Purpose:** Provide data so managers can make sound decisions about how much fire over a defined period of time can be tolerated without having intolerable impacts to habitats, e.g., caribou habitat. This should include data about extreme fires and the severity of that impact.
*REA Team Comment: This seems short-term focused and likely outside the scope of the contract.*

| Proposed Management Questions - Additions and Comments<br>Fairbanks Red, Kotzebue Blue, Nome Green, Anchorage Purple |
|---|
| Management Question from REA Team<br>- What areas have experienced significant (1000+ acres as defined by availability from earlier records) fire?<br>- What areas have high fire potential? |
| Management Question from REA Team<br>- Based on climate models, what areas will have increased or decreased fire danger?<br>Additional Questions from Fairbanks<br>- Is climate change going to change the periodicity of the fire regime?<br>- How will fires impact the permafrost?<br>- What can be predicted about the severity of fires?<br>- How will fires affect sedimentation into nearby rivers? |
| - Where do areas of high future risk for fire overlap with current caribou habitat and calving sites?<br>Additional Questions from Fairbanks<br>- Are there areas / issues with increased sedimentation?<br>- At what point should we be thinking about managing for moose rather than out caribou? |
| Management Question from REA Team with additions from Fairbanks<br>- Which villages are near predicted areas of future fire risk?<br>- In places that have experienced fire, with and without permafrost, where does the resulting vegetative structure and composition differ from the desired state, and what changes with permafrost melt? (relates to tundra fires vs wood) |
| Additional Questions from Fairbanks<br>- How will climate change affect fire suppression strategy? (added by Anchorage: What impact will these changes - when looking at existing data - have on fire policies?)<br>- Will it change the volatility of future fires? How does this interact with permafrost structure and severity? |

## NATIVE PLANT COMMUNITIES

### Climate Change/Comments

Nome

- There's not much we can do—what happens happens; except for fire suppression, but that is expensive.
- When should we use fire suppression to protect habitat?

| **Native Plants/Proposed Purpose:** Provide data so managers can make sound decisions about conservation and adaptation strategies so they can be developed based on predicted changes due to climate and other change agents. |
|---|
| **Proposed Management Questions - Additions and Comments**<br>Fairbanks Red, Kotzebue Blue, Nome Green, Anchorage Purple |

Management Questions from REA Team

- For areas designated for conservation (National Parks, Wilderness, etc.), how well do they represent all species and ecosystems for the Ecoregion?
- How will climate change affect the conservation areas' ability to support all species and ecosystems within the Ecoregion?

Additional Questions from Fairbanks

- What will be the vegetational shift in communities?
- When should plant communities be allowed to change as a result of climate change? Is there a rate of acceptable change?

Management Questions from REA Team

- What's the value of a plant community?

## INVASIVE SPECIES

**Data Sources/Comments**

- Kotzebue: Check with Alex Whiting (Native Village of Kotzebue) he wrote paper on coyotes.
- Beavers were identified by both Kotzebue and Nome community participants as invasive.
- Nome: Need to differentiate between new invasive species and where no survey was done for invasive species.

Anchorage:

- Need to clarify invasive vs range expansion.
- State & Private Forestry has useful data.

**Comments**

- Kotzebue: If new port is developed, ballast water may be a vector. Rats could also be introduced.

**Invasive Species/Proposed Purpose:** Provide data so managers can make sound decisions about how invasives access habitat communities, which will provide information about what procedures could prevent their introduction. *REA Team Comment: This would be a research project outside the scope of the contract.*

**Proposed Management Questions - Additions and Comments**

Fairbanks Red, Kotzebue Blue, Nome Green, Anchorage Purple

Management Question from REA Team

- What is the current distribution of invasive species and what are the ecological affects in these areas? (Kotzebue mentioned: alder sawflies, a lot of zoonotics are becoming more prevalent (giardia, trichinosis, brucellosis, etc.)

| |
|---|
| Management Questions from REA Team<br>- Given current patterns of occurrence and expansion, what is the potential future distribution of invasive species?<br>- What are the known and likely introduction vectors of invasive species?<br>Additional questions from Fairbanks<br>- How is climate change going to affect rare and invasive species?<br>- What will be the vegetational shift in species?<br>- When should plant species be allowed to change as a result of climate change? Is there a rate of acceptable change?<br>- Will our revegetation /mitigation strategies need to change? |

## AQUATIC ECOLOGICAL FUNCTION AND STRUCTURE

**Data Sources/Comments**

- Anchorage: ADF&G just published a document that addresses first question in second row.

| **Aquatic Ecological Function and Structure/Proposed Purpose:** Provide data so managers can make sound decisions about changes or extensions of anadromous ranges, given "new normal." *REA Team Comment: Don't know if identifying extensions is feasible outside of a detailed research project.* |
|---|
| **Proposed Management Questions - Additions and Comments**<br>Fairbanks Red, Kotzebue Blue, Nome Green, Anchorage Purple |
| Management Questions from REA Team<br>- Where are the important aquatic resources, such as spawning grounds and other fish habitats? (Kotzebue added: herring spawning grounds and areas used by waterfowl?)<br>Additional question from Anchorage<br>- Will there be positive impacts of new fisheries / waterfowl moving into an area? |
| Management Questions from REA Team<br>- Where will climate change affect these important aquatic resources?<br>Additional questions from Fairbanks<br>- How will climate change affect our accessibility to these resources?<br>- Are the extremes in the ranges likely to change? |
| Management Questions from REA Team<br>- How will climate change affect these important aquatic resources? Water temperature, flow rates, etc.<br>Additional questions from Fairbanks<br>- How may this affect barge transportation to rural villages?<br>- Will climate change lead to different background levels for water quality?<br>- Where are hazardous waste sites and how climate change exacerbate pollution entering the environment? |

## HYDROLOGY - SEA ICE - WEATHER - PERMAFROST - SOILS

**Data Sources/Comments**

Fairbanks

- UAF Permafrost Lab is working on models that will link climate to permafrost – not complete yet – many uncertainties. They have model with a 2x2km res. on SNAP.
- Ground ice information is very limited.
- Looks right now like disappearance of lakes under a warming scenario will outweigh increased lakes with disappearing permafrost.
- Three of the lowest minimum ice years have been in the last four years.

Kotzebue

- Data Needs: SNWR is looking at the extent of the permafrost in this region. Having a better understanding of this would be useful.
- Good information on topography (like LIDAR) would help attract researchers to do more work up here.
- Sea level change modeling.

Nome

- Baseline information exists about the success of fertilization in Salmon Lake. Lorna Wilson's thesis; Charlie and Jim Minard also have access to the info.
- GINA will have fish data access soon.
- AWC is on-line and Joe Buckwalter is a contact at F&G for that.
- A big data gap is spacial data—Nome is a complicated landscape with land ownership.
- No baseline—big concern about coastal marshes/lagoons are changing. We've missed the chance to capture the baseline.

**General Observations/Comments on Climate Change**

Fairbanks

- Hydrology will change because of permafrost loss.
- Climate and weather data is much easier to obtain compared to permafrost. Local knowledge will be very important.
- What are the gaps/needs for climate data? (NOAA)
- Changes in hydrology in relation to fish habitat are a concern. Also, hydrology around the villages—melting permafrost and associated increasing motorized access. (ADF&G)
- NOAA terminology usage: "Climate" is used for anything over 14 days; anything less than that is "weather".

Kotzebue

- Hunting on sea ice—have adapted to hunting on rotten ice (Blossom).
- There were ice jams in Buckland this year that caused a lot of damage.
- Rain on snow can really harm caribou and musk ox.
- More extreme events are predicted which are lost in the SNAP predictions which just use averages.
- Some communities, like Kotz, with water supply lakes, could be in trouble if melting permafrost causes water supply lakes to drain.
- Melting sea ice is a big problem for walrus.
- River ice could be important for a number of reasons. Anything from travel, to flooding at ice out.

Nome

- Changing thawing patterns and flushing events can have an impact of the fish ecology (grayling, salmonids)
- Changing climate can also create habitat that is suitable habitat for other salmon species.

- There isn't a stream near Nome that hasn't been affected by mining, but the Nome River has shown signs of recovery, at least in places.
- Changing temperature profiles in the lakes could change salmonid development dramatically.

| **Hydrology - Sea Ice -River Ice- Weather - Permafrost-Soils/Proposed Purpose:** Provide data so managers can make sound decisions about changes from "normal". "Normal" needs to be defined. + include soils. |
|---|
| **Proposed Management Questions - Additions and Comments**<br>Fairbanks Red, Kotzebue Blue, Nome Green, Anchorage Purple |
| Management Questions from REA Team<br>- What areas will experience significant "decreases" in precipitation?<br>- Fairbanks comment: Change "decreases" to "departures from normal"<br>Additional questions from Anchorage<br>- Add: and evapotranspiration after precepitation<br>- How does precipitation link to conservation element? |
| Management Questions from REA Team<br>- Where will important aquatic communities experience significant (change) degradation due to permafrost change? |
| Management Questions from REA Team<br>- Where will changes (delete: in permeability potential) affect water quality? |
| Management Questions from REA Team<br>- What is the annual extent of sea ice and changes in proximity to shore by date, and how is this changing?<br>Additional question from Fairbanks<br>- Where and how will river volumes change due to changes in river and sea ice?<br>- How will lack of sea ice impact subsistence hunting, e.g. make more dangerous / easy; increase / reduce deaths? (polar bears on land, higher waves, etc.) |
| Additional question from Fairbanks<br>- What is the likelihood of increased liquid precipitation in winter? |
| Management Questions from REA Team<br>- What affect will salt water intrusion into fresh water have? |

## Concerns and Considerations about the REA Model/Research Project

The following are concerns expressed by participants at the meetings for the overall project. Colored text is used to provide a flavor of the conversation in each location:
Fairbanks Red, Kotzebue Blue, Nome Green, and Anchorage Purple

Fairbanks Comments

1) AMT should prioritize Proposed MQ's based on Management Decisions agencies are responsible for.

*Consultant's comment: Agree, but need to distinguish between short term management questions vs long term which is more about strategies and RMP activities, not seasonal plans.*

2) It's important to get others' input as these questions have come mostly from BLM.

*REA Team Comment: Purpose of community meetings and a multi-agency Assessment Management Team, who will make the final decisions about the specific focus for the data compilation and modeling for future scenarios.*

3) Need to bound, define terms in MQ's; e.g., timeframe, species, geographic area.

*REA Team Comment: Geographic area was defined in the RFP/contract, as was the timeframe (2060) and species.*

4) How will this project take into consideration change that has occurred vs change that is predicted?
5) In general, the MQ's assume change will occur; and infer that change will not be good.

*REA Team Comment: The project is about predicting changes and assessing effects. Is this a concern that the MQ wording sounds loaded? If so, should talk about.*

6) The group should find common ground and work from there.
7) Climate change is going to bring about more extreme events, how do the MQ's address this?

*REA Team Comment: Extreme events are fairly impossible to predict.*

8) Climate change will impact other change agents - need to account for this.

*REA Team Comment: Need examples, but this is true and also nearly impossible to predict.*

9) Are the MQ's/primary focus of the REA for terrestrial or aquatic?

*REA Team Comment: This is identified in the scope of work.*

10) Are there new tools, e.g., information technologies/models, to help predict changes and impacts?
11) NPS and BLM have completed recent land use plans - they maybe useful + TNC plans/data.

*REA Team Comment: Yes those should be assessed as scenarios.*

12) May get better information from others, e.g., native oranizations may have subsistence data they are willing to share.

Kotzebue Comments

1) Can NatureServe's vulnerability index be applied to the concern about plastics in habitats?
2) Focus on the really critical elements of the model to get at future distributions.
3) Agencies in the lower 48 paradigms take root up here inappropriately. Managers make decisions that have bad repercussions for subsistence users. Need to reinvent the wheel when it comes to managing subsistence needs.

Nome Comments

1) An indicator species approach or an index approach have much less data gaps (e.g. Caribou, moose, musk ox), much more gaps in other species. Why not focus on these indicator species and try to get a handle on the vast amount of information that is available. You get better efficiency out of your effort with this approach.
2) Monitoring a number of related species and how they are related might make more sense than monitoring single species by themselves.

Anchorage Comments

1) There are some broad assumptions in models—how things will change—models should also focus on how adaptive a species may be; this should be built into the process. A management question is: *How will species adapt to changing environments?* A good example is walrus—walruses will probably adapt by moving onto shore. A lot of the modeling focuses on vulnerability, but don't take into account adaptability of species. We should keep in mind, this may go beyond the scope of REA.

Maybe getting clarity on the research questions related to this would be something that the REA could inform.

2) Restoration - How you define the goal (protecting things as they are now, v. protecting healthy ecosystems) is important. Is it adaptation, status quo, function?
3) Managing for healthy ecosystems is the important goal.
4) What about function (ecosystem services?) been a consideration here? A: Not in REA
5) How caribou populations would be impacted would be tough to model, with such high variability.
6) We need to be clear about certainty/uncertainty.
7) How can/should TEK be used?
8) 50 years out is too far; need to focus nearer term -15 years
9) Differences between the work in the lower 48 and here—many offices down there are a smaller part of a larger ecoregion—opposite in Alaska.
10) Need to make sure that socio-economic and demographics are given enough emphasis as a change element.
11) Climate change studies may eclipse the socio-economic / development aspects of the future, that could have just as significant impacts.

## Seward Peninsula REA Community Meeting Participants

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|---|---|
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| **Fairbanks-November 4, 2010** | |
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| --- | --- |
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| **Kotzebue - November 9, 2010** | |
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