Seward Peninsula - Nulato Hills - Kotzebue Lowlands

RAPID ECOREGIONAL ASSESSMENT
FINAL MEMORANDUM I-3-c

Prepared for:
Department of the Interior
Bureau of Land Management
Rapid Ecoregional Assessments

Submission Date: July 7, 2011

Submitted to:
Department of the Interior
Bureau of Land Management
222 W. 7th Ave., #13
Anchorage, AK 99513
Attn: Paul Krabacher, Ecoregional Assessment Project Manager

Submitted by:
NatureServe
1101 Wilson Boulevard, 15th Floor
Arlington, Virginia 22209

Patrick Crist, Principal Investigator
Keith Boggs, Co-Investigator

Contents

Tables

Figures

List of Acronyms

AADT	Annual Average Daily Traffic
ACEC	Area of Critical Environmental Concern
ADEC	Alaska Department of Environmental Conservation
ADFG	Alaska Department of Fish and Game
AFFID	Alaska Freshwater Fish Inventory Database
AGI	Annual Grasses Index
AKNHP	Alaska Natural Heritage Program
ALFRESCO	Alaska Frame-Based Ecosystem Code
ALT	Active Layer Thickness
AMT	Assessment Management Team
AR4	International Panel on Climate Change - Fourth Assessment Report
AVHRR	Advanced Very High Resolution Radiometer
AWC	Anadromous Waters Catalog
AWS	Associate Weather Services
BLM	Bureau of Land Management
BpS	Biophysical Settings
CA	Change Agent
CCVI	Climate Change Vulnerability Index
CE	Conservation Element
CVS	Conservation Value Summary
DCI	Dendritic Connectivity Index
DEC	Department of Environmental Conservation
DEM	Digital Elevation Model
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
EFC	Environmental Flow Components
EIA	Ecological Integrity Assessment
EIS	Environmental Impact Statement
EO	Element Occurrence
EPCA	Energy Policy and Conservation Act
ESA	Endangered Species Act
ESD	Ecological Site Descriptions
ET	Evapotranspiration
EVT	Existing vegetation type
FAO	Food and Agriculture Organization
FCC	Federal Communications Commission
FO	Field Office
FRC	Fire Regime Condition Class
FRI	Fire Return Interval
GA	Grazing Allotment
GCM	Global Climate Model
GFDL	Geophysical Fluid Dynamics Laboratory
GIPL	Geophysical Institute Permafrost Lab
GIS	Geographic Information System
HMA	Herd Management Area
HRV	Historic Range of Variation
HUC	Hydrologic Unit Code
ICLUS	Integrated Climate and Land Use Scenarios
IPCC	Intergovernmental Panel on Climate Change
Kw	K factor (soil erodibility) Values
LCM	Landscape Condition Model
LF	LANDFIRE (Landscape Fire and Resource Management Planning Tools)
MAGT	Mean Annual Ground Temperature

MLRA	Multiple Resource Land Area
MRDS	Mineral Resource Data System
NCEP	National Centers for the Environmental Prediction
NHD	National Hydrological Dataset
NPMS	National Pipeline Mapping System
NRCS	Natural Resource Conservation Service
NREL	National Renewable Energy Laboratory
NRV	Natural Range of Variability
NTAD	National Transportation Atlas Database
NVDEP	Nevada Department Environmental Protection
NWI	National Wetland Inventory
ORV	Off-road Vehicle
PRISM	Parameter-elevation Regressions on Independent Slopes Model
REA	Rapid Ecoregional Assessments
RegCM	International Centre for Theoretical Physics Regional Climate Model
ROC	Receiver Operating Characteristic
SAR	Sodium Adsorption Ratio
SClass	Succession class
SDM	Species Distribution Model
SERGoM	Spatially Explicit Regional Growth Model
SNAP	Scenarios Network for Alaska Planning
SSURGO	Soil Survey Geographic Database
STATSGO	State Soil Geographic Database
SUNY	State University of New York
SW ReGAP	Southwest Regional Gap Analysis Project
SWAP	State Wildlife Action Plan
TWI	Topographic Wetness Index
USGS	United States Geological Survey
USGS-CD	USGS 15km dynamically downscaled climate model outputs
VDDT	Vegetation Dynamics Development Tool

Executive Summary

Rapid Ecoregional Assessments (REAs) are the first step in the Bureau's Landscape Approach. REAs are intended to synthesize relevant knowledge and information within the ecoregion. This synthesis aims to inform subsequent decision-making, implementation, and monitoring by BLM and partners, and should interact with ongoing scientific research as a foundation for science-based land management. REAs are organized into a series of phases and component tasks. Phase 1 includes tasks that clarify the scope, expected data and analytic approaches to be used, and culminates in a detailed work plan for the assessment. Phase 2 completes the preparation of data, conducts agreed-upon analyses, and documents assessment results. This document summarizes the work to date on Task 3, Phase 1 to identify, evaluate, and recommend models, methods, and tools to answer management questions.

Task 3 Objectives

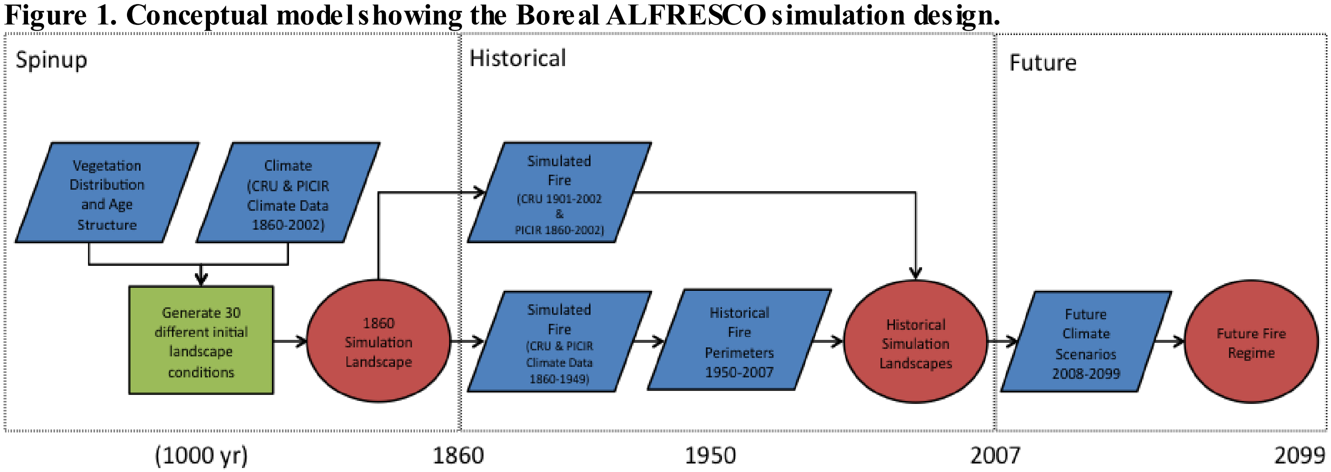
The objectives of Task 3 are:

1. List the Conservation Elements to be addressed, describing the approaches and categories in which they will be treated
2. Build *prototypical* conceptual models for Conservation Elements
3. Describe the models, methods, and tools for characterizing Conservation Elements, Change Agents, and their interactions
4. Describe specific assessment methods to answer Management Questions
5. Evaluate methods and tools for their ability to perform as intended

Model Conventions

To illustrate and describe models, we used a general concept diagram schematic (see Figure 1 as an example). The schematic include specific inputs, outputs, and processes identified within the boxes.

Figure 1. Conceptual model showing the Boreal ALFRESCO simulation design.



Recommendations for Fine-filter Conservation Element Selection and Treatment

"Fine-filter" CEs includes species that are likely vulnerable to being impacted or lost from the ecoregion unless resource management is directed towards their particular needs. The criteria include:

1. All taxa listed under Federal or State protective legislation
2. Full species with NatureServe Global Conservation Status rank of G1-G3
3. Full species or subspecies listed as BLM Special Status and those listed by applicable SWAPs with habitat included within the ecoregion
4. Important subsistence species.

We have established several distinct approaches to treating <u>fine-filter</u> CEs (i.e., species) that meet established criteria for inclusion in the REA. These include:

1. Species assumed to be adequately represented indirectly through the assessment of major coarse-filter CEs;
2. Species assumed to be adequately represented indirectly as ecologically-based assemblages;

3. Landscape Species, which are vertebrates with large home ranges and users of diverse habitat conditions, and therefore best addressed as individuals in the assessment; and
4. Local Species of concern that have localized distributions, such as many small vertebrates or plants.

We have recommended developing distribution models for coarse-filter species, ecologically-based assemblages, landscape species, and local species with existing habitat models. Although we used this treatment tool we are unable to develop distribution data for all species because of existing data gaps. Of the 70 fine-filter CEs, we recommend developing distribution maps for 25 CEs with an additional 18 CEs we are considering for modeling (Table 1). Fine-filter CEs are listed in Appendix I.

Table 1. Number of CEs recommended for developing distribution models by taxonomic group.

Criteria	Taxonomic Group	# of CEs	Distribution Model		
			Yes	No	Maybe
Ecologically-based Assemblages	Birds	2			2
	Mammals	1	1		
Landscape Species	Birds	9	7	1	1
	Mammals	8	7		1
	Fishes	18	4	14	
Local Species	Birds	6	6		
	Plants	26		12	14
	Total	**70**	**25**	**27**	**18**

Spatial Models for Conservation Elements and Change Agents

Distributions of Terrestrial CEs

Coarse Filter

We will map the terrestrial coarse-filter CEs (i.e., existing vegetation types) by mosaicking existing land cover maps and cross-walking them to a consistent statewide classification system. Additional land cover classes (black spruce versus white spruce) will be derived through inductive modeling using a variety of parameters (elevation, soils, landforms, ground plot data, etc.).

Fine Filter

We will derive terrestrial fine-filter CE distributions through two distinct modeling steps; both beginning with field observations and/or Element Occurrence records. An Element Occurrence is defined as an area of land and/or water in which a species or natural community is or was present and should have practical conservation value as evidenced by potential continued presence and/or regular recurrence at a given location.

Species presumed to be addressed in the REA through assessment of coarse-filter CEs, and those local-scale species to be treated within summaries by watershed, will require no additional modeling steps. For species to be treated within ecologically-based assemblages, or as individual landscape species, additional modeling steps are appropriate either through use/refinement of existing habitat location/suitability models or through development of new models for the ecoregion. Landscape species may be treated spatially using multiple habitat components (e.g., winter range vs. summer range). These distinctions will be established in conceptual models and then articulated as distinct spatial models. We will also apply inductive modeling tools such as Maximum Entropy (MaxEnt; Phillips et al. 2006) that use map surface inputs including vegetation type, vegetation structure, climate variables, landform, landscape position, and soil variables among others.

Distribution of Permafrost

The Geophysical Institute Permafrost Lab (GIPL) model was developed specifically to assess the effect of a changing climate on permafrost. GIPL model is a quasi-transitional, spatially distributed equilibrium model for calculating the active layer thickness (the thin layer above permafrost that seasonally freezes and thaws) and mean annual ground temperature.

Distributions of Aquatic CEs

Our aim is to provide a map depicting the current distributions for each of the nine coarse-filter CEs. There are 18 fine-filter CEs and five of them have adequate existing data to map their distributions across the REA study area. Four of the CEs have field sampling data (species occurrence and stream habitat data) that will be used to model their distribution. One CE (arctic char) is a local species only found in lakes of the Kigluaik Mountains. The remaining eight species lack both existing spatial data showing their distributions and field sampling data from which to model their distributions. Due to the significant lack of data, these eight CEs will not be included in management questions that address fish distributions.

Terrestrial CE Characterization and Conceptual Models

We describe each conceptual model by combining text, concept diagrams, and tabular summaries, in order to clearly state our assumptions about the ecological composition, structure, dynamic process, and interactions with common CAs within the ecoregion. We also characterize the primary change agents and current knowledge of their effects on each CE. Some CAs have specific effects on each CE such as the alteration of expected fire regimes, introduction of invasive species, and insect and disease infestations. We provide an example for one coarse-filter CE.

Change Agents (CA) Distributions and Effects Models

Wildfire

To assess the impact of wildfire as a change agent, we will utilize the Boreal Alaska Frame Based Ecosystem Code (ALFRESCO) model. Boreal ALFRESCO simulates the responses of subarctic and boreal vegetation to transient climatic changes. The model assumptions reflect the hypothesis that fire regime and climate are the primary drivers of landscape-level changes in the distribution of vegetation in the circumpolar arctic/boreal zone. Furthermore, it assumes that vegetation composition and continuity serve as a major determinant of large, landscape-level fires. ALFRESCO operates on an annual time step, in a landscape composed of 1 x 1 km pixels, a scale appropriate for interfacing with meso-scale climate models. The model simulates four major subarctic/boreal ecosystem types: upland tundra, black spruce forest, white spruce forest, and deciduous forest. These ecosystem types represent a generalized classification of the complex vegetation mosaic characteristic of the circumpolar arctic and boreal zones of Alaska.

Anthropogenic Activities

Major effects of development and management actions are captured in the Landscape Condition Model (LCM) using the approach developed by NatureServe. Model documentation is included in Appendix IV. The LCM is composed of the GIS spatial layers of transportation, urban and industrial development, and managed and modified land cover layers. Each input layer is given a relative weighting for its relative impact at its precise location, and with distance away from its location. A composite scoring and map surface (at 30 m spatial resolution) result from combining all input layers. The indicator is measured in a GIS by intersecting the mapped area of the ecological system with the disturbance layer and reporting the mean LCM index score for the system distribution within each HUC 10 unit. The results are an index of landscape condition from 0.0 to 1.0 with 1.0 being very high landscape condition (apparently unaltered natural conditions) and 0.0 having extremely altered condition (e.g., dense urban areas).

We recommend developing one or more versions of the LCM for the REA; as indicated by differing needs and sensitivities of the CEs.

Non-Native Species

Relatively few non-native species are currently documented in the REA. Non-native and potentially ecologically damaging animals in the study area include the Norway rat (*Rattus norvegicus*) that is restricted to the town of Nome.

Approximately 25 non-native plant species are documented with occurrences within the defined boundary of the ecoregion. Some 279 weed infestations have been documented, all of which appear to be associated with human disturbance (AKEPIC 2010). The non-native species present are generally classified as having weak to moderate impacts on the natural ecology of the region. These species are all extremely widespread throughout Alaska and are well established in other regions. It is noteworthy that of the 25 species, 15 of them are known from an abandoned homestead at Pilgrim Hot Springs. In addition to the soils being geo-thermally warmed, the site was farmed since approximately 1918.

To address the potential risk of current and future scenarios of invasive CAs we propose to first summarize results of existing modeling efforts (Bella, 2009 and Murphy et al., 2010) and then supplement this information with habitat suitability modeling specific to the REA for four highly invasive species. This includes highly invasive plants that are currently not in the REA study area, but could potentially establish in the future.

Nuisance Native Species and Diseases

Insect and disease epidemics, both natural and introduced species, are often the result of human induced changes. For example, climate change has likely increased bark beetle epidemics in spruce. The USDA conducts annual forest damage surveys by flying—using fixed-wing aircraft—a predetermined route across Alaska's forests and recording insect damage within one mile on either side of the flight path.

Of the listed insect and diseases, adequate information is available to model aspen leaf miner, willow leaf blotch miner (the major willow defoliator) and spruce beetle. We will illustrate where these known infestations are.

Climate Change

Climate change is predicted to have a range of effects as a change agent on individual CEs, and these effects are likely to vary across the distribution of a given CE within the ecoregion. Here we propose several methods for gauging climate-change effects, both on terrestrial CEs and across the geography of each ecoregion. The specific aims of our approach are to: 1) assess the magnitude of climate change for a given CE or ecoregion, 2) analyze the spatial and temporal distribution of projected future climate change, 3) use a range of future climate scenarios in conducting #1 and #2 to understand the degree of certainty of projected changes across models, and 4) identify geographic areas within an ecoregion or within the distribution of a CE where there is high model agreement of levels of change. Where there is model agreement of significant levels of change, these are the most vulnerable areas. In contrast, where there is model agreement of little to no change, these are areas of relative climatic stability.

From the envelope analysis output, we can identify portions of the climate space for each ecoregion or CE where climate variables are predicted to change by ≥ 1 standard deviation and by ≥ 2 standard deviations from the mean. This approach will reveal the temporal and spatial distribution of climate change that exceeds the normal range of natural climatic variability to which the CEs are already plausibly adapted. Where these exist, they will be summarized by subregion within the ecoregion.

Ecological Status and Integrity Assessment and Reporting

We use the NatureServe Ecological Integrity Framework for assessing CE ecological status. We propose to use a limited number of indicators of relative ecological condition and ecosystem stressors normalized to a 0.0-1.0 scale for aggregation and reporting purposes. Indicators range will center on anthropogenic disturbance, such as land use classes and stream culverts. These indicators may be totaled and averaged, then summarized to 5th level watersheds, to provide a scorecard of ecological status for each CE. These index scores may be further aggregated for summarizing ecological integrity at broader conceptual scales as needed and desired for REA reporting.

Assessment Models

Assessment models address the management questions directly. A number of them are incorporated in our CE model discussion. Remaining assessment models are summarized below.

Basic Assessment Models

Many MQs can be summarized as "Where will X coincide with Y?" seeking to identify areas where, for example, CEs will be coincident with CAs that may cause impacts. These types of MQs can be answered by a basic assessment model that will intersect existing data or distributions of a CE with a mapped or modeled CA. Areas of overlap between the CA and CE area can be displayed as a map and accompanied by summary statistics.

Subsistence assessment

Sufficient numbers of healthy animals, location of animals, and access to them are all essential for subsistence. In addition, people are constrained from hunting by jobs and high fuel prices. The purpose of the subsistence assessment model is to understand the relationships between these factors and how CAs might affect subsistence. We use local knowledge to help determine what to include in the models and how the factors could change under different development and climate change scenarios. An example of local knowledge that would be used in the model is the following: It takes less time and fuel to hunt caribou upriver because it is easier to travel upstream with an empty boat and return downstream with a loaded boat (Kofinas and Berman 2004). We will include information like this to estimate the effects of changes in animal migration patterns on subsistence hunter access.

Inputs include seasonal species range maps, access maps of trails and rivers, local knowledge, etc. The primary challenge is that we lack detailed data on animal migration (caribou) as well as detailed information from local hunters on where they hunt.

High Biodiversity Sites Assessment

We suggest that information on high biodiversity sites be given as a distinct reporting unit. This includes the Important Bird Areas dataset for Alaska, created by Audubon Alaska and/or The Nature Conservancy Portfolio database to identify specific places of importance for long-term conservation planning.

The following issues and limitations were identified in our model development process. This list is not exhaustive but highlights the key and common issues we identified. An important primary limitation is that there are still datasets awaiting delivery to us to review for suitability, which may affect our model recommendations or feasibility. Also, we have yet to investigate certain tools and while we expect to follow the same workflows illustrated in our models, we may substitute tools or manual methods for those described. Another primary limitation is that all of the model outputs are subject to the error of the input data sets as well as the assumptions made by our team and other subject matter experts consulted. Additional issues and limitations include the following:

1. We will answer some of the management questions using primarily expert opinion or literature review, due to limited data.
2. The SNK ecoregion has many data gaps that limit using the full ecological assessment criteria scorecard.
3. Succession dynamics are poorly understood for most of the existing vegetation types. Consequently, forecasting future conditions will be difficult.
4. Most of our aquatic species do not have adequate occurrence data to predict species distributions.
5. Information is not available to develop a hydrologic basin model.
6. The precipitation data are too coarse to address specific timing events of icing and to predict specific seasonality effects on particular CEs.
7. For subsistence models, we lack detailed data on animal abundance and seasonality in relationship to subsistence efforts.

Conclusions

This memo summarized our approach to the treatment of conservation elements and change agents and provides the framework to answer the management questions. We have recommended modeling all coarse-filter aquatic and terrestrial CEs identified in this memorandum. Fine filter CEs were categorized into 5 ecological-based assemblages, 35 landscape species, 32 local species, and 1 to be captured in coarse-filter CE assessment. Landscape species included mammals, birds, and fishes. Local species included all rare plant taxa and six bird species. Prototypical models for both aquatic and terrestrial coarse-filter CEs and landscape species CEs were presented as examples of our diverse approaches to addressing the management questions. We have described distributions and conceptual models for agents expected to alter the condition and distribution of CEs; the change agents included: wildfire, anthropogenic activities, invasive species and nuisance species, and climate change. Additionally, we describe the potential interactions of CAs with CEs. Guidelines for assessing the ecological status of CEs are included. Status assessments were similar among CEs and relied heavily on distribution of anthropogenic activities (e.g., numbers of culverts along streams). In general, our approach to assessing management questions related to the interaction of CEs with CAs uses a scenarios approach. Multiple approaches of modeling CE and their current and potential future interactions with CAs described here should be a robust way of addressing the management questions.

Task 3: Identify, Evaluate, and Recommend Models, Methods, and Tools

Introduction

Rapid Ecoregional Assessments (REAs) are the first step in the Bureau's Landscape Approach. REAs are intended to synthesize relevant knowledge and information within the ecoregion. This synthesis aims to inform subsequent decision-making, implementation, and monitoring by BLM and partners, and should interact with ongoing scientific research as a foundation for science-based land management. REAs are organized into a series of phases and component tasks. Phase 1 includes tasks that clarify the scope, expected data and analytic approaches to be used, and culminates in a detailed work plan for the assessment. Phase 2 completes the preparation of data, conducts agreed-upon analyses, and documents assessment results.

This document summarizes the work to date on Phase 1, Task 3 for the Seward Peninsula – Nulato Hills – Kotzebue Sound Lowlands (SNK).

Task 3 Objectives

The objectives of Task 3 are:

1. List the Conservation Elements to be addressed, describing the approaches and categories in which they will be treated
2. Build *prototypical* conceptual models for Conservation Elements
3. Describe the models, methods, and tools for characterizing Conservation Elements, Change Agents, and their interactions
4. Develop bioclimatic models for Conservation Elements
5. Describe specific assessment methods to answer Management Questions
6. Evaluate methods and tools for their ability to perform as intended

Memorandum I-3-c Organization

This memorandum summarizes our investigation and evaluation of models, methods and tools to represent the conservation elements and change agents and provide the assessments to answer the management questions. As an ecological assessment, many of the components are interlinked and thus we present them in ways consistent with an ecological approach. Some management questions (MQs) are addressed in the Conservation Element Models section because the questions are intertwined with the conceptual operation of the Conservation Elements (CEs). We then present models to represent the distribution of the Change Agents (CAs) and then models to assess other MQs. Our approach to assessing MQs that address the interaction of CEs with CAs uses a scenarios approach that is described below along with our approach to identifying model components and categories.

In each section we provide a description of our approach and relevant issues and references. We then provide diagrams of proposed models supported by references and identify any specific software tools proposed to implement the model.

Assessment Approach

The assessment approach in brief answers the MQs. Some of these are answered solely by examining CEs and CAs individually while many others involve the intersection of CEs and CAs. CAs occur or are forecast to occur during different timeframes. Each timeframe of CAs is represented by a scenario according to the following requested in BLM's scope of work:

- Current: represented by mapped CAs or those for which we can model their current distribution as of 2011.
- 2025: includes all current CAs and those forecast to occur by 2025.
- 2060: includes all of the above CA distributions plus climate change forecasts for 2060.

While several MQs are interested in effects of individual CAs or groups of CAs, the scenario approach also supports a cumulative effects assessment of the interaction of all identified CAs. The following diagram (Figure 2) depicts the high-level workflow from characterization of CEs and CAs to MQ assessment. Following that is a more detailed depiction (Figure 3) of the scenario-based assessment approach.

Figure 2. High level information workflow.

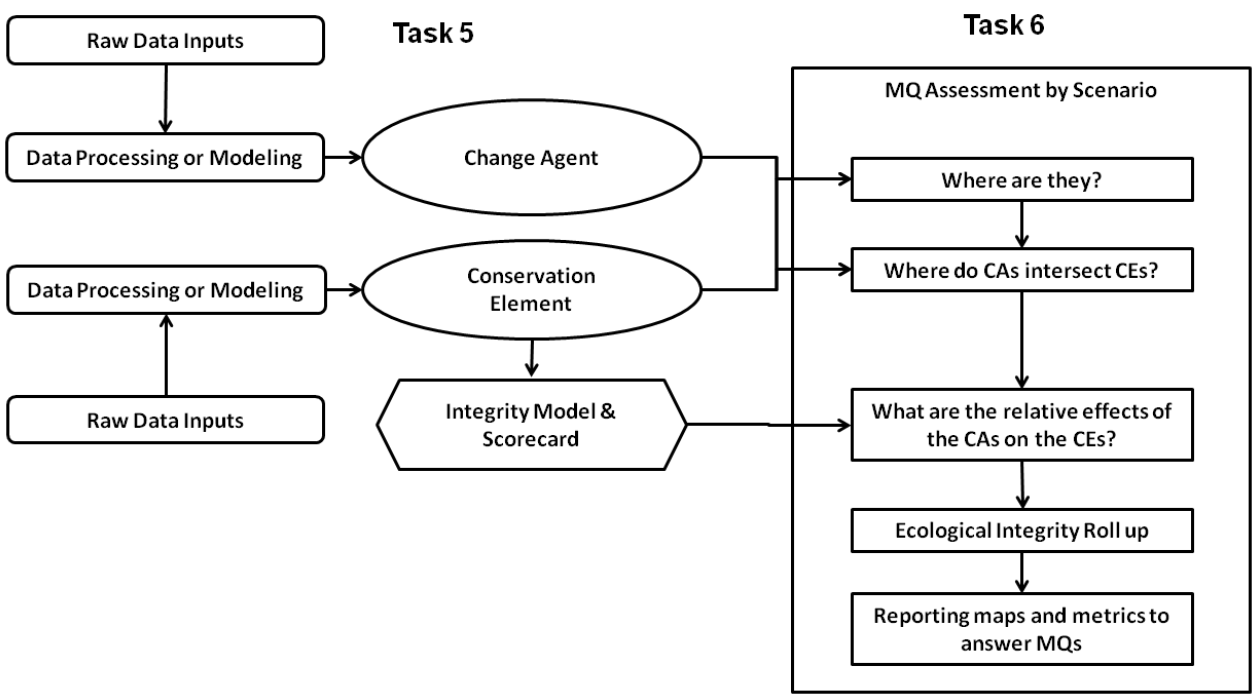
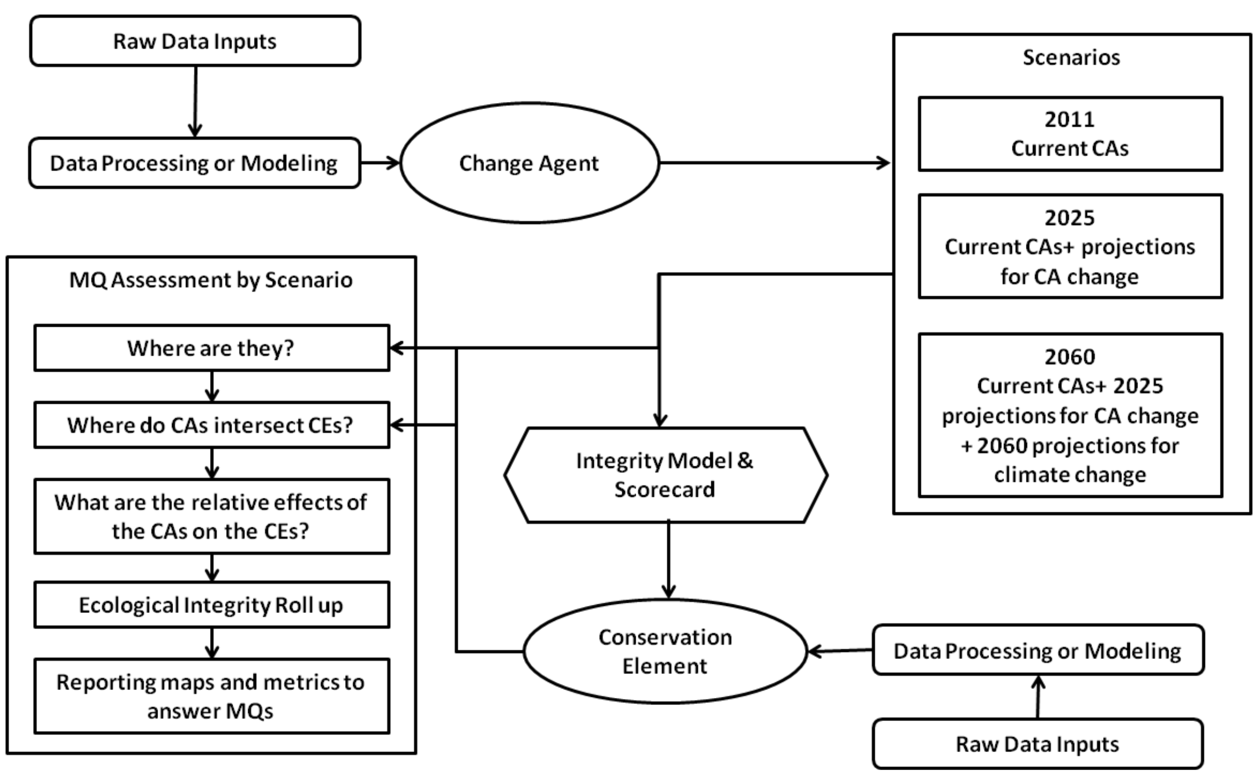


Figure 3. Detailed scenario-based information workflow.



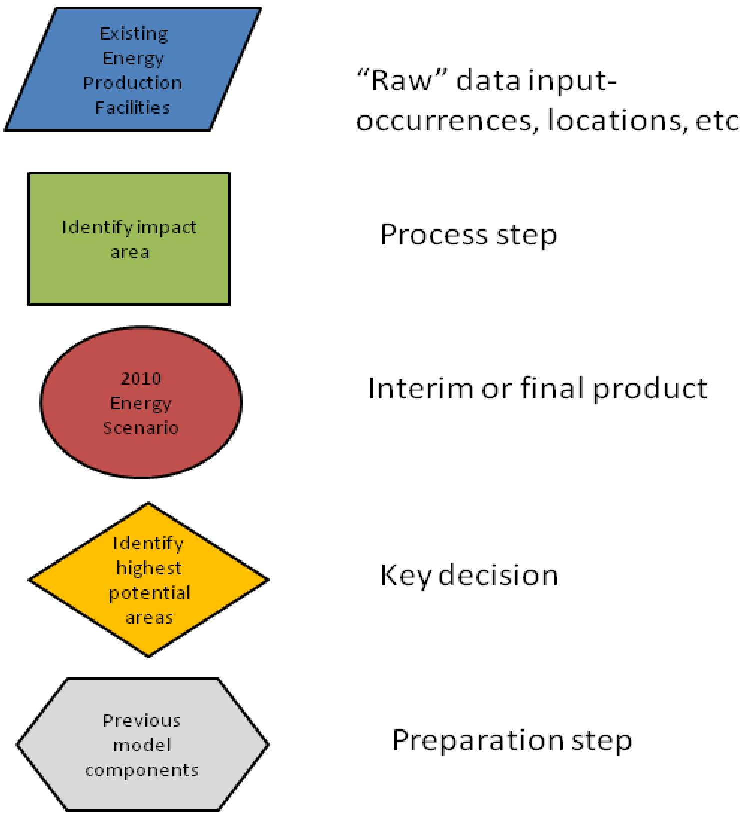
Model Conventions

To illustrate and describe models we used a general concept diagram schematic (Figure 4). The schematic include specific inputs, outputs, and processes identified within the boxes. When we used modeling software to diagram the models (e.g., CART), we utilized the outputs directly and thus those models will not follow this convention.

Model descriptions generally provide the following information with references as appropriate:

- **Inputs**: These can be raw data inputs, non-data inputs, or results of other models. In the latter case we identify which other models would feed into the described model.
- **Analytic process and tools**: These describe transformations to the data to achieve intermediate or final outputs. Tools and methods are referenced that we recommend for implementing the model.
- **Outputs:** This describes the spatial and non-spatial outputs of the model.
- **Issues:** This area identifies issues requiring clarification or further work prior to implementing the model.

Figure 4. Conventions for concept model diagrams.



Managing Uncertainty in REA Models

A rapid ecoregional assessment must take advantage of many existing data sets, often applying them for purposes never contemplated by their original developers. This fact, along with the strong need for transparency and repeatability, requires that we carefully consider ways to document and manage for uncertainty. Uncertainty within an REA takes many forms. There is variation in the accuracy, precision, and completeness of model inputs. There is uncertainty in the combinations of these data sets within spatial models, where error propagation may occur. There is uncertainty driven by our limited knowledge of conservation elements, change agents, and their interactions. Uncertainty may also be viewed from varying perspectives (e.g., from the scientists, land managers, and the public). Uncertainty for this effort is best viewed from the perspective of land managers and policy-makers who will use the REA, but will have only partial exposure to the science and technology involved in its development.

In order to manage this uncertainty, the REA process includes a series of mechanisms for documenting the data sets, information sources, processing steps, and outputs. The steps of this process offer opportunities to manage the inherent uncertainties associated with REAs. We have taken an approach that maximizes these opportunities, including:

- **Data Documentation.** Throughout tasks 2-3 of the REA, we have documented several hundred extant data sets in terms of their thematic and spatial precision, accuracy, and completeness, relative to the ecoregion. FGDC metadata will be provided for all data sets ultimately used in the REA, and our project database provides additional opportunities to capture expert perspective on the relative utility of each data set for the intended modeling purposes of the REA. Of course, since our intent is to provide the best available information for the REA, this requires combining many extant data sets for complete coverage. In a number of these instances, while the original data set may have been assessed for accuracy with independent field observations, there will remain a shortage of independent samples for reporting on the accuracy of the combined data set. In each of these cases, expert qualitative review of the updated data sets will be sought and documented. This process will identify data gaps, i.e., needs for additional field observations for use in model development and assessment.

- **Repeatability.** Conceptual modeling provides an important mechanism for stating the assumptions that apply in any complex process. We are systematically organizing scientific references that are drawn upon in the REA for easy access by subsequent users. Conceptual models form the foundation for subsequent spatial models. All spatial models will include documentation of processing steps; e.g., using ESRI ModelBuilder™ so that spatial models may be repeated, analyzed in detail, and updated when new input layers become available.
- **Calibration.** In some instances in spatial model development there are opportunities for sensitivity analysis, comparison of similar models, and error documentation. For example, climate forecasts include multiple model simulations that may be compared with each other to identify areas of strong agreement or disagreement. Inductive spatial models of habitat distribution, using tools like MaxEnt, provide probability and error surfaces as a standard output for model evaluation and potential calibration.
- **Interpretation.** Finally, inherent in the design of the REA is a series of judgments about the appropriate interpretation of results. For example, the selection of 5th level watersheds as primary reporting units reflects a judgment about the expected resolution of analysis – based on the resolution of modeling inputs – and appropriate spatial scale for interpreting results. We will, therefore, clearly communicate the importance of avoiding over-interpretation of results. Likewise, it is important for model reviewers to recognize that inputs need to be of sufficient resolution to report at this same level, and no finer.

Conservation Element Models

Recommendations for Fine-filter Conservation Element Selection and Treatment

The "fine-filter" includes species that, due to their conservation status and/or specificity in their habitat requirements, are likely vulnerable to being impacted or lost from the ecoregion unless resource management is directed towards their particular needs. For species to be addressed in this assessment, we proposed, and the AMT accepted, several selection criteria for their inclusion and treatment in the assessment. These criteria include:

a. All taxa listed under Federal or State protective legislation (including species, subspecies, or designated subpopulations)
b. Full species with NatureServe Global Conservation Status rank of G1-G3[1]
c. Full species or subspecies listed as BLM Special Status and those listed by applicable SWAPs with habitat included within the ecoregion
d. Important subsistence species.

We have established several distinct approaches to treating species that meet established criteria for inclusion in the REA. These include:

a) ***Species assumed to be adequately represented indirectly through the assessment of major "coarse-filter"***;
b) ***Species assumed to be adequately represented indirectly as ecologically-based assemblages***; that is, due to similar group behavior and habitat requirement, a recognizable species assemblage is defined and treated as the unit of analysis. These species do not correspond to the a)-group above because they are reliably affiliated with any one of the coarse-filter CEs. Examples include the marine mammal haul-out sites, or seabird colonies.
c) ***Landscape Species***, which are vertebrates with large home ranges and users of diverse habitat conditions, and therefore best addressed as individuals in the assessment***;*** These species occur over large proportions of the ecoregion and have habitat requirements that are clearly distinct from all other taxa of concern.
d) ***Local Species*** of concern that have localized distributions, such as many small vertebrates or plants**.** These species do not fall within categories a-c. We are gathering current locational information, but will not aim to develop conceptual models for these elements.

[1] See http://www.natureserve.org/explorer/ranking.htm for NatureServe Conservation Status Rank definitions

Biologists from the Alaska Natural Heritage Program used the above criteria to designate a species to either a coarse filter or an ecologically-based species assemblage, based on the knowledge of experts within the program as well as known distributions. Only Willow Ptarmigan and the three subsistence plant species were adequately addressed through coarse-filter units (Table 2). Five ecologically-based assemblages were identified in the statement of work and three of our fine-filter CEs will be addressed within the ecologically-based assemblage models (Table 3). Thirty-five wide ranging species occurring in multiple coarse filter units and were identified as landscape species (Table 4). Thirty species with restricted distributions were identified as local species (Table 5). Although all ecologically-based assemblages and landscape species were targeted for developing new distribution models, only some of these species and/or ecologically-based assemblages were determined feasible for modeling by biologists at the Alaska Natural Heritage Program (Appendix I). Lack of adequate distribution data or habitat parameters limited final species selection for developing new distribution models. We have a few local plant species that we are considering new developing distribution models for. These species were either previously modeled by Cortés-Burns (2009) or have specific habitat requirements that potentially could be modeled. These local species will potentially be incorporated as an additional product for the REA. We also have developed models for all terrestrial species as part of the GAP project. All local bird species will have a habitat-based model and potentially an inductive model depending on the availability of statewide data. A summary of all species by taxonomic group recommended for distribution models is indentified in Table 6.

Table 2. Species addressed through coarse-filter units.
Subsistence species are italicized.

Coarse-filter Unit	Taxonomic Group	Fine Filter CEs
Arctic Scrub Birch-Ericaceous Shrubland	Plants	*Blueberry, Crowberry/Blackberry*
Arctic Dwarf-Shrubland	Plants	*Blueberry, Cloudberry/Salmonberry, Crowberry/Blackberry*
Arctic Wet Sedge-Sphagnum Peatland	Plants	*Cloudberry/Salmonberry*
Arctic Acidic Dwarf-Shrub Lichen Tundra	Plants	*Crowberry/Blackberry*
Arctic Non-Acidic Dwarf-Shrub Lichen Tundra	Plants	*Crowberry/Blackberry*
Arctic Mesic-Wet Willow Shrubland	Birds	*Willow Ptarmigan*

Table 3. Ecologically-based assemblages' taxonomic group and the CE species to be included in them.
Subsistence species are italicized.

Ecologically-based Assemblage	Taxonomic Group	Fine Filter CEs
Migratory Bird Habitats	Birds	Waterfowl breeding areas including Yellow-billed Loon, King Eider, Common Eider, King Eider
Raptor Concentrations	Birds	Arctic Peregrine Falcon,
Seabird Colony Sites	Birds	Aleutian Tern
Critical Fish Habitats (known spawning habitat)	Fish	*Pink Salmon, Chum Salmon, Chinook Salmon*, and *Sheefish*
Marine Mammal Haul-Out Sites	Mammals	Pacific Walrus

Table 4. Number and list of species categorized as landscape species.
Subsistence species are italicized.

Taxonomic Group	Landscape Species
Birds (9)	Bar-tailed Godwit, Black Scoters, Bristle-thighed Curlew, Common Eiders, King Eider, McKay's Bunting, Red Knot, *Yellow-billed Loon*, *Canada Geese*
Mammals (8)	Alaskan Hare, Polar Bear, *Beavers, Black Bear, Brown Bear, Moose, Muskox, Western Arctic Caribou*
Fishes (18)	Alaska blackfish, Arctic lamprey, Pacific lamprey, Broad whitefish, Humpback whitefish, Round whitefish, Bering cisco, Rainbow smelt, *Arctic char, Arctic grayling, Pink salmon, Chum salmon, Chinook salmon, Coho salmon, Sockeye salmon, Dolly Varden, Pike, Sheefish*
Total (35)	

Table 5. Number of species assessed as local species by taxonomic group.

Taxonomic Group	# of taxa
Birds	4
Plants	26
Total	30

Table 6. Number of species recommended for developing new distribution models by taxonomic group.

Criteria	Taxonomic Group	# of CEs	Distribution Model		
			Yes	No	Maybe
Ecologically-based Assemblages	Birds	2			2
	Mammals	1	1		
Landscape Species	Birds	9	7	1	1
	Mammals	8	7		1
	Fishes	18	4	14	
Local Species	Birds	6	6		
	Plants	26		12	14
	Total	**70**	**25**	**27**	**18**

Distributions of Coarse and Fine Filter Terrestrial CEs

See the Task 2 memorandum for details on proposed data sets for distribution modeling and final lists of terrestrial fine-filter and coarse-filter CEs. Distributions for terrestrial CEs take several forms. Terrestrial coarse-filter CEs are currently being described and mapped by mosaicking existing land cover maps and cross-walking them to a consistent statewide classification system (Figure 5).

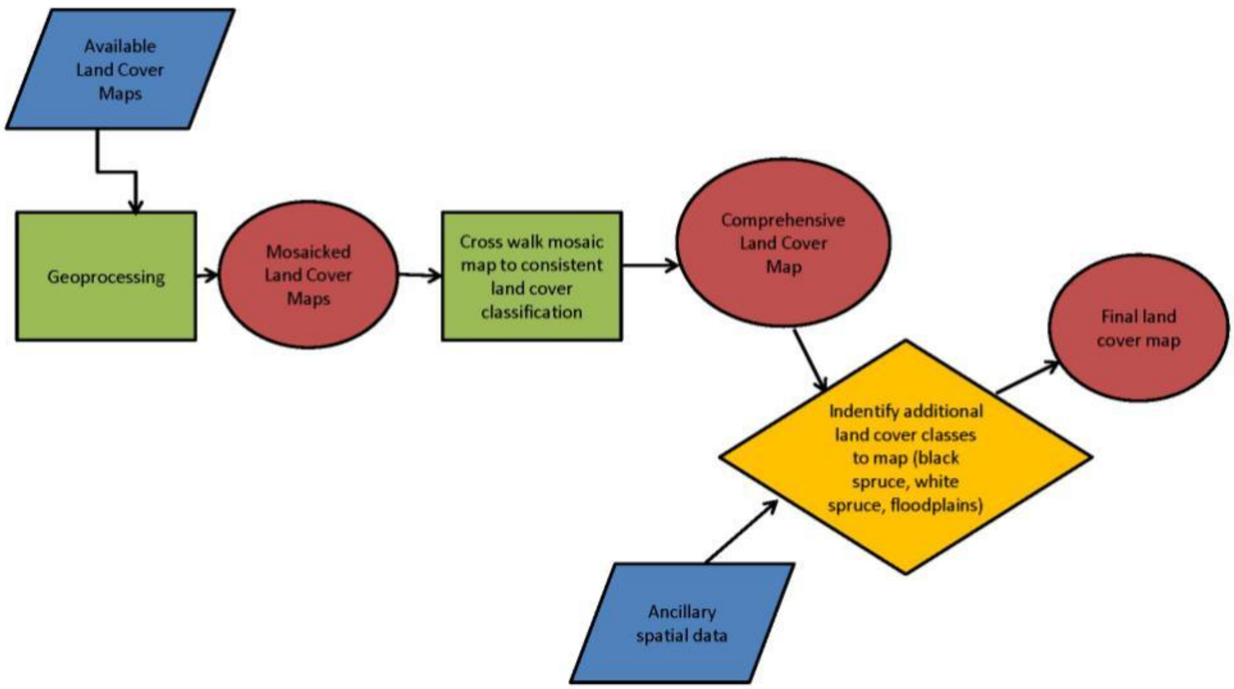
A land cover map is a core component of the REA for a variety of purposes including a GAP analysis and the Ecological Integrity Assessment. The land cover classes are the terrestrial coarse-filter CEs units. In order to provide a comprehensive land cover map we will integrate four separate maps into one comprehensive map. In the initial map we will include all of the land cover classes described in each map with some combining of similar classes resulting in 100+ land cover classes. We will then develop a second map by cross-walking and collapsing the 100+ land cover classes to a standardized classification (approximately 30 classes). We will mosaic the four land cover maps with ERDAS Imagine using 30 m pixels as the base spatial size. The detailed map (100+ land cover classes) may be used for some of our analysis. For example, it will contain more spatially explicit data on lichen cover and biomass that can be used for describing potential caribou habitat.

Only one of the four maps separated the black spruce class from the white spruce class. These classes, however, are critical for understanding fire frequency and vegetation succession. We will derive these classes through inductive modeling using elevation, aspect, landform (floodplain vs. upland), and range. In addition, we will use georeferenced samples from our Plot Reference Database as training data. These data were partially derived from the LANDFIRE Reference Database (LFRDB). The LFRDB has extensive vegetation class labeling errors and will require a review of all data points. We will also delineate the SNK project area floodplains. Currently, two of the land cover maps separated floodplains from uplands. We will heads-up digitize the remaining floodplains of the SNK using the existing 2001 mosaicked LandSat imagery (30 m pixel).

We will then nest the collapsed land cover classes within the ecoregion conceptual model developed by the USDI (US Department of Interior) National Park Service Arctic Network. It includes four units: Coastal, Upland, Lowland and Aquatic. These units have only been mapped for the northern 25% of the REA. We will map the Upland and Lowland units for the remainder of the REA study area by overlaying a surficial geology map (cite map here) over our land cover map. We will map the Coastal unit using the detailed land cover classes. The freshwater coarse-filter aquatic unit is described in the Aquatic CE Characterization and Conceptual Models section.

We will provide a cross-walk between the collapsed land cover classes and Ecological Site Descriptions (ESDs) applicable to the ecoregion. The USDA NRCS is now compiling the Ecological Site Descriptions for the ecoregion and those will be available in October 2011.

Figure 5. Concept diagram for modeling distributions of coarse-filter terrestrial CEs.



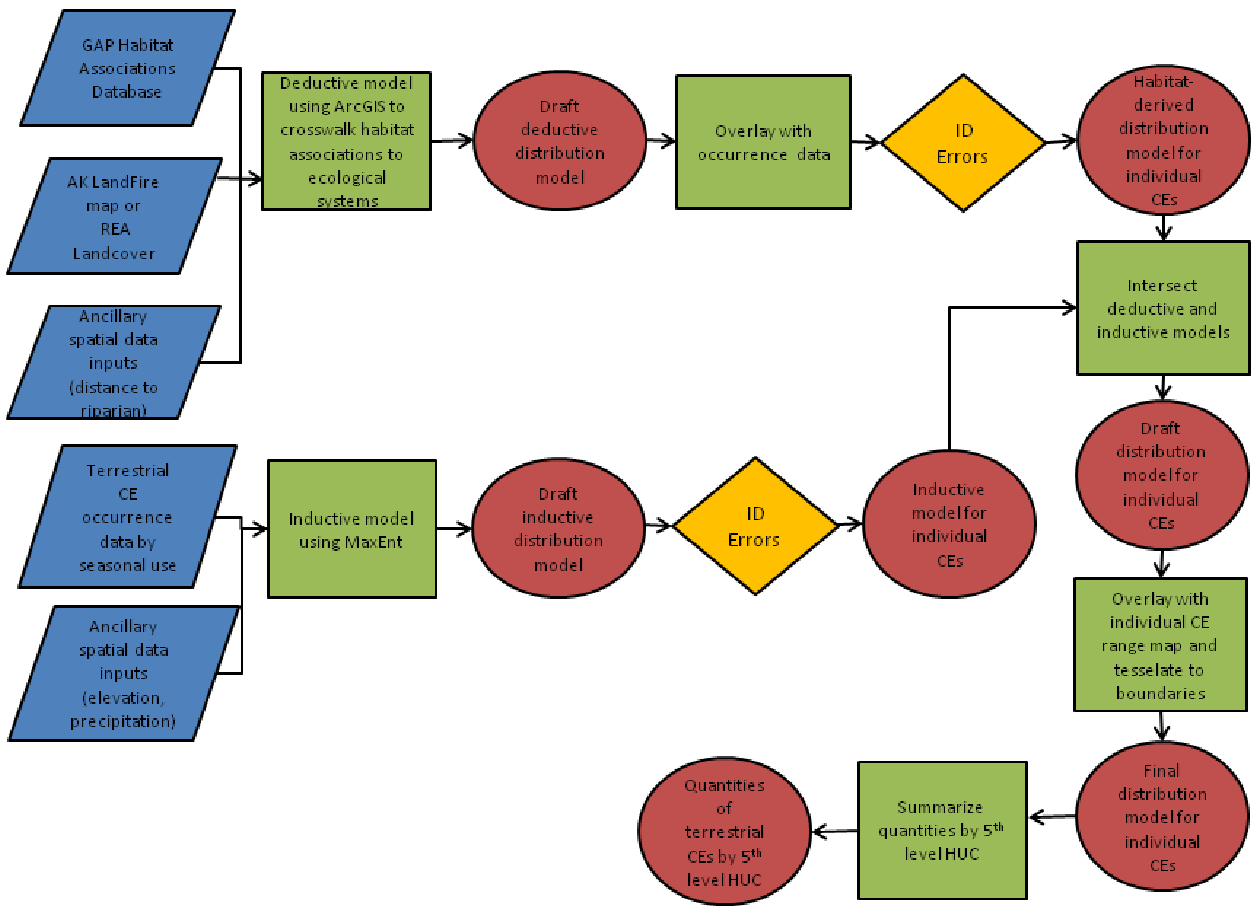
Terrestrial fine-filter CE distributions can be derived through two distinct modeling steps; both beginning with field observations and/or Element Occurrence records from the Alaska Natural Heritage Program. For clarification, an Element Occurrence (EO) is defined as an area of land and/or water in which a species or natural community is or was present and should have practical conservation value as evidenced by potential continued presence and/or regular recurrence at a given location. Field observations are the basis for an element occurrence.

Species presumed to be addressed in the REA through assessment of coarse-filter CEs, and those local-scale species to be treated within summaries by watershed, will require no additional modeling steps. Summary statistics of known observation/occurrences by 5th level HUC will be the primary output (Figure 5).

For species to be treated within ecologically-based assemblages, or as individual landscape species, additional modeling steps are appropriate either through use/refinement of existing habitat location/suitability models (e.g. those created by the Alaska GAP project) or through development of new models for the ecoregion (using the ecoregion-wide land cover map). Landscape species may be treated spatially using multiple habitat components (e.g., winter range vs. summer range). These distinctions will be established in conceptual models and then articulated as distinct spatial models. We will employ methods similar to those being used by the Alaska Gap Analysis Project (www.akgap.info) to model the current distribution of terrestrial vertebrate landscape species. First, we will develop a distribution model that is based exclusively on habitats within the region that the species is known to be associated with. Such habitat associations are based on literature review and expert opinion, which are then cross-walked to corresponding ecological systems in the land cover map. This is a standard deductive modeling approach utilized by most state based Gap Analysis Programs

(GAP). This step has already been completed for all Landscape CEs at the statewide scale using the LandFire map (www. Landfire.gov) Our intention is to rerun the deductive models for landscape species using the land cover map being developed specifically for the SNK ecoregion, with hopes that it will improve the quality of our models. Then, for those CEs with sufficient occurrence records, we will also develop a second distribution model that uses inductive techniques (statistical models of climatic and physical limits), such as MaxEnt. Inductive modeling tools such as MaxEnt use georeferenced observations combined with map surfaces to produce a probability surface for suitable habitat that might support a given CE (e.g., Guisan and Thuiller, 2005; Liu et al. 2005). Map surface inputs can include vegetation type, vegetation structure, climatic variables, landform, landscape position, and soil variables among others. The final CE distribution model will be the intersection of these two independently derived models, clipped to the species known range. Our goal in combining the strength of these two modeling techniques is to improve the quality, precision and application of the CE distribution maps. Once these individual distribution models are created and or refined from existing models, the areal extent of habitat will be summarized by 5th level HUC (Figure 6).

Figure 6. Concept diagram for modeling distributions of fine-filter terrestrial CEs.



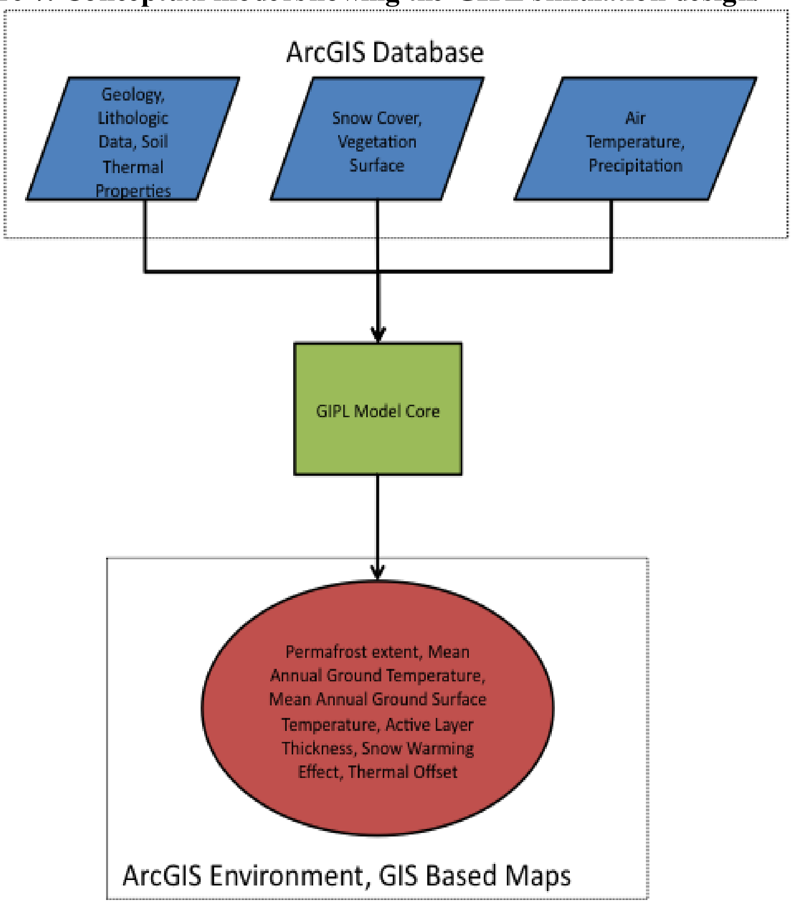
Distribution of Permafrost

Permafrost is distributed across the SNK ecoregion. To the north, the study area is underlain by continuous permafrost (>90%), while to the south it is underlain by discontinuous permafrost (50-90%) (Jorgenson et al. 2008). We will assess the effect of a changing climate on permafrost within the REA using the Geophysical Institute Permafrost Lab's (GIPL) model. The GIPL model is a quasi-transitional, spatially distributed equilibrium model for calculating future scenarios of soil thermal dynamics including: 1) active layer thickness (ALT; the thin layer above permafrost that seasonally freezes and thaws) and 2) mean annual ground temperature (MAGT).

Inputs

Input parameters to the GIPL model are spatial (2 x 2 km) datasets of mean monthly air temperature and precipitation, prescribed vegetation, soil thermal properties, and water content, which are specific for each vegetation, soil class, and geographic location. Climate forcing data from the Scenarios Network for Alaska and Arctic Planning (SNAP) are used to drive the model. Other input variables include: snow water equivalent (SWE); height of vegetation cover; thermal diffusivity of vegetation in the frozen and thawed state; thermal conductivity of frozen and thawed soil; volumetric later heat of ice fusion; and volumetric heat capacity of snow cover and frozen and thawed ground. The GIPL model is combined with ArcGIS to facilitate preparation of input parameters and visualization of simulated outputs (Figure 7).

Figure 7. Conceptual model showing the GIPL simulation design.



Analytic Process and Tools

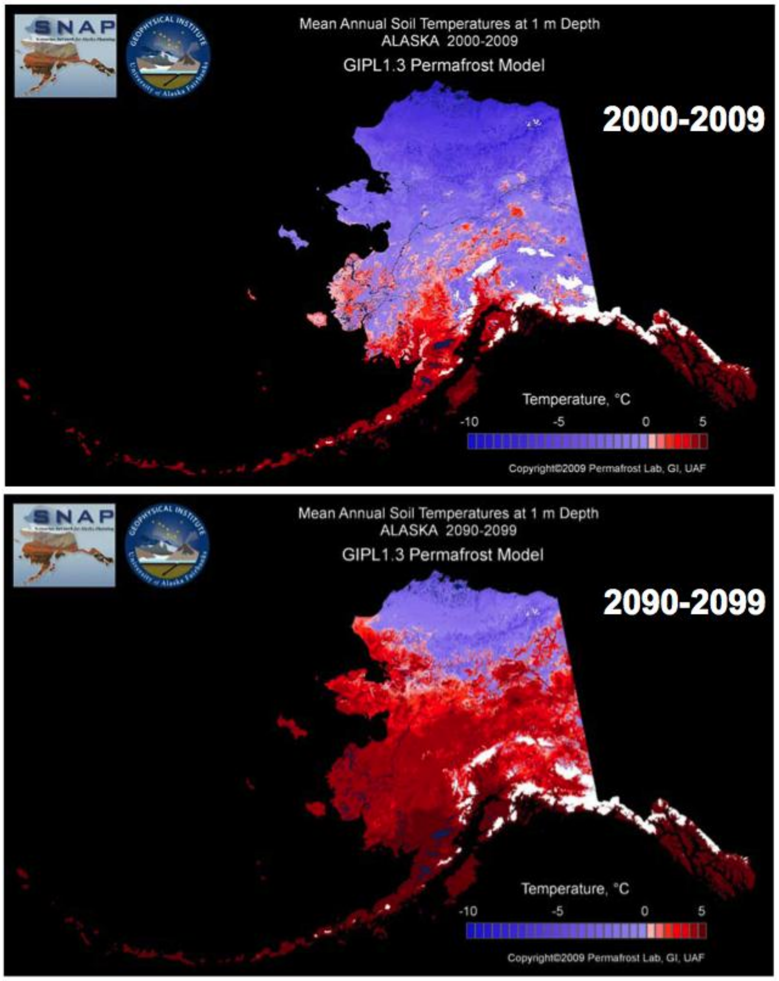
The GIPL model calculates the maximum active layer thickness (ALT) and mean annual ground temperature (MAGT) at the bottom of the active layer. In permafrost regions, MAGT is the same as the mean annual temperature at the permafrost table (upper surface of permafrost). In permafrost-free regions, which do not occur within the REA study area today but are projected to occur in the future, MAGT is the mean annual temperature at the bottom of the seasonally frozen layer.

The approach to determine ALT and MAGT is based on an approximate analytical solution that includes freezing/thawing process and provides an estimation of thermal offset due to the difference in frozen and thawed soil thermal properties (Kudryavtsev et al. 1974). This approach is the core of the GIPL model and treats the complex system including air, snow cover, surface vegetation, and the active layer as a set of individual layers with different thermal properties.

Outputs

The primary outputs of the GIPL model are spatial and tabular estimates of ALT and MAGT identifying areas that may become ice-free in the future. For the REA, we will report current conditions and those projected for 15 (2020s) and 50 years (2060s) into the future. The reporting unit for these outputs will be at the level of the ecoregion. We provide a sample output from a single replicate of a statewide run of GIPL showing temporal changes in the spatial distribution of mean annual soil temperature (Figure 8).

Figure 8. GIPL output showing potential temporal changes in the distribution of mean annual soil temperatures in Alaska.



Terrestrial CE Characterization and Conceptual Models

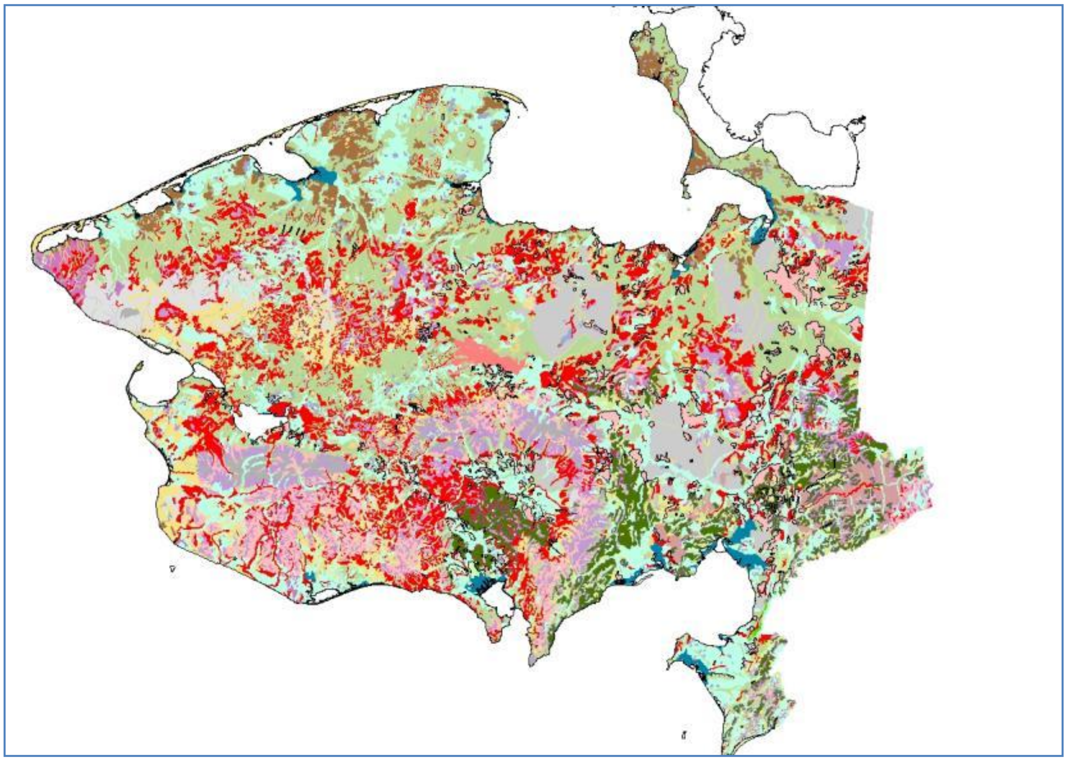
The following section is an example of a description of a terrestrial coarse filter CE and the ecological factors that affect it. This basic format will be applied, with some variation, for each of the terrestrial coarse-filter CEs, landscape species CEs, and ecologically-based species assemblage CEs. Our conceptual models combine text, concept diagrams, and tabular summaries, in order to clearly state our assumptions about the ecological composition, structure, dynamic process, and interactions with common CAs within the ecoregion.

Here we use the Arctic Scrub Birch-Ericaceous Shrubland vegetation type, a characteristic terrestrial coarse-filter type, for purposes of illustration. For each coarse filter we will provide a short description for each of the collapsed land cover classes (approximately 30 classes) and the ecological factors that affect it.

Scrub Birch-Ericaceous Shrub Land Cover Class Example: Characterization

This class occurs throughout arctic Alaska, from the Bristol Bay lowlands in southwestern Alaska to the North Slope on the Arctic Ocean. It nests within the Upland System (Lawler et al. 2009) and is common on low elevation mesic mountain slopes, hill slopes, and flats. Patch size is small to matrix-forming. Soils are mesic. The total low- and tall-shrub cover is >25%, and *Betula nana*, *Vaccinium uliginosum*, or *Ledum palustre* ssp. *decumbens* typically dominate or co-dominate. *Salix* spp. (such as *Salix pulchra*) do not dominate but may co-dominate. Herbaceous species are sparse, and feathermosses (*Hylocomium splendens* and *Pleurozium schreberi*) and lichens may be common. Its distribution within the Seward Peninsula portion of the REA is displayed in Figure 9.

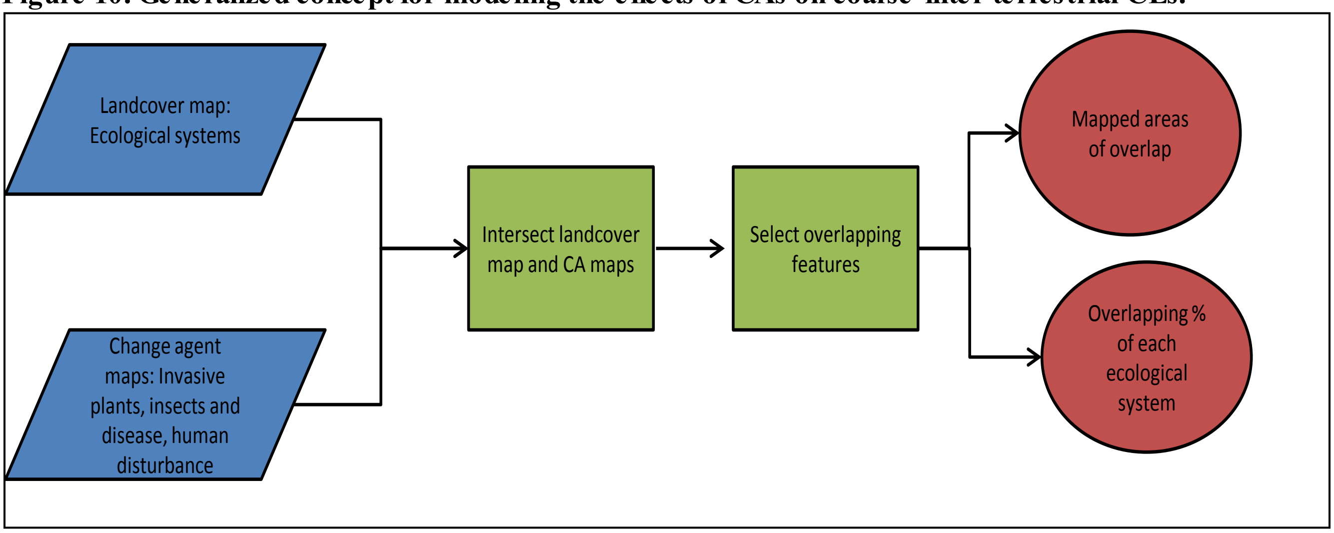
Figure 9. The distribution (given in red) of the Alaska Arctic Scrub Birch-Ericaceous Shrubland existing vegetation class within the Seward Peninsula portion of the REA.



Change Agent Effects Conceptual Model on Terrestrial CEs

In this section we characterize the primary change agents and current knowledge of their effects on this CE. Some CAs have specific effects on each CE such as the alteration of expected fire regimes, introduction of invasive species, and insect and disease infestations. For illustrative purpose, we provide conceptual models that combine text, concept diagrams, and tabular summaries, in order to clearly state our assumptions about the ecological composition, structure, dynamic process, and interactions with common CAs within the ecoregion (Figure 10).

Figure 10. Generalized concept for modeling the effects of CAs on coarse-filter terrestrial CEs.



Coarse Filter CEs: Example Wildfire CA Effects

To address management question #87 "How will habitats that support terrestrial species of concern likely change due to disturbance or climate change over the next 15 and 50 years?" it requires that we describe vegetation succession within each collapsed land cover class following disturbance by the various CAs (fire, invasive plants, human disturbance, and climate change). For example, to understand caribou habitat we need to determine rates of change in lichen availability following fire.

We provide two approaches to describe and model succession. The first is ALFRESCO that describes the response of forested types to fire. We give a full description in the CA Class I: Wildfire section. This model is not yet available for non-forested types. The second is the Vegetation Dynamics Development Tool (VDDT) developed by ESSA Technologies. We provide a description of VDDT in the next section. Within Alaska, the VDDT models are also only accurate for wildfire in forested types. To improve the non-forested VDDT models we will do a full literature search. We anticipate this will improve the models for the floodplain, thermokarst topography and lichen dominated land cover classes.

The final products to address the management question "How will habitats that support terrestrial species of concern likely change due to disturbance or climate change over the next 15 and 50 years?" are:

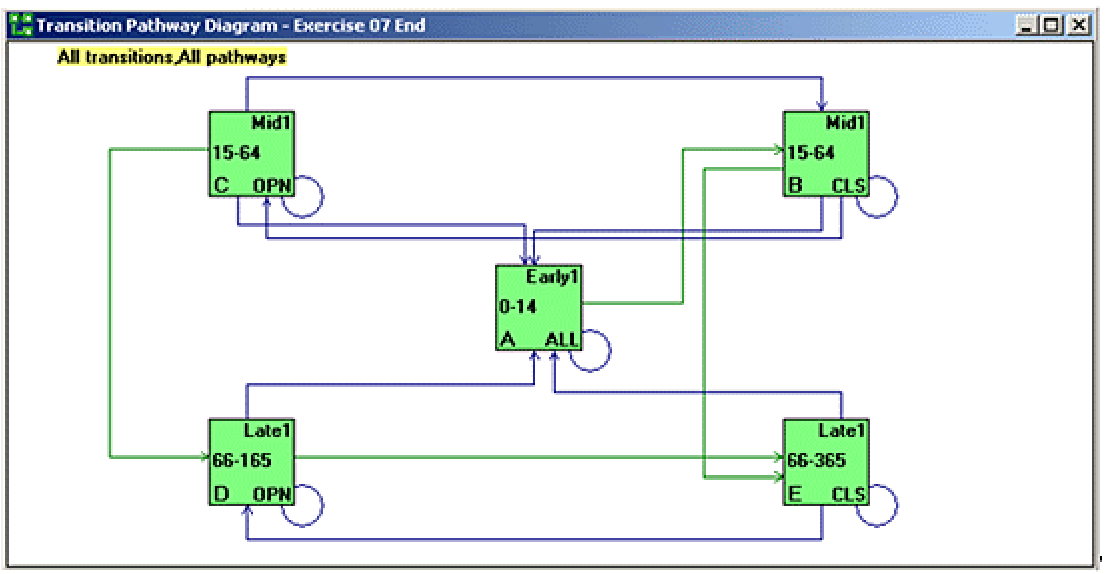
- VDDT models for land cover classes with seral information (methods given below)
- A table showing probable changes in area of the land cover classes in 15 and 50 years.

Vegetation Dynamics Development Tool (VDDT)

The VDDT methods given below are from the ESSA Technologies website at http://www.essa.com/tools/vddt/index.html. The Vegetation Dynamics Development Tool (VDDT) is a Windows-based computer tool which provides a state and transition landscape modeling framework for examining the role of various disturbance agents and management actions in vegetation change. It allows users to create and test descriptions of vegetation dynamics, simulating them at the landscape level.

VDDT assumes that the landscape has been stratified into units with similar transition pathways. The default convention is that this stratification identifies a unique state and transition model. Within each model, vegetation states are defined as combinations of the predominant cover type and structural stage, called state classes. Movements between classes are described by two types of pathways: changes driven by probabilistic transitions (e.g., fire, climate) and deterministic changes due to the passage of time (e.g., regeneration, growth, or self-thinning).

Figure 11. Illustration of a VDDT state and transition model.
State classes are shown with boxes; transitions between classes are marked with arrows.



Probabilistic transition pathways specify, for each class, the type of transition, its probability (which defines the return frequency) and its impact on vegetation. Changes due to deterministic transitions are defined by the time a cell remains in a state class and by the new state class to which it will move after this time has elapsed. VDDT translates the information on transition pathways into a diagram on the screen.

How does it work?

Each VDDT model simulates the changes that occur within one type of vegetation community. This community is represented by a number of cells, each initially assigned an age and state class. Using the pathways and probabilities defined for that vegetation community, the model simulates the probability of each cell being affected by one of the transition types, and if a transition does occur, moves the cell to the appropriate class. Disturbance probabilities depend on the current state of the cell, defined by its state class. They are independent of the state of the neighboring cells and their transition history.

What does a user need to define?

Users need to define the state classes, pathways and transition probabilities for each model. A model may have more than one set of probabilities defined to represent different management regimes or ecological conditions. Creating a database with this information may easily be done entirely within VDDT.

Figure 12. Example of defining state classes, pathways and transition probabilities within VDDT.

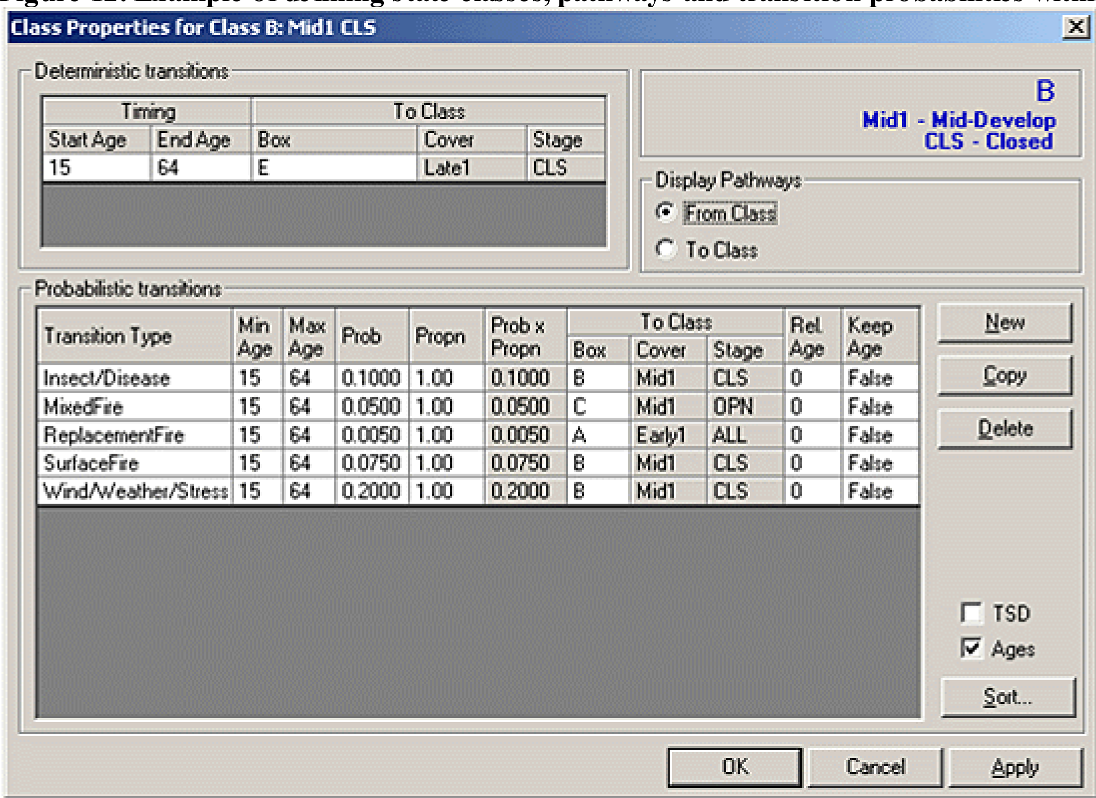
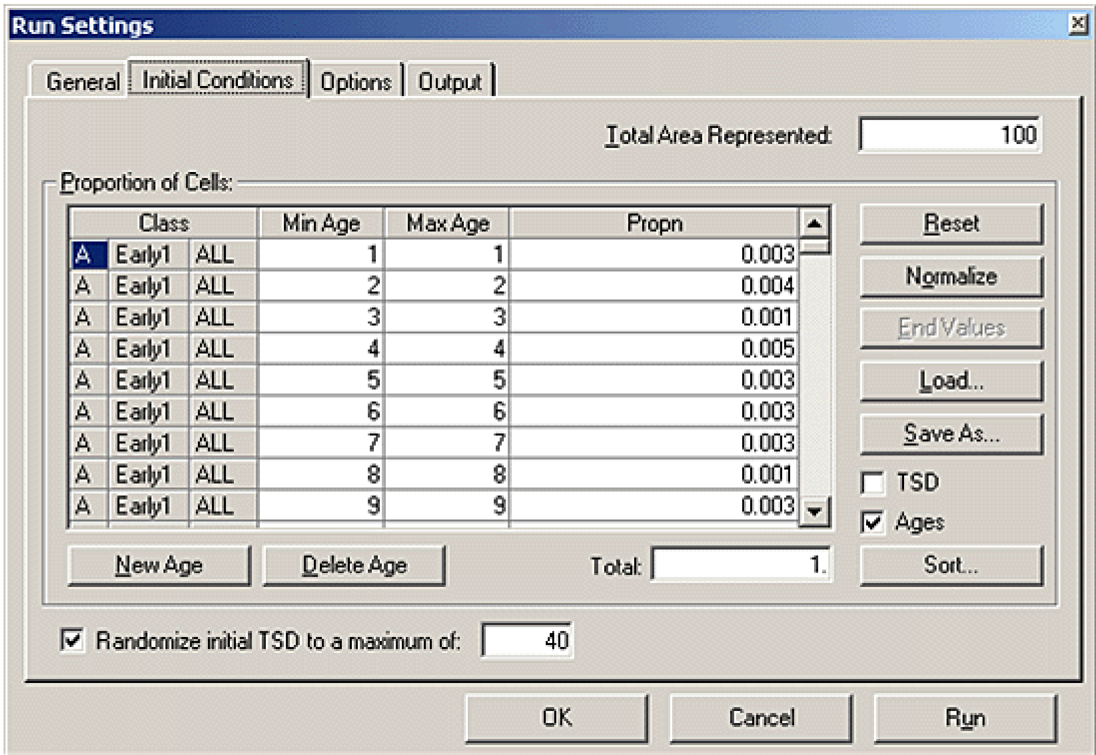


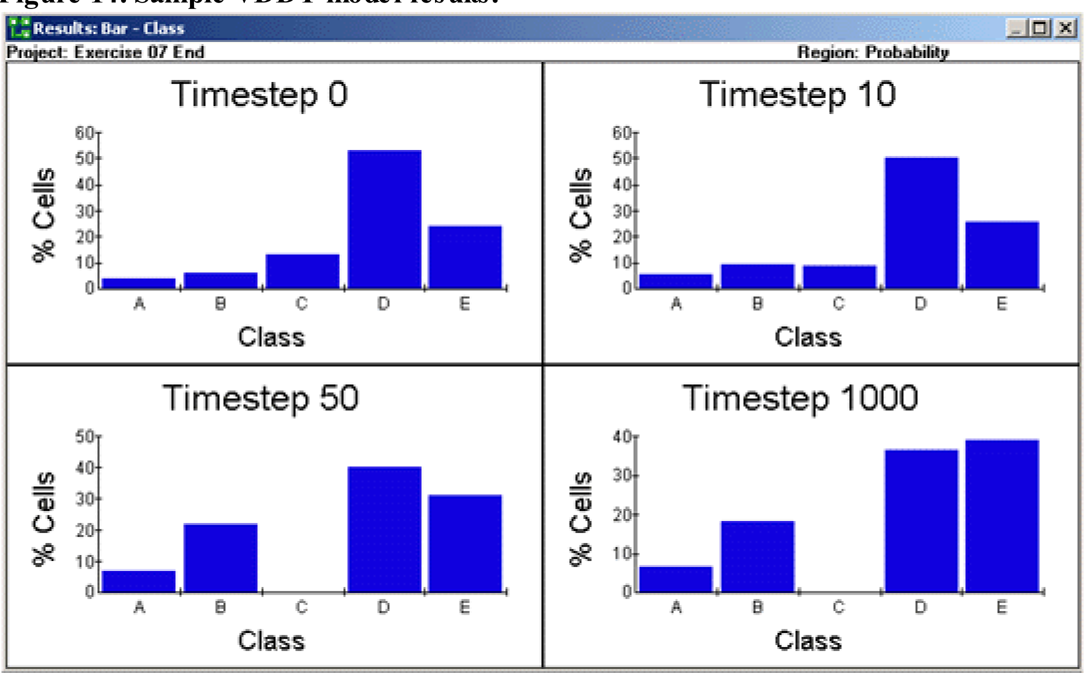
Figure 13. Example of defining initial conditions within VDDT.



What results are produced?

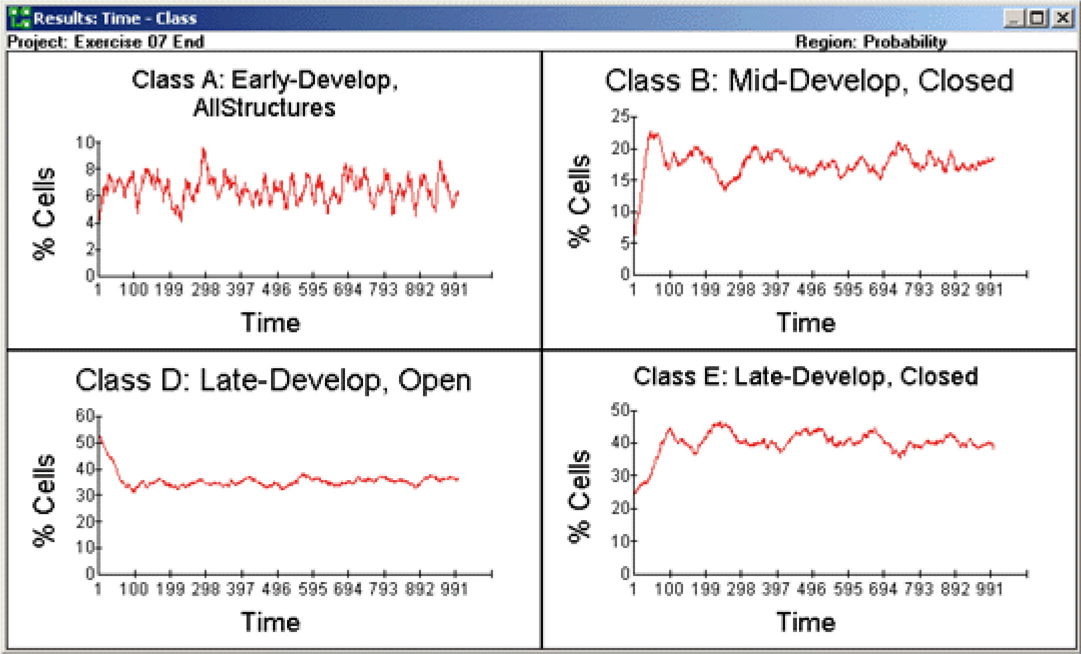
Model results can be viewed as the changes in the distribution of the cells in different categories (such as state class, structural stage, cover type, or area affected by different transition types) at a single point in time.

Figure 14. Sample VDDT model results.



Graphs can be created to show the change over time in the proportion of cells in a given class (upper set) or the percentage of cells that were affected by disturbance or succession (lower set).

Figure 15. Example of VDDT outputs showing change over time.



VDDT Example for Scrub Birch-Ericaceous Shrubland

As a VDDT example, we describe the effect of wildfire on the Scrub Birch-Ericaceous Shrub land cover class. Knowledge of the effect of other change agents (e.g., invasives, insects and disease, reindeer grazing) is not available. Fire return interval estimates vary from 240 to 1,000+ years. According to lake-core records, the fire return interval is approximately 240 years on the Seward Peninsula and 1,000+ years on the Beaufort Coastal Plain (Jennifer Allen pers. comm.). Other studies give a fire return interval of 260 years (SD 170) for the past 1,500 years on the Noatak National Preserve (preliminary data from Higuera et al. 2008), and 611 years for the Noatak River watershed for all vegetation below 600 m (Racine et al. 1985).

Racine et al. (1987) studied low shrub tundra post-fire vegetation recovery on the Noatak and Seward Peninsulas and found the following. Post-fire increases in soil thaw in tussock tundra stabilized or returned to pre-fire levels within 5-6 years. Bryophyte cover increased rapidly, reaching 75-100% in 2-3 years. Dominant species, not present in unburned low shrub tundra, included *Ceratodon purpureus*, *Marchantia polymorpha*, *Polytricum* spp., *Arctagrostis latifolia*, *Poa arctica*, *Senecio congestus* and *Carex bigelowii*. Shrub recovery ranged from nearly 0-100% within 8 years, with willows recovering at one site.

The Scrub Birch-Ericaceous Shrubland model for characterizing the natural disturbance regime (natural range of variation, NRV) has three boxes that represent early, mid, and late seral stages (Table 7).

Class A: After fire, herbaceous species such as *Festuca altaica* and *Hierochloe alpina* typically dominate. Low shrubs can resprout following fire, quickly regaining dominance of a site. This class may persist for more than 5yrs if fire severity is high enough to remove the organic layer.

Class B: This class represents an open shrub class. Under appropriate conditions, the canopy can close around age 25, causing a transition to Class C, but most sites will remain open indefinitely. This class is dominated by shrubs, often *Betula nana*, *Vaccinium uliginosum*, *Ledum decumbens*, *Salix pulchra*, *S. barclayi* or other *Salix* spp. may also be common (Viereck 1979, Viereck et al. 1992). This class can persist in the absence of disturbance or follow an alternate succession pathway to Class C (probability = .0012). Replacement FRI = 250 years causes a transition to Class A.

Class C: This class represents a mature closed-canopy shrub class that may occur on a minority of sites where conditions are appropriate. The canopy will close in around age 25. This class is dominated by shrubs, often *Betula nana*, *Vaccinium uliginosum*, *Ledum decumbens*, *Salix pulchra*, *S. barclayi* or other *Salix* spp. may be common (Viereck 1979, Viereck et al. 1992). This class persists in the absence of disturbance. Replacement FRI = 250 years cause a transition to Class A.

Table 7. Transition probabilities and return intervals for fire in the Scrub Birch-Ericaceous Shrub land cover class under natural conditions (presumed natural range of variability, NRV).
These probabilities are used in the VDDT model to estimate the relative abundance of each class over time.

From class	To class	Transition type	Probability	Return interval (years)
A	A	Replacement fire	5%	250
B	A	Replacement fire	5%	250
C	A	Replacement fire	5%	250

Ecological Status Assessment and Reporting: Terrestrial CEs

In order to assess ecological status for CEs within the ecoregion, we propose to begin the assessment at the level of each CE, or with groups of CEs, as they are distributed within each 5th level watershed. NatureServe's ecological integrity framework sets up practical criteria and indicators for this purpose (Faber-Langendoen et al. 2006, Unnasch et al. 2008). This framework provides a scorecard for reporting on the ecological status of a given CE within a given location, and facilitates the aggregation and synthesis of the component results for broader measures of ecological status at landscape scales. Using this framework, indicators are chosen to provide a measurement for a limited set of key ecological drivers ("attributes") for each CE. Ecological attributes may include natural characteristics, such as native species composition, or stressors such as effects of relevant change agents, that are well known to affect the natural function and integrity of the CE. The key ecological attributes are organized by "rank factors" of **Landscape Context** and **Condition**. For this REA, the reporting unit is at the Watershed 5th Level (HUC – 10). The NatureServe EIA framework also organizes indicators into categories based on required effort, with "Level 3" indicators addressed through quantitative field measurement, "Level 2" indicators emphasizing qualitative field review, and "Level 1" indicators addressed through remote sensing. In part because of project constraints, indicators that we recommend emphasize ecosystem stressors that can be more readily measured using remotely sensed data – "Level 1" indicators. Spatial models that reflect these indicators serve as the link between the conceptual models and the spatial representation of ecological integrity.

Below we provide further illustration using criteria and indicators organized for the Arctic Scrub Birch-Ericaceous Shrubland. Table 8 provides a concise summary, or scorecard, for describing and measuring each indicator. We also evaluated whether to use wild-fire or insects and disease in the Ecological Integrity Assessment for coarse-filter units. Our conclusion for fire is we can't say whether fire regime is human induced or natural. For insect and diseases we also could not determine whether insect and disease is human induced or natural, and the available data are limited to only forests, alder and willow classes. Consequently, we will not use wildfire or insects and disease in the Ecological Integrity Assessment.

Landscape Context

The key ecological attribute of landscape condition, relative to effects of human alteration to landscape pattern and process, falls within this rank factor of "Landscape Context." Here we propose one primary indicator: the Landscape Condition Index.

Landscape Condition Index

Major effects of development and management actions are captured in the Landscape Condition Model (LCM) using the approach developed by NatureServe (Comer and Hak 2009) (see Appendix IV for a description of the development of the model). The indicator is measured in a GIS by intersecting the mapped area of the CE distribution with the LCM and reporting the mean LCM index score for the type distribution within each HUC 10 unit. The results are an index of Landscape Condition from 0.0 to 1.0 with 1.0 being very high landscape condition (apparently unaltered natural conditions) and 0.0 having extremely altered condition (e.g., dense urban areas).

Condition

The key ecological attribute of ecological condition is comprised of ecological drivers that underlie natural food web dynamics and native species composition. Given human alteration, indicators of ecological composition, structure, and function for a CE fall within this rank factor of "Condition." Here we propose one indicator: an Invasive Plant Index, as a numerical index to contribute to our scorecard for ecological integrity. Invasive species as a CA are addressed in the section CA Class IIIa: Non-Native Species. As stated above, we lack data to be able to assess Insects and Diseases as an indicator, but they will be addressed as a CA (see CA Class IIIb: Nuisance Native Species and Diseases section).

Invasive Plant Index

Stressor based indicators, based on non-native species abundance and invasiveness, are a tractable measure of ecological integrity for the region. This indicator is measured for CEs reported in 5th level HUCs, using the number of non-native infestations for species a) that are highly invasive (invasiveness scores >70) and b) for less invasive species. CEs with one or more infestation of highly invasive species or > 25 total infestations are regarded as more degraded (index score <0.5), CEs with 1-24 infestations are regarded as moderately degraded (0.5-0.9), CEs with no infestations are regarded as intact (1.0).

Scorecard and Status Categories

Each indicator is scored according to criteria described above and then the score is either used directly as an index or an indicator index is calculated between 0 and 1, with 1 being 100% sustainable and 0 being totally degraded (and presumably transitional to a wholly different ecological state). We will report ecological status scores within three categories, effectively segmenting the 0.0-1.0 scale with two distinct numerical thresholds. These categories include "Sustainable," defined as the indicator falls within the expected natural range of variation (NRV). At the other extreme, "Degraded" status occurs where the indicator is well outside its expected range as hypothesized by NRV, to the degree that conditions suggest imminent loss of the CE at that location. The third category, "Transitioning," occurs where a given indicator is outside its expected range, as hypothesized by NRV, but to a measurably lesser degree than the "Degraded" condition, so that imminent loss of the CE is not predicted. The mean index scores of these indicators can then be averaged.

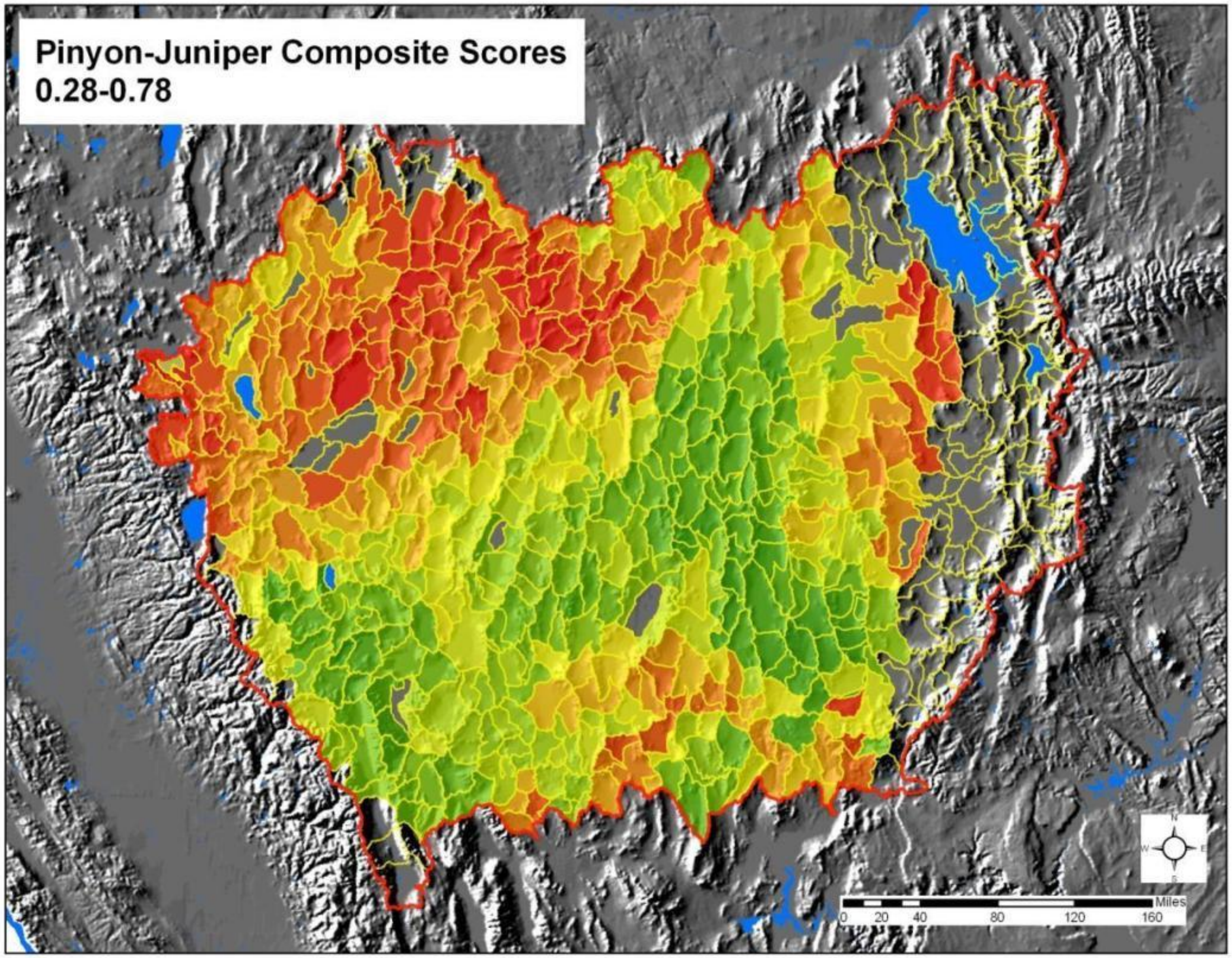
In our Scrub Birch-Ericaceous Shrub land cover class example (Table 8), a hypothetical set of mean index scores are included in the far right column of Table 8. The combined index score for this system within a given 5th level HUC watershed at a given point in time (e.g., currently) is 0.93. When speaking of relative significance and reporting on ecological status for the REA, we can choose to report along either a 0.0-1.0 relative scale, or where knowledge and data permit, we can choose to use our segmented scoring options (now applying threshold values from the scorecard) to report on relative status within Sustainable, Transitioning, or Degraded categories. With a composite score of 0.93, this hypothetical example would be reported as Sustainable.

We will also provide mapped results using 5th level HUC watersheds. An example of the Pinyon-Juniper ecological system is given for illustrative purposes (Figure 16). Given limitations in current knowledge, mapped information, and management need, we may be best to report on ecological status for all terrestrial coarse-filter units combined within each watershed. In effect, the ecological status score will be an indication of overall landscape intactness or condition, relative to human disturbances. Status measures for individual landscape species CEs appears to be more tractable and meaningful with current knowledge and data. Additionally, while we propose to report on relative ecological status for terrestrial CEs in terms of 5th level HUCs, we could consider reporting within a limited set of other spatial reporting units, such as established managed land units. However, for this REA, we propose to report only using 5th level HUC watersheds, leaving reporting with additional units to subsequent efforts by BLM (e.g., under ecoregional direction).

Table 8. Ecological Integrity Assessment scorecard for the Arctic Scrub Birch-Ericaceous Shrubland (or terrestrial landscape).

RANK FACTOR	Indicator / Justification	Rating Thresholds: Sustainable	Rating Thresholds: Transitioning	Rating Thresholds: Degraded	Index Score
LANDSCAPE CONTEXT					
	Landscape Condition Model (LCM) Index Land use impacts vary in their intensity, affecting ecological dynamics that support land cover types	Cumulative level of impacts is sustainable. Landscape Condition Model Index is > 0.8.	Cumulative level of impacts is transitioning type between a sustainable and degraded state. Landscape Condition Model Index is 0.8 – 0.5.	Cumulative level of impacts has degraded type. Landscape Condition Model Index is <0.5.	0.90
CONDITION					
	Invasive Species Index Invasive species can impact ecological systems and species.	System is sustainable with no non-native species infestations. Invasive Species Index is 1.	System transitioning to degraded state by presence of non-native species with 1-24 infestations of non-native species. Invasive Species Index is 0.5-0.9.	System is degraded by invasive species. One or more infestations of highly invasive species or > 24 total infestations. Invasive Species Index is <0.5.	0.95
Overall Ecological Status Rank (1.85/2 = 0.93)	**Mean Index Score**				0.93

Figure 16. Ecological Status Assessment for the Pinyon-Juniper ecological system by 5th level watershed HUC. Green indicates sustainable, yellow is transitioning, red is degraded and gray HUCs indicate the system does not occur in the HUC.



Terrestrial CEs: Landscape Species

For illustrative purposes we have developed a conceptual model for the Bristle-thighed Curlew (see Appendix II). This type of conceptual modeling approach, distribution model development and status assessment will be used for all fine-filter landscape species CEs.

Distributions of Coarse and Fine Filter Aquatic CEs

As established in memorandum I-1-c, aquatic coarse-filter CEs are categorized based on the ecoregion-wide conceptual model that defines all "aquatic" ecosystem types. These types include what are commonly referred to as aquatic habitats and include headwater streams, lowland streams/sloughs, rivers, hot springs, large and connected lakes, small and connected lakes, large and unconnected lakes, and small and unconnected lakes. Our aim is to provide a map depicting the current distributions for each of the nine coarse-filter CEs. The datasets used to map the distributions of the aquatic coarse-filter CEs are described in the Task 2 memorandum.

There are 18 fine-filter aquatic CEs (all fish species) and five of them have adequate existing data to map their distributions across the REA study area. Four of the CEs have field sampling data (species occurrence and stream habitat data) that will be used to model their distribution. One CE (arctic char) is a local species only found in lakes of the Kigluaik Mountains. The remaining eight species lack both existing spatial data showing their distributions and field sampling data from which to model their distributions. Due to the significant lack of data, these eight CEs will not be included in management questions that address fish distributions. A summary of how each fine-filter CE will be treated is provided in Table 1 of Memo I-2-c for Task 2.

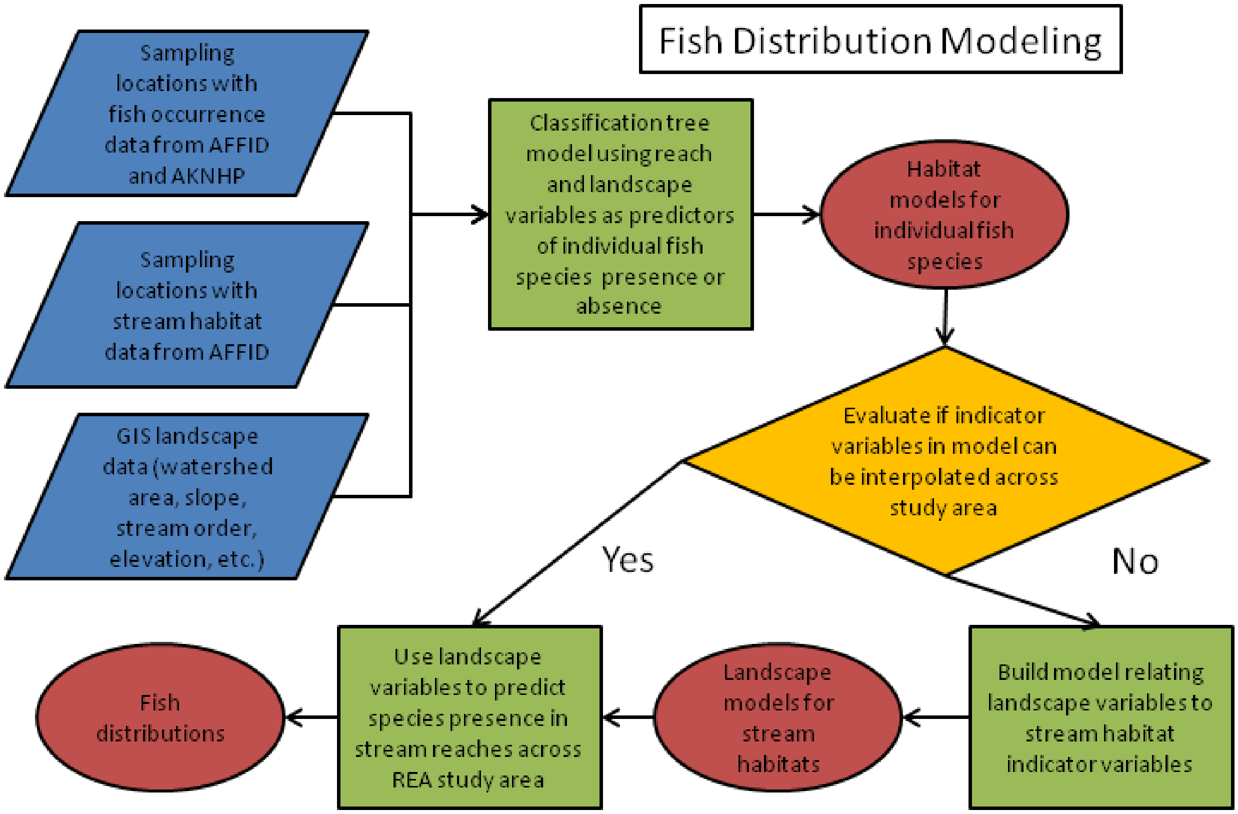
Distribution Models

The Alaska Department of Fish and Game (ADF&G) Alaska Freshwater Fish Inventory Database (AFFID) includes species occurrence, stream habitat, and spatial data for 260 field sampling sites in the REA study area. Stream habitat data included water chemistry (measured in-situ) and stream channel, stream flow, and riparian vegetation measurements. Some derived spatial data were also calculated for each site such as elevation and catchment area. We propose using data from the AFFID to model distributions for four of the fine-filter CEs: Dolly Varden, arctic grayling, Alaska blackfish, and Coho salmon. Since the AFFID surveys were conducted in August, the models will reflect potential habitat for these fishes during summer and may not reflect other seasonally important habitats. Sample sites were selected by 1) targeting the longest stream reaches not listed in the Anadromous Waters Catalog (AWC) and 2) sampling across the stream network to estimate variation in habitat and landscape variables (Weidmer et al. 2004). Although sample sites were not randomly located, they were placed to target variation in stream habitats both within and between stream orders. Habitat model predictions will most likely be biased towards low order streams as a result of the ADF&G study objectives guiding these surveys.

For the three resident fishes (Dolly Varden, arctic grayling, and Alaska blackfish), distribution models will be used to identify stream reaches that provide potential summer habitat and will provide more coverage than the point data (sampling sites) currently available. The distribution model for Coho salmon will be used to identify potentially important summer rearing areas in headwater streams, a habitat that has not been sampled extensively in the REA study area. The Coho salmon model will build upon the important habitat indicator variables validated by Nemeth et al. (2009) in the Nome and North rivers.

Fish distribution models will utilize classification tree analysis to identify stream habitat and landscape indicator variables useful for predicting stream reaches as either habitat or not habitat (Figure 17). All analyses will be conducted using the R statistical software package and the mvpart library (R Development Core Team 2009, Therneau et al. 2011). Methods for classification tree analysis will follow those prescribed in McCune and Grace (2002). The species occurrence and stream habitat data will come from the AFFID and AKNHP databases. The AKNHP has point locations, but no stream habitat data while the AFFID contains concurrent data for species occurrences and stream habitat. The AFFID also has some landscape variables useful for predicting stream habitat, such as catchment area and elevation. Other variables will be added to the classification tree models based on existing literature identifying landscape variables useful for predicting stream habitat (Burnett et al. 2009 and references therein, Nemeth et al. 2009, Walker et al. 2007). These include stream order, stream gradient, number of branches off of the mainstem, watershed slope, topographic wetness index (TWI), riparian vegetation type, wetland cover, and others. The TWI is an index used to quantify the control of topography on hydrologic processes and has been used to predict stream water chemistry (Ogawa et al. 2006, Shaftel et al. 2010). The calculation for TWI is easily processed in GIS: TWI = ln (A/tanb), where A = watershed area and b = local slope (Sorensen et al. 2005). If classification tree analysis results utilize stream habitat variables as indicators of fish presence, then additional analysis will be necessary to relate landscape variables to the appropriate stream habitat indicator variables. Ultimately, each fish CE distribution model will utilize landscape variables as predictors of fish distribution in aquatic habitats across the REA study area.

Figure 17. Concept for modeling the distribution of aquatic fine-filter CEs.



Aquatic CE Characterization and Conceptual Models

The following section provides an illustration of conceptual modeling components for aquatic CEs. This basic format will be applied, with some variation, for each of the aquatic coarse-filter CEs and landscape fine-filter CEs. Our conceptual models combine text, concept diagrams, and tabular summaries in order to clearly state our assumptions about the ecological composition, structure, dynamic process, and interactions with common CAs within the ecoregion. These conceptual models serve as the foundation for spatial models that enable us to gauge the relative ecological status of each aquatic CE within 5^{th} level HUCs. Here we illustrate this process using one aquatic coarse-filter CE, headwater streams, and one aquatic fine-filter CE, Coho salmon (*Oncorhynchus kisutch*).

Each model begins by characterizing what the CE is, and how it nests within the broader conceptual model already established for each ecoregion. In this example, headwater streams nest within the Aquatic Model components of the Seward Peninsula – Nulato Hills – Kotzebue Lowlands ecoregional conceptual model (see Memo 1c).

Aquatic Coarse Filter CE Example: Headwater Streams

<u>**Conservation Element Characterization**</u>

Headwater streams include all perennial first-order streams, which occur across the landscape in high elevation mountain ranges and also in coastal or interior lowlands. Our description of habitats and fish communities in headwater streams relies on two ADF&G studies in the REA study area. In 2004, 118 first through third order streams on the Seward Peninsula were sampled for fish and preliminary results were provided by Weidmer (2011). Another project was conducted in 2009 across a range of tributary sizes on the Lower Yukon River, although the fish communities and environmental data are described separately for small, medium, and large streams with catchment areas draining <100, 100-500, and >500 km^2, respectively (Buckwalter et al. 2010).

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. Generally, several studies have shown that physical and chemical variables and associated fish communities in low order streams are strongly related to stream gradient and elevation (Bryant et al. 2004, Walker et al. 2006). 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.

Headwater streams provide important spawning and rearing habitat for several of the resident and anadromous fish CEs: 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 high gradient habitats (Bryant et al. 2004, Walker et al. 2006). 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).

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 have been shown to 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 ecosystems may be more vulnerable to development as a change agent than other aquatic habitats due to their density across the landscape and the use of culverts as opposed to bridges for road crossings. Culverts have a higher likelihood of failing to allow adequate passage for fish, high flows, and sediments or 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).

In addition to roads, mining can also negatively affect headwater 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). 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.

The predicted changes of climate in the REA study area include increased precipitation, increased temperatures, decreases in the winter snowpack, earlier spring snowmelt, longer growing season, increased evapotranspiration, decreased permafrost extent, increased active layer thickness, and earlier ice breakup and later freeze-up (Loya 2011, Schindler and Rogers 2009). Climate change may increase the extent of headwater 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.).

Wildfire can impact aquatic systems in many ways including, but not limited to, increased sedimentation due to vegetation removal and higher peak flows due to lower evapotranspiration also from loss of vegetation (Rieman and Clayton 1997). Wildfires also have the potential to increase permafrost melting and 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).

The impacts of invasive species on aquatic systems, such as headwater streams, include displacement of native aquatic fauna and alteration of stream food webs (McClory and Gotthardt 2008). No aquatic invasive species have been reported in the REA study area.

Ecological Status Indicators

In this section we characterize the primary change agents for which data is available and current knowledge of their effects on the aquatic CEs. Effects are characterized according to the key ecological attributes of the aquatic resources in the study area, which include connectivity, surrounding land use, surface hydrology, water quality, and aquatic biota condition. There is very limited data available that can be used to indicate the status of the key ecological attributes, therefore not all attributes currently have indicators. A scoring system for each indicator is presented below and used to describe the status of the CEs within each 5th level HUC as sustainable, transitioning, or degraded. For indicators that do not scale from 0 to 1, the index values for each category are as follows: 0.9 for sustainable, 0.65 for transitioning, and 0.25 for degraded. Due to the lack of information identifying aquatic threshold responses in the study area for the indicators (e.g. no water quality data exists to correlate the number of APDES permits that will affect aquatic biota), the thresholds between categories will be based on published literature from other areas or best professional judgment and presented to the assessment management team for review and rescaling as needed. Draft thresholds are presented in the scorecard below (Table 9).

1. **Key Ecological Attribute: Connectivity –** Changes in stream connectivity affect the flow of animals, materials, and nutrients with larger, longer corridors providing greater extent of habitat for wildlife and increased buffering capacity to the aquatic resource.
    a. Indicator: Dendritic Connectivity Index (DCI) – The DCI is a tool developed to quantify the longitudinal connectivity in stream networks with passage barriers and is based on the passability of barriers and the length of the stream network (Cote et al. 2009). The ADF&G Fish Passage Inventory Database will be used to identify the location and passability of culverts on the Nome road system. The ~230 miles of roads surrounding Nome comprise the only road network in the REA study area. Culverts were ranked into three categories: blocking fish passage, allowing passage during limited flow regimes, and allowing passage during all flow regimes for the model fish, a 55 mm Coho salmon. The DCI will be calculated separately for the anadromous and resident life history strategies for each watershed with culverts. The DCI is scaled from 0-1 and will be averaged for the two life history strategies to generate the score for a 5th level HUC. The current threshold values separating degraded, transitioning, and sustainable are preliminary and may require revision.
2. **Key Ecological Attribute: Surrounding Land Use Context** – land use in the watershed, even when far removed from the stream, can alter the hydrologic regime and impact water quality through changes in substrate and non-point source discharges on the landscape.
    a. Indicator: Landscape Condition Model (LCM) – The LCM aggregates the effects of development and land management activities in the REA study area to create a map surface of index scores at 30 m pixel resolution. The index ranges from 0 to 1 with 1 indicating a pristine landscape condition. The datasets and methods used to create the LCM index are described in detail in Appendix IV. The distribution for each aquatic CE within a 5th level HUC will be intersected with the LCM map surface and averaged to indicate the ecological status in the watershed.
    b. Indicator: Non-native species – The existence of non-native plant species in the riparian zone of streams can affect the quality and quantity of allochthonous inputs to stream food webs. This indicator is based on the methods developed for terrestrial coarse filters except that it is limited to a 500 m buffer zone around the aquatic coarse filter (hot spring, lake, or stream). Invasive species have been ranked on a scale of 0-100 based on their invasiveness in Alaska and highly invasive species (ranking > 70) are treated differently in the scorecard than less invasive species.
    c. Indicator: Placer Mining Ditches – the NHD flow line feature class includes locations of ditches from historic placer mining activity on the Seward Peninsula. The length of placer mining ditches will be calculated for each watershed and reported as a percentage of the total stream network for that watershed. The resulting index of ditching intensity will range from 0 – 1, but will likely span a smaller distribution (~ < 50%) and thresholds for the degraded, transitioning, and sustainable categories will be scaled accordingly.
3. **Key Ecological Attribute: Surface Hydrology** — The surface hydrologic regime of stream ecosystems is often termed a "master variable" that shapes the biological conditions within the stream. Flow conditions – including their magnitude, timing, and duration – create a range of habitat opportunities, disturbances, and constraints that

determine what organisms can persist within a stream ecosystem. The integrity of stream flow regimes is assessed conventionally using stream gage data, comparing current conditions to historic or modeled reference conditions. Unfortunately, stream gage data are not available for this ecoregion. StreamStats is a tool developed by the USGS that makes stream flow statistics for both gaged and ungaged sites easily accessible. It is currently under development for the Cook Inlet Basin and expected to be completed in 2013 whereupon it may be expanded to other areas of the state. Due to very limited development in the REA study area, it is expected that the natural hydrologic flow regime remains intact for the aquatic coarse-filter CEs. Future changes in hydrologic flow regimes based on climate change will be described in conceptual models for the coarse filter CEs.

4. **Key Ecological Attribute: Water Quality** – The natural water chemistry of the aquatic resources affects the diversity of organisms and life history stages that can utilize a given habitat. Water quality can be affected by discharges both within the watershed and also wet and dry deposition of contaminants carried over long distances. Water quality data exhibits substantial variation both seasonally and inter-annually, similar to hydrologic data, and requires long-term sampling to accurately identify the baseline conditions. No long-term data exist for the aquatic resources in the study area.
    a. Indicator: State Impaired Waters – The Alaska Department of Environmental Conservation (ADEC) publishes a list that categorizes waters as impaired relative to their "designated uses" due to individual water quality properties. The state listings register the effects of degraded water quality due to altered turbidity, altered temperature, and a wide range of chemical contaminants. Impaired waters are placed in two categories based on the intensity of the impairment: Category 4 water bodies do not require a Total Maximum Daily Load (TMDL) because one has already been developed, other pollution controls are in place, or the impairment is not caused by a pollutant; Category 5 waters are impaired and require development of a TMDL or recovery plan.
    b. Indicator: Alaska Pollution Discharge Elimination System Permits – APDES permits are issued for wastewater discharges into water bodies. Limits are set on the amount and types of pollutants allowed to protect water quality. The number of APDES permits within a watershed will be used to indicate discharges that may have effects on the aquatic biota.
5. **Key Ecological Attribute: Aquatic Biotic Condition –** This key ecological attribute focuses on the integrity of the faunal community within the water – a critical biological condition. Reference conditions have not been established for aquatic biological communities in the REA study area, although many streams have been sampled for fish community composition and may provide a baseline for future comparisons should development occur in these watersheds and post-development sampling is conducted. We have found no data describing other aquatic biota in the REA study area, such as macro-invertebrates or algae.

Table 9. Draft Aquatic CE ecological status scorecard.
This scorecard will be used for both coarse-filter and fine-filter CEs and adapted as necessary.

Key Ecological Attribute and Indicators	Definition and Measurement	Sustainable (0.9)	Transitioning (0.65)	Degraded (0.25)
Dendritic Connectivity Index	Measurement of network connectivity based on number of barriers and passability.	> 0.8	0.5 – 0.8	< 0.5
Landscape Condition Model Index	The LCM includes effects from development and land management activities. (See Appendix IV for a detailed description).	> 0.8	0.5 – 0.8	< 0.5
Non-Native Species	The number of infestations within a 500 m buffer around coarse filter CEs.	No infestations	1-25 infestations for species with ranking < 70	> 25 infestations for species with ranking < 70 or ≥ 1 infestation for species with ranking > 70
Place Mining Ditches	The length of placer mining ditches as a proportion of the entire stream network within a 5th level HUC.	< 5%	5 – 30%	> 30%
Stream Other Water Quality Conditions: State-Listed Water Quality	Measures the integrity of water quality conditions in individual water bodies based on the presence and severity of state listings of	None	1 – 2 Category 4 water bodies	> 2 Category 4 or ≥ 1 Category 5 water bodies

Key Ecological Attribute and Indicators	Definition and Measurement	Sustainable (0.9)	Transitioning (0.65)	Degraded (0.25)
Impairment	water quality impairments for State 303(d) reporting requirements under the federal Clean Water Act.			
Alaska Pollution Discharge Elimination System Permits	Density of permitted and legacy point discharges within 5th level HUCs. From Alaska and EPA permit databases.	None	1 – 2	> 2
Fish Stock of Concern	Based on ADF&G management, commercial, subsistence, and sport fish stocks may be categorized as a yield, management, or conservation concern.	None	1 – 2 of yield concern	> 2 of yield concern of ≥ 1 of management concern

Sum the indicator scores and divide by number of indicators to calculate ecological status for each CE. Degraded watersheds have ecological status scores less than 0.5, transitioning watersheds have scores between 0.5 and 0.8, and sustainable watersheds have scores greater than 0.8.

Aquatic Landscape Species CE Example: Coho Salmon

Conservation Element Characterization

Coho salmon are distributed throughout the southern half of the REA study area. The northern part of the study area represents the northern extent of their range and they are found in the Buckland, Koyukuk, and Noatak rivers. The Wulik and Kivalina rivers and Kuchiak Creek are the only water bodies that support Coho salmon north of the REA study area. Coho salmon escapements are monitored for the commercial fishery using counting towers or weirs on several rivers of Norton Sound: North, Kwiniuk, Niukluk, Nome, and Snake rivers. Other rivers are monitored by aerial surveys, although no counts are conducted in the Port Clarence or Kotzebue Sound districts (Menard et al. 2010). Spawning habitat for Coho salmon identified in the Anadromous Waters Catalog is located in watersheds of the Archuelinguk, Andreafsky, Bonasila, Beaver, Yellow, Anvik, North, Unalakleet, Inglutalik, Tubutulik, Niukluk, Kuzitrin, Solomon, Eldorado, Flambeau, Nome, Snake, Penny, Cripple, Sinuk, Agiapuk, and American rivers (Johnson and Blanche 2010).

Coho salmon spawn in small streams of moderate gradient and spend 1 to 2 years rearing in freshwater before migrating to sea, where they spend one full year before returning to spawn (Quinn 2005). Coho rearing habitat ranges from mainstream rivers to small headwater streams and may be one of the CEs most affected by development blocking access to upstream habitat as their abundance has been linked to the quantity and quality of freshwater habitat available to them (Nemeth et al. 2009). Studies specifically focusing on Coho salmon in the REA study area include estimates of abundance and spawning distribution on the Unalakleet River (Joy and Reed 2007) and the development of a habitat based escapement goal for Coho on the Nome and North rivers (Nemeth et al. 2009).

As described under the conceptual model for headwater streams, wildfire can impact aquatic ecosystems by increasing sedimentation and peak flows due to vegetation loss (Rieman and Clayton 1997). In Interior Alaska, stream nitrate and primary production increased post-fire, while dissolved organic carbon and dissolved organic nitrogen decreased (Betts and Jones 2006). In eastern Oregon, fish distributions were observed prior to and several years following a large and intense wildfire and subsequent flooding and landslides. Both steelhead and rainbow trout had returned to their original distributions after four years indicating a high resiliency to this change agent (Howell 2006). Changes in riparian vegetation cover, stream nutrients, sedimentation, and discharge have the potential to impact Coho salmon habitat and food availability post-fire.

The predicted changes of climate in the REA study area include increased precipitation, increased temperatures, decreases in the winter snowpack, increased river discharge, earlier spring snowmelt, increased growing season length, increased evapotranspiration, and earlier ice breakup and later freeze-up (Loya 2011, Schindler and Rogers 2009). Coho salmon abundances are expected to increase in northern latitudes due to increasing temperatures, which will extend the growing season and increase juvenile growth and survival (Schindler and Rogers 2009). In addition, increased precipitation has the potential to increase habitat availability for Coho salmon in small streams and wetlands that are utilized for rearing habitat.

Ecological Status Assessment Indicators

The indictors used in the ecological status assessment for coarse filters will also be used for the fish species. All of these indicators affect habitat conditions, which will also affect the fish populations utilizing those habitats. An additional indicator for fine filter CEs is included under the aquatic biotic condition attribute.

Key Ecological Attribute: Aquatic Biotic Condition – This key ecological attribute focuses on the integrity of the faunal community within the water – a critical biological condition.

a. Indicator: Sport, Commercial, or Subsistence Stock Status – Many of the fine-filter CEs are harvested by sport, commercial, or subsistence users. Some salmon stocks within a watershed have been identified by ADF&G as stocks of concern for yield, management, or conservation (Sustainable Salmon Fisheries Policy, 5 AAC 39.222). Yield concern is the inability to maintain harvestable surpluses above the escapement goal; management concern is the inability to maintain the sustainable, biological, or optimal escapement goal; and conservation concern is inability to maintain the sustained escapement threshold. Several of the Norton Sound subdistricts list chum and Chinook as stocks of yield concern (Menard et al. 2010).

Ecological Integrity Roll-up

BLM has established a desire to report on overall ecological integrity by 5th level watershed. While specific methods for this measurement remain in development, we propose to provide ecological integrity scores for each 5th level watershed based upon the ecological status scores for CEs occurring within each watershed. For example, there may be one overall terrestrial coarse-filter CE status score, based on the summed per-pixel value of the landscape condition layer overlain on their combined distribution. Separately, there could be an overall score for 2-3 aquatic coarse filter CEs within the watershed, with their composite score based upon the relative proportional contribution of each aquatic CE in that watershed. Finally, a landscape species score might be derived from the component status scores of the several species with distributions in the watershed, proportionally calculated. During task 6, options for roll-up will be further explored and determined through analysis demonstration and consultation with BLM leadership and the AMT.

Change Agents (CA) Distributions and Effects Models

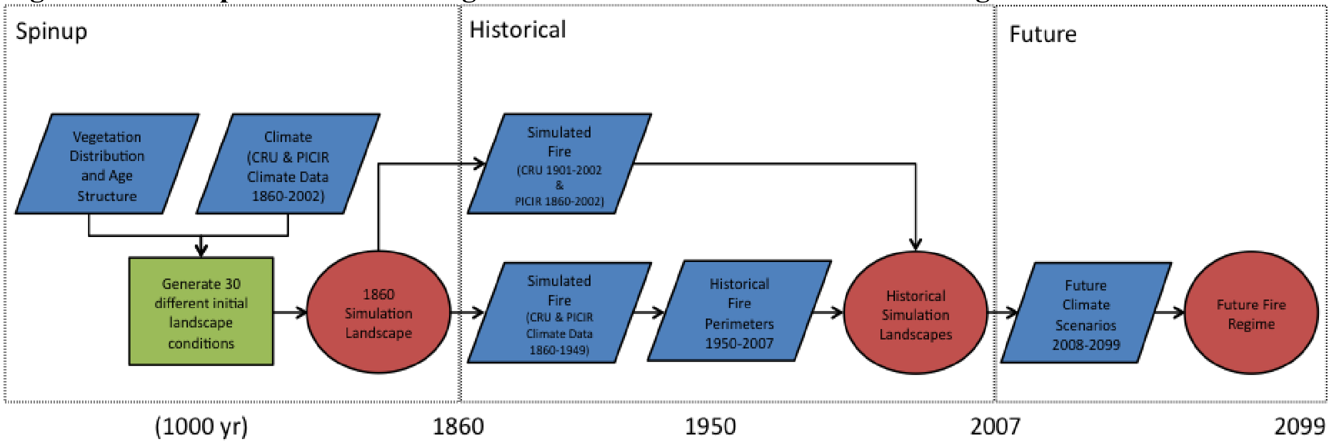
CA Class I: Wildfire

To assess the impact of wildfire as a change agent, we will utilize the Boreal Alaska Frame-Based Ecosystem Code (ALFRESCO) model (Figure 18). Boreal ALFRESCO simulates the responses of subarctic and boreal vegetation to transient climatic changes. The model assumptions reflect the hypothesis that fire regime and climate are the primary drivers of landscape-level changes in the distribution of vegetation in the circumpolar arctic/boreal zone. Furthermore, it assumes that vegetation composition and continuity serve as a major determinant of large, landscape-level fires. ALFRESCO operates on an annual time step, in a landscape composed of 1 x 1 km pixels, a scale appropriate for interfacing with meso-scale climate models. The model simulates four major subarctic/boreal ecosystem types: upland tundra, black spruce forest, white spruce forest, and deciduous forest. These ecosystem types represent a generalized classification of the complex vegetation mosaic characteristic of the circumpolar arctic and boreal zones of Alaska.

Inputs:

Input parameters to Boreal ALFRESCO are spatial datasets of historical and simulated fire perimeters and burn severity, vegetation, stand age, canopy cover and topography. Climate forcing data from the Scenarios Network for Alaska Planning (SNAP) are used to drive the model.

Figure 18. Conceptual model showing the Boreal ALFRESCO simulation design.



Analytic process and tools:

Boreal ALFRESCO is a state-and-transition model of successional dynamics that explicitly represents the spatial processes of fire and vegetation recruitment across the landscape (Rupp et al. 2000*a*). ALFRESCO does not model fire behavior, but rather models the empirical relationship between growing-season 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 (Chapin et al. 2003).

The fire regime is simulated stochastically and is driven by climate, vegetation type, and time since last fire (Rupp et al. 2000a, 2007). Boreal ALFRESCO employs a cellular automaton approach, where an ignited pixel may spread to any of the eight surrounding pixels. "Ignition" of a pixel is determined using a random number generator and as a function of the flammability value of that pixel. Fire "spread" depends on the flammability of the receptor pixel and any effects of natural firebreaks including non-vegetated mountain slopes and large water bodies, which do not burn.

The ecosystem types modeled were chosen as the simplest possible representation of the complex vegetation mosaic occupying the circumpolar arctic and boreal zones and ignore the substantial variation in species composition within these and other intermediate vegetation types. Detailed descriptions of the vegetation states and classification methodology can be found in Rupp et al. (2000a, 2000b, 2001, 2002). The vegetation data used in the model spinup process was derived by reclassifying the 1990 AVHRR vegetation classification (http://agdcftp1.wr.usgs.gov/pub/projects/fhm/vegcls.tar.gz) and the 2001 National Land Cover Database vegetation classification (http://www.mrlc.gov) into the four vegetation classes represented in ALFRESCO (tundra, black spruce, white spruce, deciduous). Differences among tundra vegetation types recognized in the vegetation classifications were ignored, and all tundra types were lumped together as a single tundra class. Tundra types that identified some level of spruce canopy on site were indicated. The actual spruce-canopy level was determined using growing-season climate thresholds.

Remotely sensed satellite data is currently unable to distinguish species-level differences between black and white spruce. We therefore stratified spruce forest using deterministic rules related to topography (i.e., aspect, slope position, and elevation) and growing-season climate. Aspect and slope were used to identify "typical" black spruce forest sites (i.e., poorly drained and northerly aspects) throughout the study region. Growing-season climate and elevation were used primarily to distinguish tree line white spruce forest. In addition, we used growing-season climate thresholds to distinguish young deciduous forest stands from tall shrub tundra. These deterministic rules were also used to denote the climax vegetation state (i.e., black or white spruce forest) for each deciduous pixel. In other words, the rules were used to predetermine the successional trajectory of each deciduous pixel. In this manner, we were able to develop an input vegetation data set that best related the original remotely sensed data into the four vegetation types represented by Boreal ALFRESCO, based on a sensible ecological foundation.

Outputs:

The primary outputs from Boreal ALFRESCO are spatial and tabular estimates of: 1) percent area burned, 2) percent area re-burned, 3) fire return interval (years) and 4) vegetation composition (none, tundra, black spruce, white spruce, deciduous). For the REA, we will report current conditions and those projected for 15 (2020s) and 50 years (2060s) into the future. The reporting unit for these outputs will be at the level of the ecoregion. We provide a sample output from a single replicate of a statewide run of ALFRESCO for western Alaska showing temporal changes in the spatial distribution of vegetation (Figure 19) and a table showing the fire history for the three main ecoregions of the REA (Table 10).

Figure 19. ALFRESCO output showing potential temporal changes in the distribution of vegetation in western Alaska.

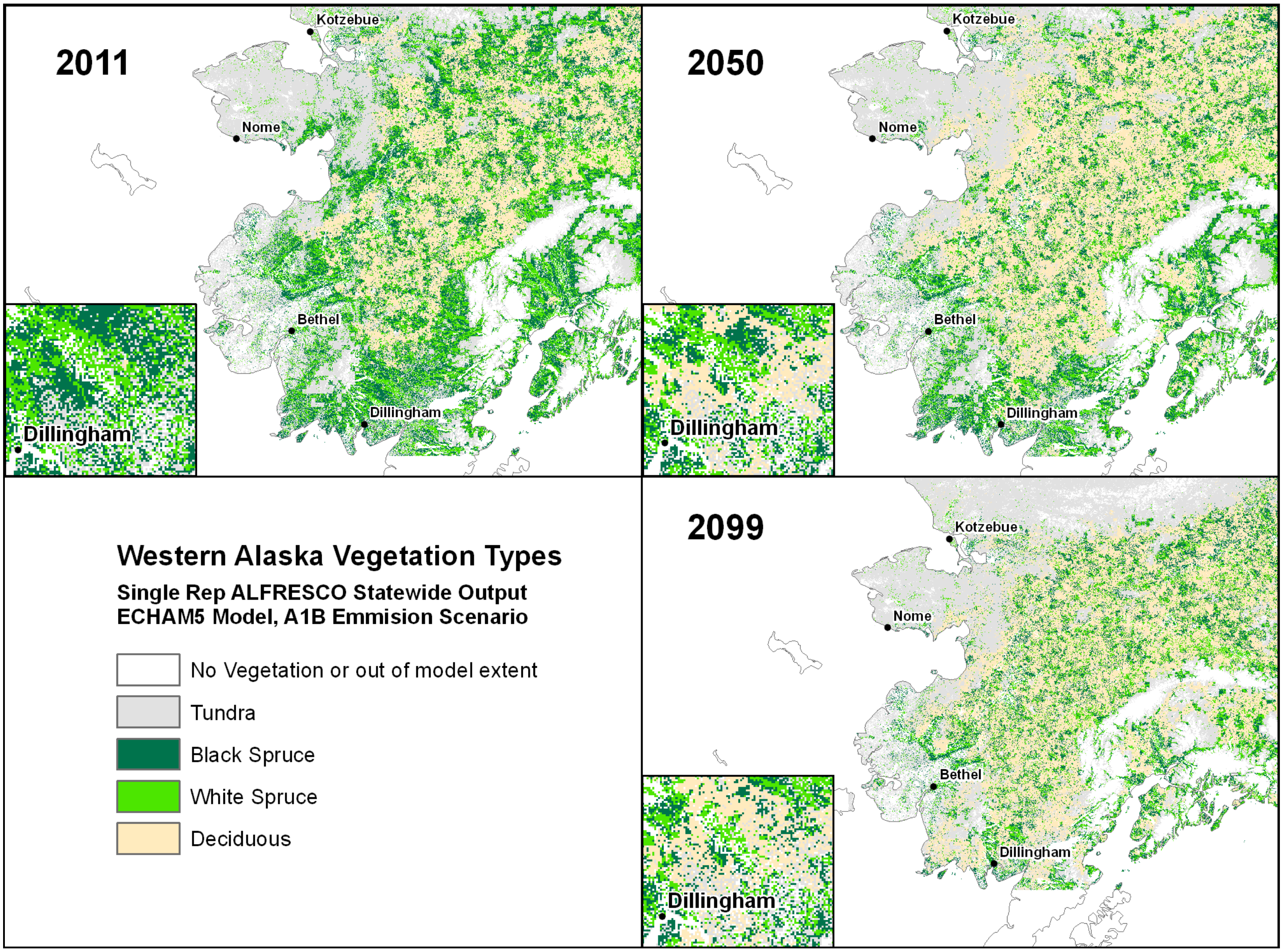


Table 10. Fire history (1950-2007) for the three main ecoregions of the REA.
(Data are from Joly et al. 2008)

Ecoregion	% Area Burned	% Area Re-burned	Fire Cycle (years)
Kotzebue Lowlands	6.8	15.1	859
Seward Peninsula	13.9	2.0	418
Nulato Hills	20.5	8.6	283

CA Class II: Anthropogenic Activities

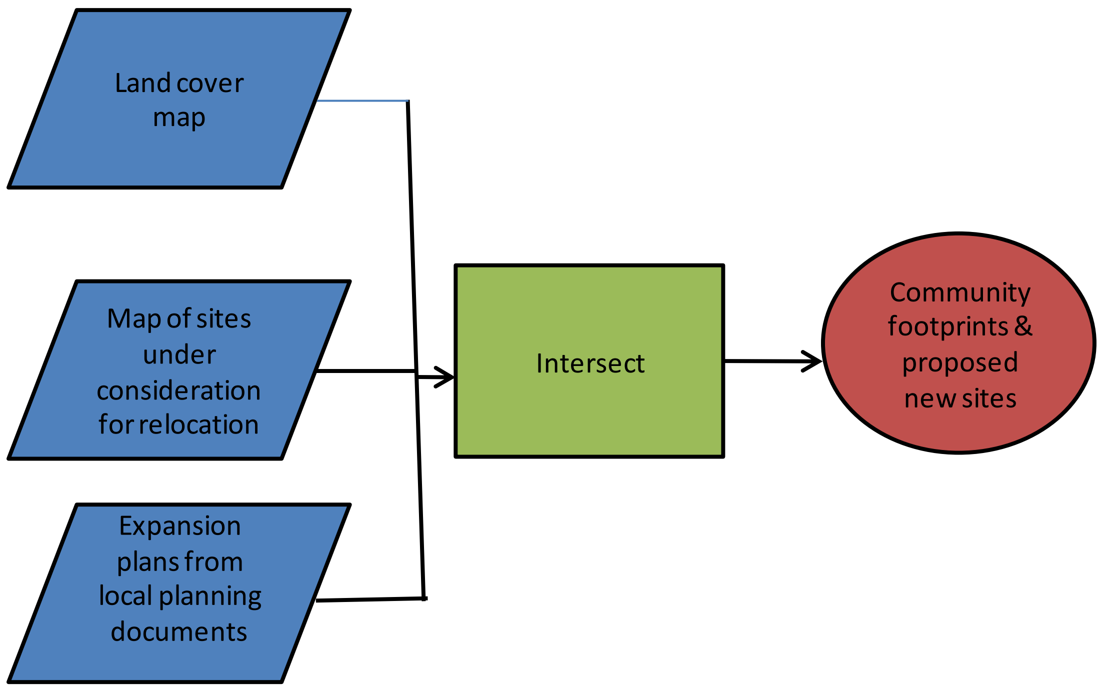
In this section we present models to generate development CAs for the current or 2025 scenarios. CAs are described in detail in Memorandum 1.2.c. Major effects of development and management actions may be summarized in the Landscape Condition Model (LCM) using the approach developed by NatureServe (Appendix IV). The LCM is composed of the GIS spatial layers of transportation, urban and industrial development, and managed and modified land cover layers. Each input layer is given a relative weighting for its relative impact at its precise location, and with distance away from its location. A composite scoring and map surface (at 30-90m spatial resolution) result from combining all input layers. The results are an index of landscape condition from 0.0 to 1.0 with 1.0 being very high landscape condition (apparently unaltered natural conditions) and 0.0 having extremely altered condition (e.g., dense urban areas).

We recommend developing one or more versions of the LCM for this REA, depending on the relative sensitivities of applicable CEs, and available data to reflect those sensitivities. In comparison to the lower 48 USA model (Appendix IV), we anticipate including regionally-specific data layers, such as those depicting reindeer grazing, remote recreation areas, alternative energy development, mining sites, contamination sites, trails and ice roads, low density development, and seasonal, gravel roads.

Community Development

We will include maps of existing communities and modify them to estimate what communities will look like in the future. The population of communities ranges from about 200 to 3,500. Population growth has been very low; in some places the population is decreasing. We will also include information from local municipal plans.

Figure 20. Concept diagram for modeling current and future communities.



Oil and Gas Development

We will include maps of areas with oil and gas potential. Offshore oil development in the Chukchi Sea is north of the study region. Estimates are that employment and infrastructure impacts will be in the North Slope borough (Northern Economics 2009).

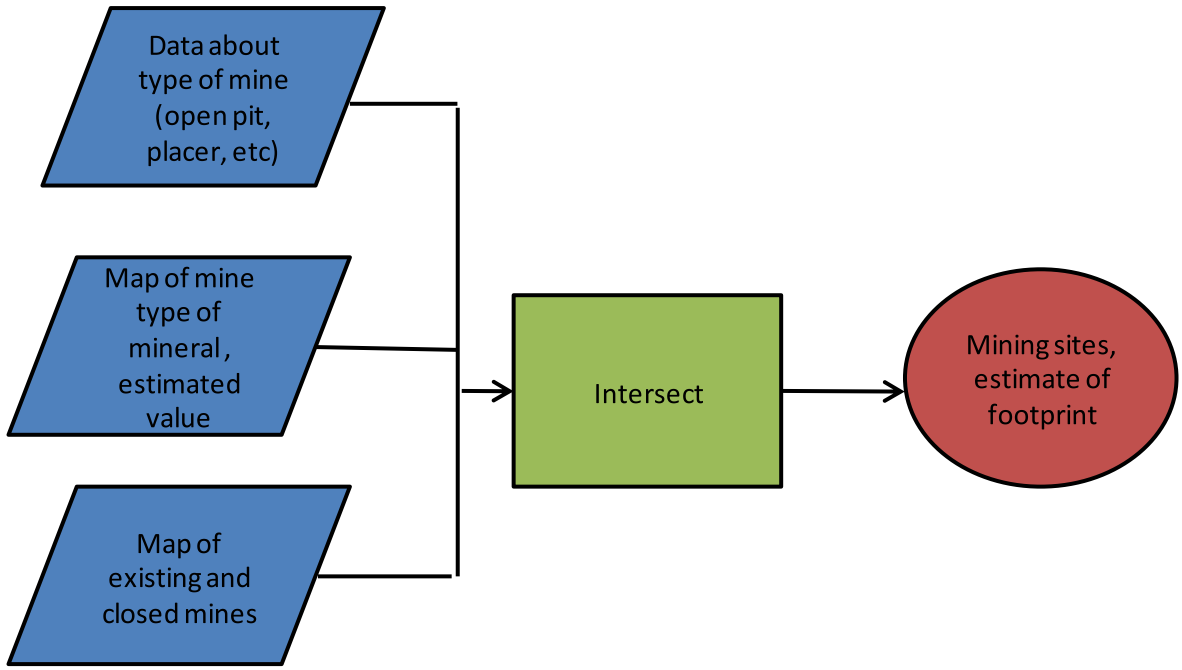
Alternative Energy Development

We will use maps of existing and planned alternative energy sites (AEA/ISER 2011). There are currently several wind generation sites in the region. Additional alternative energy sites are being developed. Most are wind generation. Wind powers lowers the amount of diesel fuel used to generate electricity and slows the increase in fuel costs. Outputs from this model will show that energy development is small-scale compared to other parts of the US, and will provide inputs to subsistence model.

Mining

Existing mines within the region are Rock Creek, which is currently inactive, and placer mines on the Seward Peninsula. The Red Dog zinc mine is adjacent to the region. We will use existing studies of the effects of placer mines on the environment and information about rehabilitation to further characterize mine sites. Large areas in the northern part of the SNK have been identified as having potential for mineral development. This model also converts point data to an estimate of the footprint of mine sites.

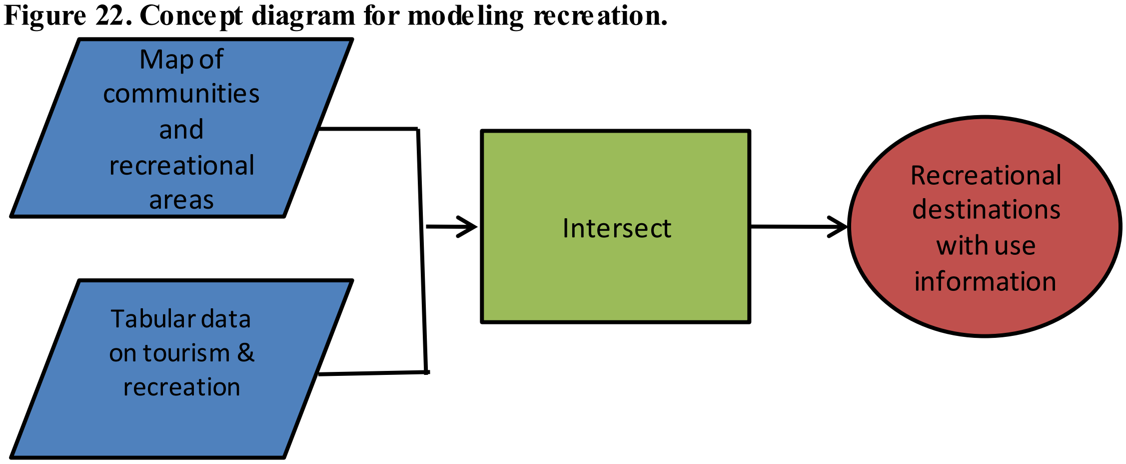
Figure 21. Concept diagram for modeling mining sites using information about footprint, ecological impact, and restoration efforts.



Recreation

Recreational use of the region is very small and seasonal. We will overlay existing visitor data with destination areas. Even though the numbers are small, local subsistence hunters report conflicts with sport hunters. We will identify areas where hunter use conflicts have been reported, using reports to ADFG, and comparison of subsistence moose and caribou harvests to harvests by other hunters

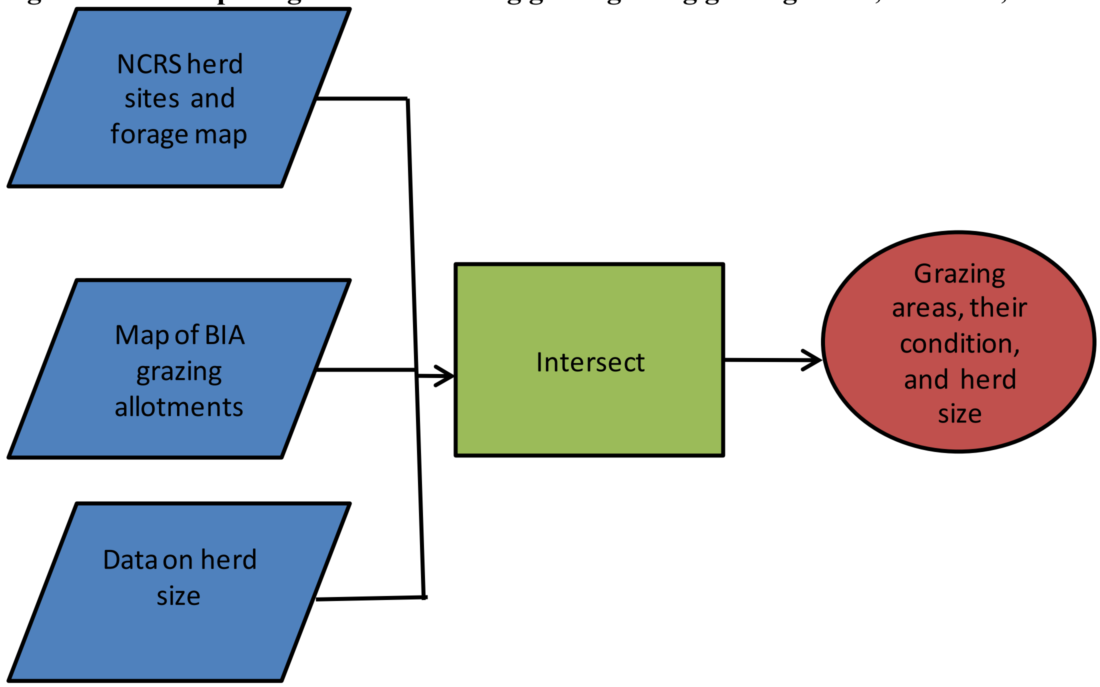
Figure 22. Concept diagram for modeling recreation.



Grazing

We will combine maps of grazing areas, herd size and forage to estimate baseline grazing conditions. Local knowledge helps estimate future impacts on vegetation. The Western Arctic Caribou Herd (WACH) has increased from 75,000 in the mid 1970s to over 450,000 and the herd is expanding its range on the Seward Peninsula. In the 1990s, over 17,000 reindeer left with migrating caribou (Rattenbury et al. 2009). Local herders have been trying to develop ways to keep their animals. According to Finstead (2007), supplemental feeding in pens has helped herders to retain their herds. Supplemental feeding and less use of grazing areas would lessen the impact of reindeer on the landscape.

Figure 23. Concept diagram for modeling grazing using grazing areas, herd size, and forage condition.



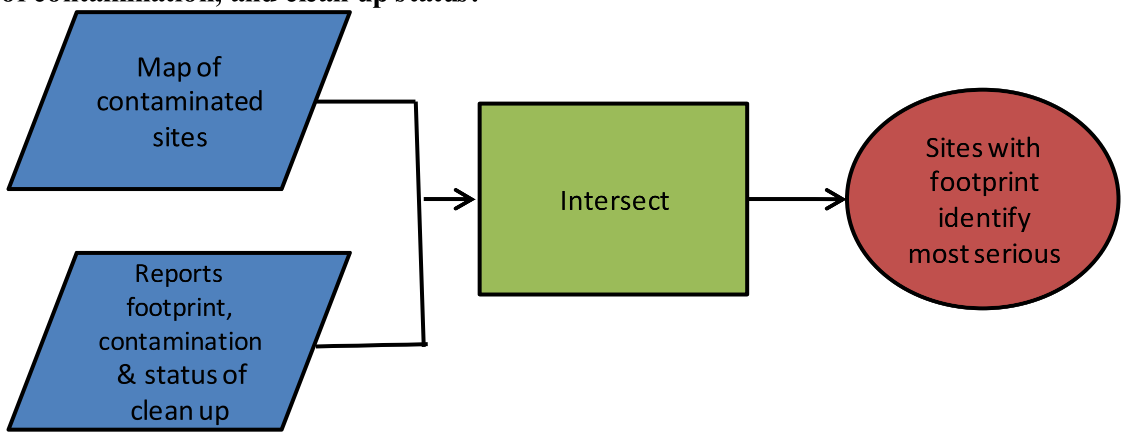
Military Sites

We will include a map of current and former military sites. The Stewart River Training Area is about 25,000 acres and it used by military, and for subsistence. The deactivated White Alice radio communication sites in the region are included on the Alaska Department of Environmental Conservation (DEC) map of contaminated sites because of leaking storage tanks.

Contaminated Sites

Maps from DEC provide point data for contaminated sites. We will combine information from the DEC database and review reports to include estimates of the size, type of contamination, and clean up status for each site. This model will estimate footprints from point data.

Figure 24. Concept diagram for modeling contaminated sites using information about size of site, type and extent of contamination, and clean up status.



CA Class IIIa: Non-Native Species

Throughout their global range, Norway rats are more common in cold climates and occur in northern latitudes with similar climatic zones to those found in Alaska. Although apparently limited in distribution in western Alaska, the invasiveness potential of this species in Alaska is considered extremely high (Walton and Gotthardt, in prep.). Norway rats are responsible for reductions in biodiversity of insular avifauna, and are exceptional nest predators. Numerous seabird colonies are located along the Seward Peninsula coast. If rats become invasive in these areas, it could be catastrophic to seabird populations, particularly during the nesting season when birds are especially vulnerable. Additionally, Norway rats provide supplemental prey to introduced foxes, which also prey on native bird species. The impacts of a rat invasion are far reaching and may also indirectly impact marine intertidal communities by reducing densities of intertidal foraging birds, which in turn may cause intertidal communities to shift from algae to invertebrate dominated because marine herbivores are released from predation.

A total of 26 non-native plant species are documented with occurrences within the defined boundary of the ecoregion (Table 11). The number of weed infestations is documented at 279, all of which appear to be associated with human disturbance (AKEPIC 2010). The non-native species present are generally classified as having weak to moderate impacts on the natural ecology of the region (see Carlson et al. 2008). These species are all extremely widespread throughout Alaska.

Highly invasive non-native plants are however known from outside the REA study area. These species may have the capacity to significantly affect ecosystems in the SNK area if they become established. Second, many of these species are currently uncommon in Alaska and therefore control efforts are much more likely to be effective than for common weeds. *Cirsium arvensis*, *Hieracium aurantiacum*, *Melilotus alba*, and *Phalaris arundinacea* are four highly invasive species (invasiveness ranks: 76-83) that have been increasingly found in natural areas that could potentially establish in the REA. For example, a *M. alba* population is known from Galena on the Yukon River just outside the REA boundary – this species is expanding rapidly on floodplains across Alaska and water dispersal is believed to be one of the primary modes of seed movement (Conn et al. 2007). Ecological impacts of this species in Alaska include suppression of early successional plants, including willows (Spellman and Wurtz 2010), alteration of soil nutrients (Sparrow et al. 1995, Rzeczycki unpub. data), and pollinator communities (Schneller and Carlson 2011).

The abundance and distribution of non-native plants in Alaska is changing rapidly (Carlson and Shephard 2007, Conn et al. 2008). Change in the range of any species is a function of spatial alteration of suitable habitat, dispersal potential to those habitats, and adaptation to new habitats. Climate is well accepted to be a major component in determining habitat suitability for invasive plants (see Broennimann et al. 2007) and is likely to interact directly on habitat suitability for example by increasing growing degree days or increasing available soil moisture through precipitation. Climate change is also expected to have indirect impacts on habitat suitability of non-native species by two mechanisms: alterations to disturbance regimes and alterations to antagonist and mutualist populations. Increases in fire frequency and extent are likely to elevate susceptibility of Alaskan habitats to non-native plants (Villano and Mulder 2008). Likewise, increases in temperature are likely to increase forest pest populations, such as spruce beetles (see Berg et al. 2006). Loss of dominant overstory vegetation and increased open ground is likely to facilitate non-native population establishment. Last, climate change may affect populations of competitors, herbivores, pollinators, etc., which is likely to influence population growth and establishment of non-native plant species. However, indirect effects are likely to be very important and beyond our predictive capacity.

Dispersal is one of the most important factors in determining species' distributions (Darwin 1859, Sax et al. 2007). Suitable habitat for non-native species may be present, but is unoccupied simply because propagules have not arrived. The pattern of non-native plant distributions in Alaska is closely associated with the density of people. In the mid 1900s non-native plant populations were first concentrated in the three largest cities (Anchorage, Fairbanks, and Juneau) and the agricultural research stations. Weed populations have spread from these foci along road corridors, where now more than 90% of all non-native plant infestations are associated with roads or trails (AKEPIC 2011). In recent years, increasing numbers of infestations are being recorded in natural areas adjacent to roads or trails. Thus, for most species in Alaska invasion appears to follow a rather predictable pattern of introduction to a human population center, followed by increase in size and spatial extent of populations along road systems, and last establishment into natural areas.

Table 11. Non-native plants, number of records, and invasiveness ranks for species found in the region. From AKEPIC 2010, Carlson et al. 2008

Species	Number of records	Invasiveness rank	Species	Number of records	Invasiveness rank
Bromus inermis	2	62	*Phleum pratense*	1	54
Capsella bursa-pastoris	3	40	*Plantago major*	29	44
Cerastium fontanum	1	36	*Poa annua*	3	41
Chenopodium album	28	37	*Poa pratensis*	4	52
Crepis tectorum	28	56	*Polygonum aviculare*	12	45
Descurainia sophia	1	41	*Rumex acetosella*	1	51
Elymus repens	1	50	*Rumex crispus*	1	48
Galeopsis bifida	4	50	*Senecio vulgaris*	1	36
Galeopsis tetrahit	2	50	*Stellaria media*	19	42
*Hordeum jubatum**	33	63	*Taraxacum officinale*	28	58
Hordeum vulgare	2	39	*Trifolium pratense*	2	53
Leucanthemum vulgare	3	61	*Trifolium repens*	14	59
Matricaria discoidea	31	32	*Tripleurospermum inodorum*	3	48

*The nativity of this species in Alaska is in question.

Since the presence of non-native species are good indicators of ecological condition or stress (see Lopez and Fennessy 2002, Magee et al. 2008, Magee et al. 2010, Mack and Kentula 2010), we use the number of known infestations of all non-native plants and highly invasive plants as a metric in the ecological integrity assessment for ecological systems. Second, to address MQs associated with the potential threats of highly invasive species we propose to use habitat suitability modeling for highly invasive plants that are currently not in the REA, but could potentially establish in the future (Figure 25). Areas with high current and potential future habitat suitability will be used to identify regions most susceptible to establishment by the invasive plants. CEs that are most likely to affected by the establishment of four non-native plant species (*Cirsium arvensis*, *Hieracium aurantiacum*, *Melilotus alba*, and *Phalaris arundinacea)* will be identified.

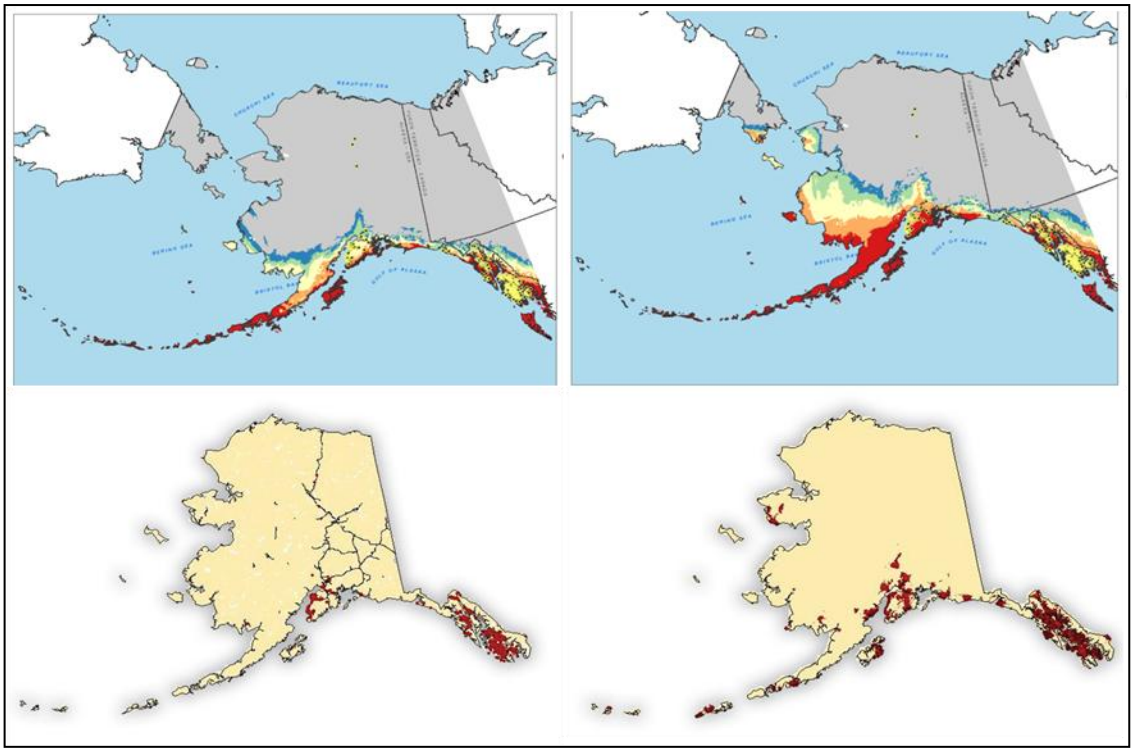
Inputs:

Invasive Plant Habitat Suitability –

Non-native plant location data will be derived from the statewide weed database (AKEPIC). All infestations are georeferenced and precision is 0-30 m for 85% of infestations. This resolution should be adequate for identifying potential overlap with CEs and for habitat suitability modeling.

To address the potential risk of current and future scenarios of invasive CAs we propose to first summarize the literature from previous modeling efforts in Alaska (Bella, 2009 and Murphy et al., 2010) and then supplement this information with habitat suitability modeling specific to the SNK ecoregion using updated species locations and finer scale climate layers for four highly invasive species: *Cirsium arvensis*, *Hieracium aurantiacum*, *Melilotus alba*, and *Phalaris arundinacea*, perceived to a major threat to the ecology of the region.

Figure 25. Current (left) and projected 2080-2099 (right) habitat suitability for *Phalaris arundinacea* from Bella (2009) and Murphy et al. (2010).
Panels above are from Bella (2009) and panels below are from Murphy et al. (2010). Both models indicate increasing habitat suitability in the REA.



Analytic process and tools:

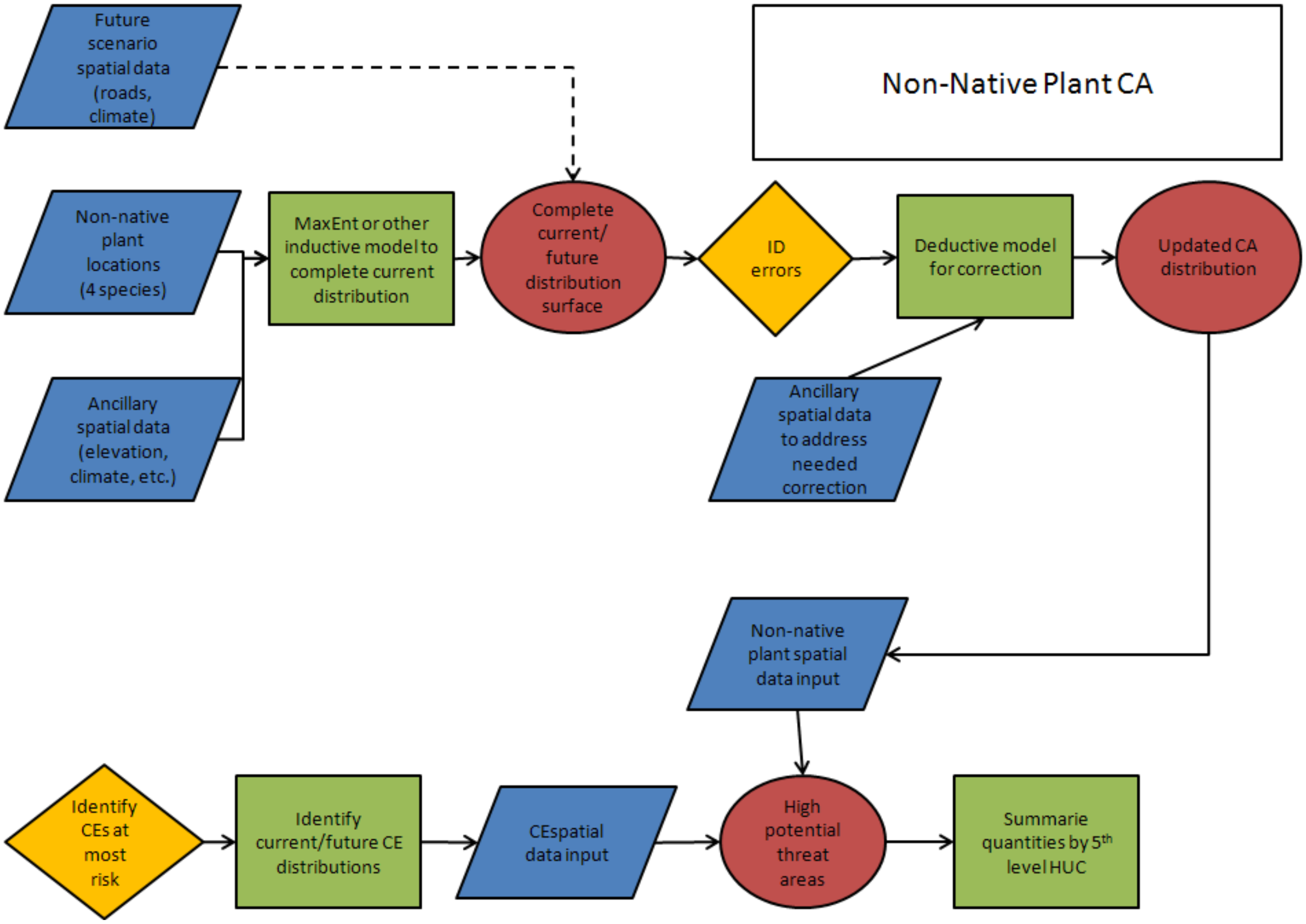
Both current distribution and potential future distribution of the four invasive plants will require the application of both inductive and deductive modeling methodologies. Each scenario will use the conceptual model described in Figure 26. We will develop probability risk models using inductive model methodology using, but not limited to, tools such as Maximum Entropy (MaxEnt; Phillips et al. 2006). The product of these types of models are defined as a 0-1 probability surface that may be defined with scenario specific threshold values that allow the user to either confine or expand the reflective risk profile of the CA.

The required basic data layer needed for addressing invasive plants is location data. Models will use the existing infestation locations (n = 301 *C. arvense*, n = 1,959 *H. aurantiacum*, n = 1,894 *M. alba*, n = 6,205 *P. arundinacea*) and ancillary data layers including elevation and landform, distance to roads, rivers and streams, and climate variables. While absence data is available, we do not recommend against their use, as we have hundreds to thousands of presence points for these species. The spatial predictor layers or "ancillary data" will include climate variables (from SNAP), DEMs, and potentially roads, streams and rivers, distance to coast, etc. Models will be applied to address future scenarios representing potential shifts in species range as they apply to both current and future distributions of predictor variables. By withholding a sub-sample of the existing infestation we will be able to estimate the accuracy and validity of the current distribution models.

Outputs: A spatial representation of current and future distributions of four species will be generated. Habitat suitabilities of these species will then be summarized by probability of occurrence at 5th level HUCs.

Issues: While predictive maps are a useful surrogate for large landscape the data poses a risk of misinterpretation when the analysis unit is too fine grained. Additionally, uneven distributions in available field samples may limit our ability to validate and assess the model in certain portions of the ecoregion.

Figure 26. Concept for modeling the distribution and effects of terrestrial CAs.



CA Class IIIb: Nuisance Native Species and Diseases

Insect and Disease Distribution

Insect and disease epidemics, both natural and introduced species, are often the result of human induced changes. For example, climate change has likely increased bark beetle epidemics in spruce. The USDA conducts annual forest damage surveys by flying—using fixed-wing aircraft—a predetermined route across Alaska's forests and recording insect damage within one mile on either side of the flight path. They draw polygons on a DEM and, for tree, willow and alder defoliators, record degree of damage in three categories of increasing intensity. For spruce bark beetle damage they record tree mortality. We will answer MQ 134 "Where have recent beetle outbreaks occurred?" using aerial surveys of disease and insect activity identified in the last decade (see Table 12 as an example from 2010 surveys). The USDA Forest Health is just now conducting studies to understand the relationship of these insects and diseases to their host species (John Lundquist pers. comm.) and adequate information is known for beetle infestations.

Table 12. The major insect and disease activity as detected during aerial surveys in Alaska, 2010. For defoliation species (i.e., birch, cottonwood and willow), significant contributors include sawflies, leaf miners, and leaf rollers for the respective host. Drought stress and unrecognized diseases may also cause reduced foliation or premature foliage loss.

Insect or Disease	Statewide Acres	Host
Alder canker	44,230	Alder
Aspen leaf miner	453,658	Aspen
Birch defoliation	33,290	Paper birch
Cottonwood defoliation	14,085	Balsam poplar, and Black cottonwood
Large Aspen tortrix	8,592	Aspen
Northern Spruce Engraver Beetle	21,600	Spruce
Spruce beetle	77,783	Spruce
Willow defoliation	562,675	Willow

CA Class IV: Climate Change

Climate Change Effects on Terrestrial Conservation Elements

Climate change is predicted to have a range of effects as a change agent on individual CEs, and these effects are likely to vary across the distribution of a given CE within the ecoregion. Here we propose several methods for gauging climate-change effects, both on terrestrial CEs and across the geography of each ecoregion. The specific aims of our approach are to: 1) assess the magnitude of climate change for a given CE or ecoregion, 2) analyze the spatial and temporal distribution of projected future climate change, 3) use a range of future climate scenarios in conducting #1 and #2 to understand the degree of certainty of projected changes across models, and 4) identify geographic areas within an ecoregion or within the distribution of a CE where there is high model agreement of levels of change. Where there is model agreement of significant levels of change, these are the most vulnerable areas. In contrast, where there is model agreement of little to no change, these are areas of relative climatic stability.

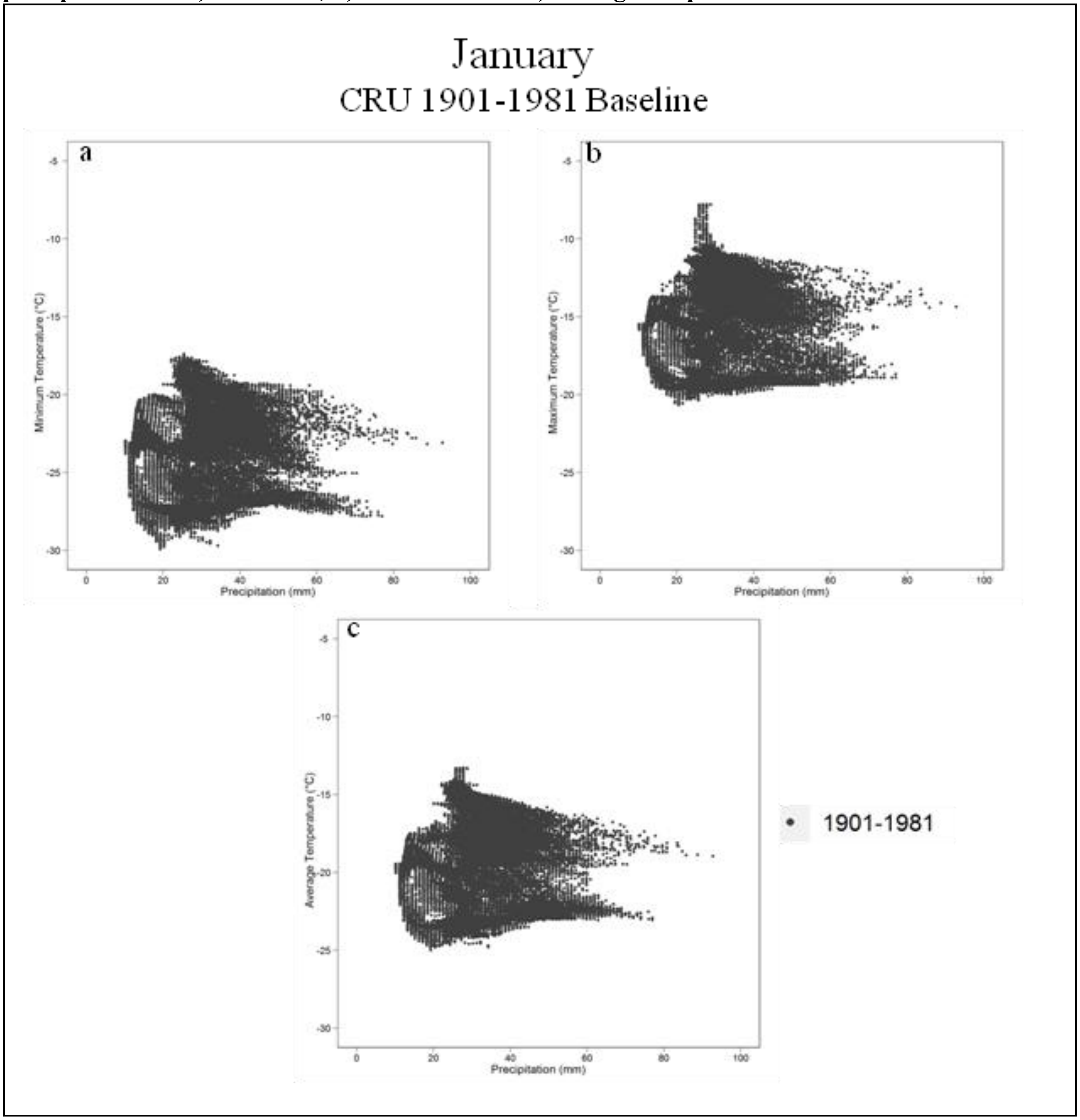
We next outline the primary steps and provide sample data outputs that we intend to produce for CEs within a given ecoregion.

Step 1. Establish historical bioclimatic envelope. This initial step establishes a baseline “climate space” across the spatial extent of an ecoregion or across the known distribution of a CE. Climate space can be defined as the range of values for primary climate data that occur across the spatial extent of the target. This is a necessary “back casting” step to establish a baseline from which to measure current trends in climate change, and future projections of potential change.

Data: CRU 2km, monthly maximum temperature, minimum temperature, precipitation; georeferenced sample locations of each CE from across the ecoregion (and beyond), or gridded shape file of ecoregion

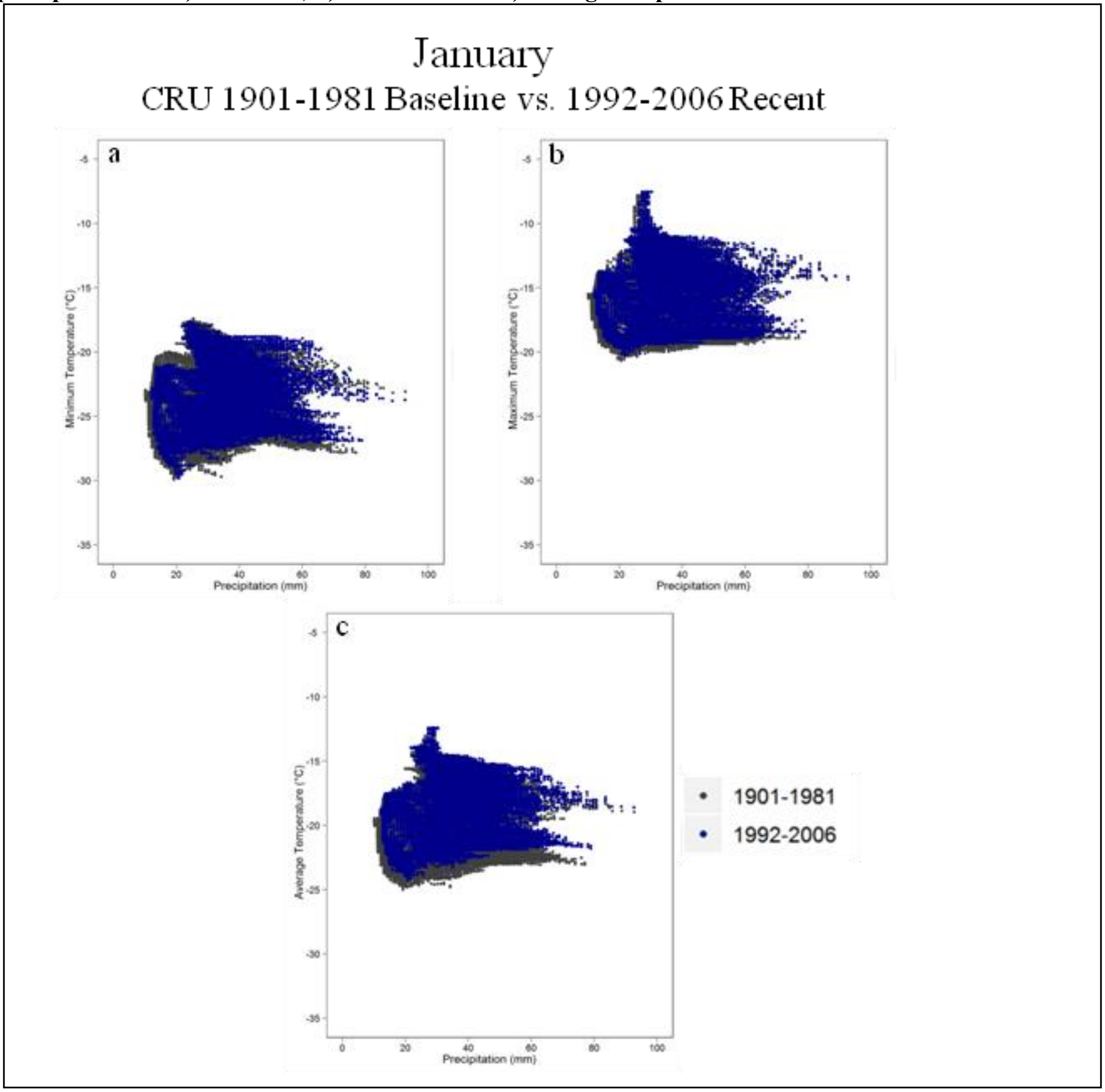
Methods: Using historical data derived from CRU (Climate Research Units) downscaled with PRISM to 2km data, we will use the 36 climate variables of monthly maximum temperature (°C), monthly minimum temperature (°C), and monthly total precipitation (mm) to build a queryable CRU database for spatial climate analyses. We will create a baseline climate data layer from 1901-1981, representing an 80-year record of average climate for each variable for each month, and the standard deviation for that month and variable over the same 80-year interval. For each 2km pixel within an ecoregion (Figure 27), or each 2km pixel that overlaps with the known distribution of a terrestrial CE, we will map climate space on graphs of monthly temperature vs. precipitation, their standard deviations, and annual averages.

Figure 27. Example of 20th century baseline climate envelope for January for the SNK ecoregion showing precipitation vs. a) minimum, b) maximum and c) average temperatures.



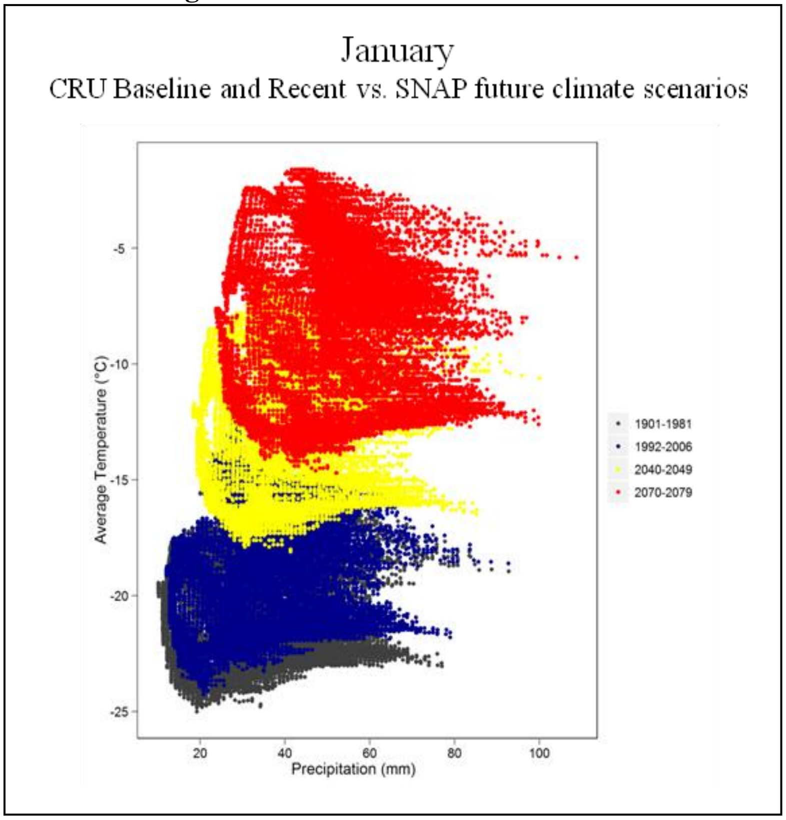
Step 2. Conduct CRU "departure" analysis for the current time period relative to 20th century baseline. From the CRU database, we will create a time series representing very recent climate trends, 1992-2006. When compared against the baseline, mapping recent climate space can reveal the magnitude and directionality of observed trends in climate space, that is, the climate change that is already occurring in this ecoregion and across the distributions of the CEs (Figure 28). To quantify how recent changes compare to baseline climates, and as one measure of significance, we will identify the extent of change that is ≥1 standard deviation from the mean of baseline climate. We can then project these statistically significant changes back onto geographic space, so that the specific locations of the greatest observed climate change can be identified.

Figure 28. Analyzing observed trends in current climate space for January within the SNK ecoregion including precipitation vs. a) minimum, b) maximum and c) average temperatures.



Step 3: Project future climate envelope. To explore climate change impacts to the ecoregion and CEs, we will use monthly climate variables derived from a 5-model ensemble of global circulation models run for the 4th Assessment Report of the IPCC. The SNAP Climate Projections are a 2km downscaled climate dataset created by the Scenarios Network for Alaska and Arctic Planning (SNAP) at the University of Alaska Fairbanks. The dataset provides decadal averages for each monthly variable: maximum temperature, minimum temperature, average temperature, and total precipitation. The modeled outputs from the 2020's and the 2050's will be used from the SNAP dataset. Future trends in climate space from this range of climate model outputs will be graphed for a qualitative understanding of the direction and magnitude of climate change (Figure 29). Agreement across many climate models for significant changes in climate space for a given ecoregion or CE indicates high vulnerability to climate change with relative certainty. Conversely, agreement across many climate models for non-significant changes in climate space indicates relative climate stability.

Figure 29. Future climate space compared to baseline for January average temperature vs. total precipitation for the SNK ecoregion.



Mapping Climate-Induced Stress on CEs. From the envelope analysis output, we can identify portions of the climate space for each ecoregion or CE where climate variables are predicted to change by ≥ 1 standard deviation and by ≥ 2 standard deviations from the mean. This approach will reveal the temporal and spatial distribution of climate change that exceeds the normal range of natural climatic variability to which the CEs are already plausibly adapted. Where these exist, they will be summarized by 4th level watershed.

Step 4: Model spatial distributions of the bioclimatic envelope for each CE

The intent of this step is to provide an indication of directionality in range shift that may occur among selected landscape species CEs. Output of this step can be used in subsequent analysis of changing landscape conditions from predicted future land uses.

This step will use the CRU 2km dataset and the SNAP Climate Projections to produce a current niche and potential bioclimatic shift for given CE under future emission scenarios. A current bioclimatic envelope will be generated using MaxEnt (Phillips et al. 2006), which is a niche modeling algorithm that estimates a distribution across geographic space based on the relationship between observed occurrence localities and environmental variables. The current bioclimatic envelopes will use the CRU 2km monthly data to define the current niche of a species, which will then be used to estimate future range shifts using the SNAP Climate Projections of downscaled spatial climate surfaces from 5 different GCMs. Multiple GCMs allows an assessment of the degree of agreement across a range of global climate models, thereby offering an assessment of uncertainty. Two time slices will be explored: 2020's and 2050's. This will complete a time series of data from 1901 to mid-century based on temperature and precipitation envelopes.

It is important to note that this model identifies only the part of the niche that is defined by the observed records. Therefore, it is important to include a wider range of species occurrence than just the REA study area. It should also be noted that the variables used in a climate envelope model are unlikely to define all possible dimensions of environmental space and realistically projects a suitable bioclimate. It is therefore important to consider which species are appropriate for this kind of modeling.

SDM algorithm: MaxEnt version: 3.3.3e

MaxEnt parameters/settings:

Replicate runs: 10 bootstrapping

Test points: 20% of localities (pixels) will be set aside for testing model validity using AUC and ROC indicators.

Random seed (which selects a different 20% for test for each replicate run)
Output format: logistic (For ease of interpretation: probability of presence from 0 to 1)
Threshold selection: will be based on integrating 1) results of fractional predicted area, 2) training omission rate, 3) test omission rate and 4) comparison to current known distributions.
Analysis of variable contribution (information about the contribution of each variable toward the predictive spatial model: which variable(s) most important?)

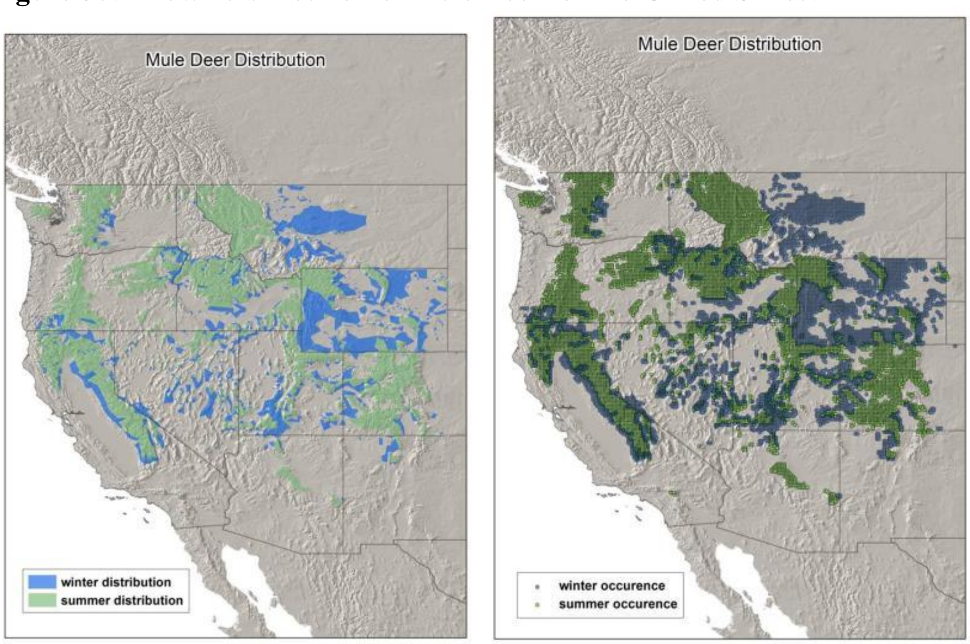
Map outputs from Step 4 will be evaluated to gauge the relative degree of predicted range shift for each CE by the 2050s time period. These outputs will be post-processed to remove portions of predicted ranges known to be excludable; e.g., expansion onto inhospitable substrates, as currently documented by scientific literature. Additionally, overlay of climate envelope maps from current and 2050 time periods with biophysical landform maps will provide an indication of relative biophysical variability. These may serve as an initial indication of adaptive or buffering capacity, as a diversity of apparent biophysical environments will tend to provide a buffer of micro-environments suitable for easing adaptation by species. All results of these analyses (i.e., degree of range shift, level of biophysical buffering capacity) will be summarized by 4th level watershed.

We intend to develop bioclimatic envelope models for 10 terrestrial fine-filter CEs: 7 birds and 3 mammals. The bird CEs include Peregrine Falcon, Bar-tailed Godwit, Bristle-thighed Curlew, Hudsonian Godwit, Kittlitz's Murrelet, Red Knot and Yellow-billed Loon. The mammals include the Alaskan hare, muskox and caribou (western arctic herd). For caribou, we will strive to develop two models: one for caribou winter range (largely falling within the study area) and another that addresses bioclimatic conditions on the calving grounds (largely falling outside and adjacent to the study area). Development of the second model is contingent upon gaining access to caribou telemetry data. Each of these species was selected for inclusion because they show evidence of being constrained ecologically due to complex habitat characteristics, which lend themselves to this type of analysis. Although we will not develop bioclimatic models for beaver and black bear specifically, proposed ALFRESCO forecasts for boreal forest distributions (see discussion under CA Class I: Wildfire) will capture the directionality in range shift of the forest types that these species are most associated with, and we will provide interpretation of those results for these species.

Climate Envelope-Shift Example

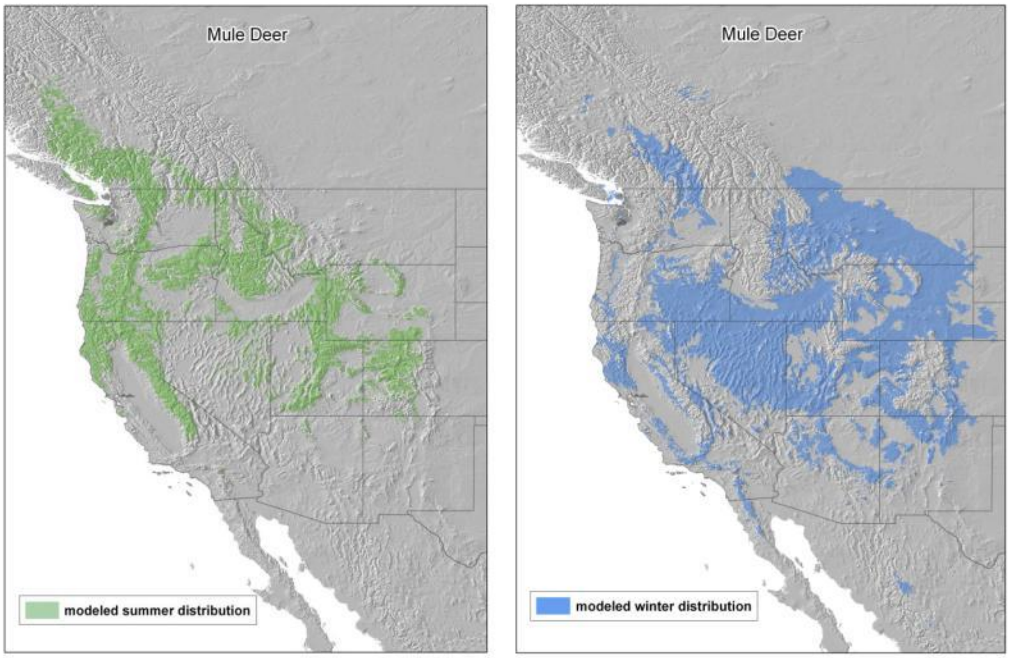
To illustrate the proposed process, we present a Mule Deer (*Odocoileus hemionus*) climate envelope shift example. For species such as Mule Deer who rely on seasonal habitats, we must generate two models, one for summer and one for winter, to accurately reflect the species bioclimatic niche. MaxEnt was used to model the current climatic niche of Mule Deer based on a 50 year average baseline of observed average temperature and total precipitation. Future projections were conducted using an ensemble of 16 different GCMs, downscaled to 10km for the A2 emissions scenario. The decadal time slices used were 2010, 2040, and 2070.

Figure 30. Known distribution of Mule Deer for the United States.



The suitable bioclimate of Mule Deer is based on known seasonal habitat areas across the western US. This distribution data is converted to points to be input into the MaxEnt modeling algorithm, with 20% of the points set aside for model testing.

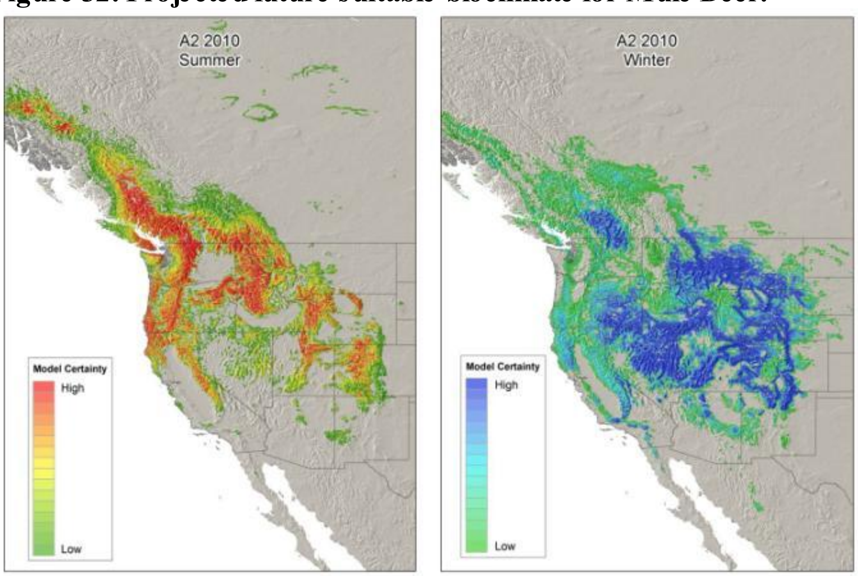
Figure 31. Current suitable bioclimate for Mule Deer in western North America.

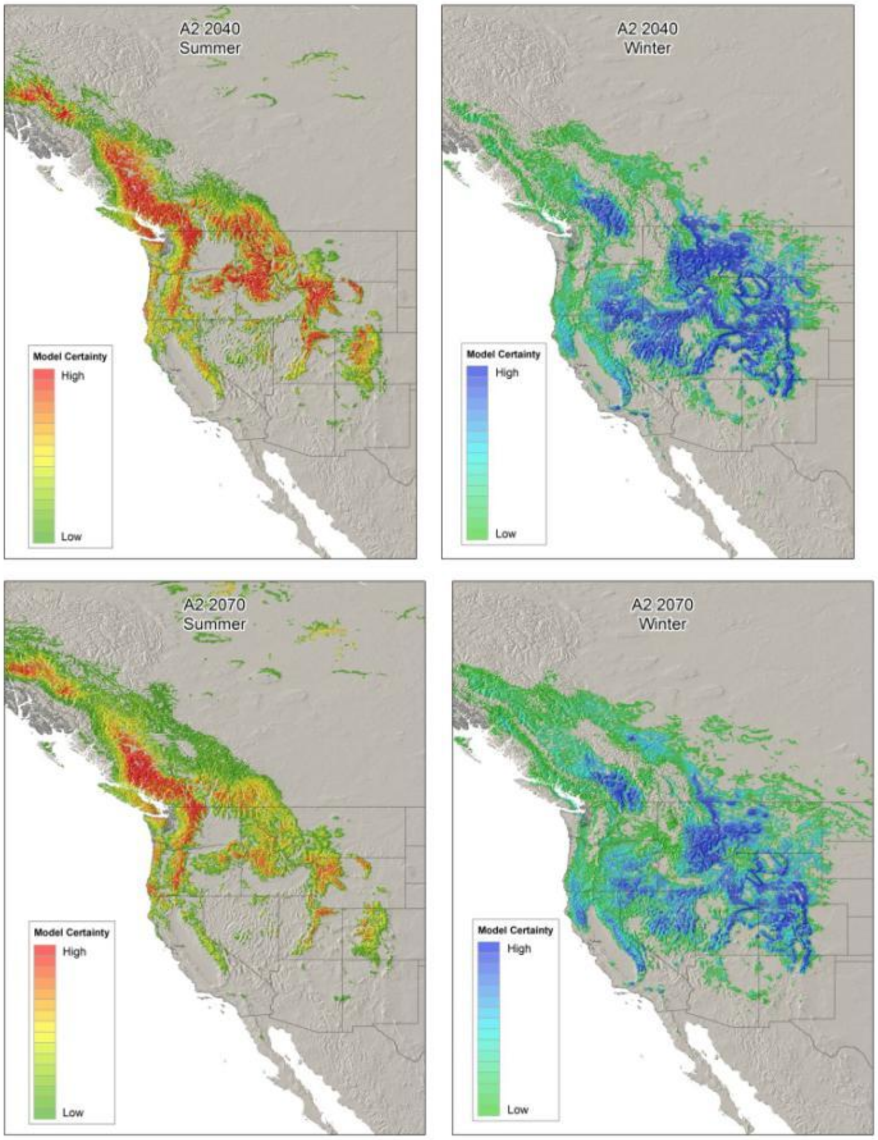


These figures are the modeled current bioclimate distribution of Mule Deer based on average temperature and total precipitation for the months of each season for a 50 year baseline. The MaxEnt raw output probability surface has been converted to a presence/absence map after applying a threshold. Thresholds are chosen to maximize the agreement between observed and predicted distributions.

Projecting the degree of model agreement for the distribution of suitable bioclimate into the future (for example, 2040 and 2070 as illustrated in Figure 32) provides insight into the potential areas of sustained suitable environments for Mule Deer, and the areas of significant climate shifts beyond the current range of bioclimate currently occupied by Mule Deer.

Figure 32. Projected future suitable bioclimate for Mule Deer.





Assessment Models

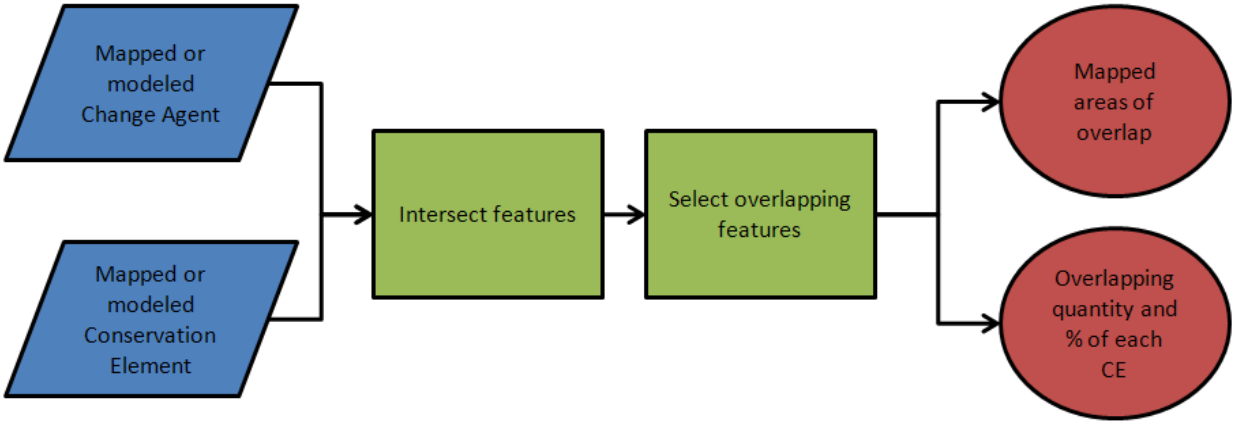
Assessment models specifically address the requirements for answering MQs. In this section we describe the components of assessment models followed by diagrams and descriptions of the various models required to conduct the assessments. We do not present every permutation of models needed to address every MQ, rather we describe the component models and then reference these to the MQs in Categories. Note that some assessment models that are highly interactive with CE distributions are described in the section Conservation Element Models.

Key model components include inputs, assessment/analytical processes, and outputs. Inputs are generally composed of existing data or may include outputs from other models. Most of the assessment processes are quite simple despite the fact that the models themselves may be quite complex. Many MQs can be answered by simply intersecting or adding the inputs with an assessment model in a simple GIS process. Outputs are typically maps and summary statistics for the entire ecoregion and by reporting unit.

Basic Assessment Models

Many MQs can be summarized as "Where will X coincide with Y?" seeking to identify areas where, for example, CEs will be coincident with CAs that may cause impacts. These types of MQs can be answered by a basic assessment model (Figure 33) that will intersect existing data or distributions of a CE with a mapped or modeled CA. Areas or portions of overlap between the CA and CE area can be displayed as a map and accompanied by summary statistics.

Figure 33. Basic assessment model.



Inputs: Spatial distributions of CAs and CEs.
Analytic process and tools: GIS intersect function will be used to integrate these layers.
Outputs: A summary map that shows areas of overlap and summary statistics.
Issues: This simple assessment model is used to answer MQs about where CEs overlap with CAs. It does not model actual response of the CEs to the CAs; those more complex issues are addressed in different MQs and through different models. This model, however, is foundational in many other models which first require the intersection between CEs and CAs.

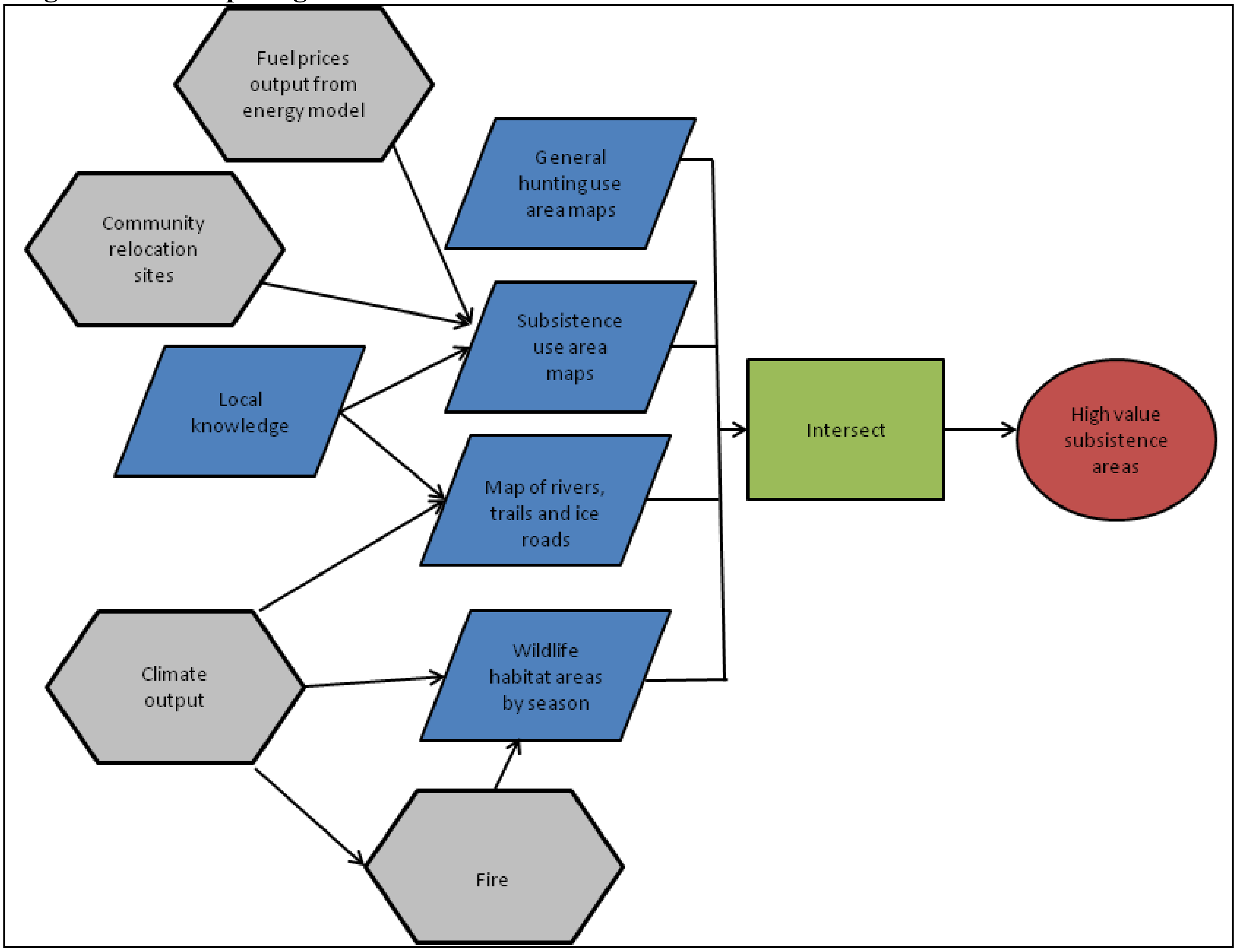
Other Specific Assessment Models

Subsistence Assessment

Sufficient numbers of healthy animals, location of animals, and access to them are all essential for subsistence. In addition, people are constrained from hunting by jobs and high fuel prices. The purpose of the subsistence assessment model is to understand the relationships between these factors and how CAs might affect subsistence. In addition our model needs to account for the highly seasonal nature of subsistence. We use local knowledge to help determine what to include in the models and how the factors could change under different development and climate change scenarios. The term "local knowledge" comes from Kofinas and Berman (2004) and includes information from both Alaska Natives and non-Natives on social and ecological systems. It is broader than Traditional Ecological Knowledge (TEK). An example of using local knowledge in the model is the following: It takes less time and fuel to hunt caribou upriver because it is easier to travel upstream with an empty boat and return downstream with a loaded boat (Kofinas and Berman 2004). This kind of information helps us to better estimate the effects of changes in animal migration patterns on subsistence hunter access. Another example is that early freeze-up on rivers allows for good travel conditions during winter and easier access to more distant locations. This helps to model the effects of climate change on subsistence. The process for developing the subsistence models is illustrated in Figure 34.

Inputs: Seasonal species range maps, access maps of trails and rivers, community location maps, outputs from climate model, energy model, fire model, economic forecasts, and local knowledge.
Analytic process and tools: Identify areas that are important for animal migration and hunter access.
Outputs: Map.
Issues: We lack detailed data on animal migration (caribou) as well as detailed information from local hunters on where they hunt. Radio collar data could provide better information about animals. Information from hunters is not available.

Figure 34. Concept diagram of subsistence harvest model



High Biodiversity Sites Assessment

We suggest that information on high biodiversity sites be given as a distinct reporting unit. This includes 1) the Important Bird Areas dataset for Alaska, created by Audubon Alaska 2) and The Nature Conservancy Portfolio database to identify specific places of importance for long-term conservation planning.

Rare Plant Associations and Land Cover Classes within the REA

We will also list the rare plant associations and associated land cover classes within the REA study area, along with their conservation status. For plant associations, a few studies have been completed that occur in the REA. In general, plant association information will remain a data gap.

For land cover classes/ecosystems, we will report the percent of the REA study area covered by each type. This will help us assess the distribution and status of rare land cover classes and ecosystems. We will also provide a frequency analysis of mapped patch sizes.

Protected Areas Database

For the revised Management Question "What are the proportions of CEs that coincide with different management areas?" we propose to use the USGS Protected Areas Database (PAD) for the boundaries within which to report the land cover class percentages.

Modeling Limitations

The following issues and limitations were identified in our model development process. This list isn't exhaustive but highlights the key and common issues we identified. An important primary limitation is that there are still data sets awaiting delivery to us to review for suitability which may affect our model recommendations or feasibility. Also, we have yet to investigate certain tools and while we expect to follow the same workflows illustrated in our models, we may substitute tools or manual methods for those described. Another primary limitation is that all of the model outputs are subject to the error of the input data sets as well as the assumptions made by our team and other subject matter experts consulted. Additional issues and limitations include the following:

1. Many MQs involving assessment of integrity and significance necessarily involve scoring, categorization, and or thresholding of data and are largely based on team expert opinion.
2. The SNK ecoregion has many data gaps that limit using the full ecological assessment criteria scorecard. The SNK region is lacking information on historic range of variation and has therefore excluded it from our assessment criteria.
3. Succession dynamics are poorly understood for most of the existing vegetation types. The absence of basic succession models limits our ability to successional pathways. Most models are known to have poor accuracy and will be excluded from our analysis.
4. Most of our landscape aquatic species lack adequate occurrence data to predict species distributions.
5. We are missing general information related to hydrology to apply in a hydrologic basin model.
6. The precipitation data is too coarse to address specific timing events of icing and to look at specific seasonality effects on particular CEs.

Implications for Management Questions

In Appendix III we present the management questions, linking each to the data and methods we intend to use to answer them. The purposes of this table are:

1. Present our recommendations for which MQs will be addressed and which are deferred because they are: a) out of scope of an REA, b) lack adequate data to assess, or c) lack a practical model for assessment.
2. Associate input data sources to each MQ
3. Associate categories of models to each MQ
4. Provide additional comments explaining other columns
5. Raise additional or new questions about specific MQs to be addressed by the AMT.

Most questions have been retained and accepted with either the original question retained or simple reframing. Several management questions are pending review by the AMT before final decisions are determined. Other questions have been labeled "Out of Scope" due to lack of available data needed for modeling efforts. A few management questions are potentially unanswerable and were left in the table as discussion points for AMT Workshop 3 on June 8-9th. A basic literature search is recommended for some management questions, especially management questions lacking appropriate modeling tools, to provide the most current information without embarking on a research endeavor.

Data Evaluation Results for Management Questions

Below are summarized known data gaps for CEs and CAs.

Wildfire CA

Nearly all of the wildfire-specific MQs were accepted. A single question related to future fire regime and caribou habitat (MQ 130) is listed as possibly redundant and shall be discussed at AMT3. In addition, at this time, we cannot specifically answer the question regarding the link between the potential future fire regime and permafrost except via a literature review (MQ 120). The larger Integrated Ecosystem Model for Alaska Project currently underway aims to address this question by coupling the soil thermal regime model (GIPL) and the fire regime model (ALFRESCO) to forecast future fire and permafrost scenarios.

Climate Change CA

As written in the data discovery section of the memo, precipitation in the SNAP Climate Scenarios is limited to snow water equivalent (mm; SWE). MQs that address snow or snow-on-ice cannot be specifically assessed at this time.

Anthropogenic Activities CAs

There are no detailed data or estimates available to link community infrastructure to soil change, storm surges, permafrost thaw, or erosion. Nor are there models to determine levels of risk or vulnerability of infrastructure to climate change effects. ISER has an infrastructure database and has estimated the replacement value of infrastructure, but those estimates are very general.

Aquatic Coarse and Fine Filter CEs

For the management questions (MQ) that address aquatic resources, two are suggested for removal because they are redundant with other questions. MQ 12 "Given likely scenarios for changes in hydrological systems, what changes can be expected in subsistence species" will be addressed by the proposed changes to MQ 16 "Where are predicted changes in hydrologic regime associated with important aquatic resources?" Subsistence species will be addressed as important aquatic resources. Likewise, MQ 118 "Where will Essential Fish Habitat likely experience significant and abrupt deviations from normal temperature regime?" will be addressed by the proposed changes to MQ 117 "Where are predicted changes in air temperature associated with important aquatic resources?" Essential Fish Habitat includes spawning and rearing habitat for salmon, which will be addressed as important aquatic resources.

There are eight fine-filter aquatic CEs that lack available data with which to map their distributions in the study area. For these fish species, MQ 60 "What is the current distribution of each CE?" and MQ 62 "Where do current CE distributions overlap with CA?" will be answered using species habitat preferences described in the literature, but won't be addressed using spatial intersections of change agents with distribution models. There are also other MQs that lack the necessary data for a complete assessment. MQ 114 "What is the condition of these various aquatic systems?" will be answered using available datasets described under the ecological integrity assessment in Volume 3. But, aquatic resources in the study area are lacking long-term hydrological, chemical, and biological datasets with which to characterize baseline conditions or infer deviations from the reference condition. There are no known occurrences of aquatic invasive species in the study area and there is also limited information describing vectors for their transmission, potential effects on native aquatic resources, and predictions of future distributions. This data gap will be reflected in the assessments for MQs 138, 139, 140, and 143, which will rely on published literature only.

Terrestrial Fine Filter CEs

Four questions for terrestrial species CEs cannot be addressed in this assessment. Although there are insect relief area maps, predicted increases in mosquito/insect populations are unknown and makes MQ 73 potentially beyond the scope of this assessment. MQ 74 on climate change interactions on wildlife populations cannot be modeled spatially and is therefore outside the scope of the project. MQ 75 Interactions between snowfall and wildlife populations cannot be addressed due to the coarseness of SNAP’s models. There are no data available on icing events and habitat availability to address MQ 80.

Terrestrial Coarse Filter CEs

There are no known data gaps for management questions relating to coarse filter CEs.

Nuisance Native Species and Diseases

There are no spatial datasets available to answer management questions on coyotes and beavers. All four of these proposed questions were removed.

Non-Native Species

There are no known data gaps for management questions relating to non-native species CEs.

Hydrology, Sea Ice, Weather, Permafrost, Soils

Three questions related to the marine system are listed as out of scope. The questions related to future scenarios of sea ice (MQ 148), coastal erosion (154) and storm surges (MQ 23) and can only be addressed in a general sense for the ecoregion as a whole. While there is on-going research focused on these topics for western Alaska, at this time the available data and models are limited.

While all of the hydrology related questions are listed as accepted, our knowledge of future hydrological regimes is limited. Models developed thus far in Alaska are largely restricted to single watersheds and are not applicable at an ecoregional level. To assess climate change effects on aquatic species and communities we therefore are limited to a simple model of summer precipitation (P) - potential evapotranspiration (PET).

Conclusions

This memo summarized our approach to the treatment of conservation elements and change agents and provides the framework to answer the management questions. We have recommended modeling all coarse filter aquatic and terrestrial CEs identified in the Memorandum I-2-c for Task 2. Fine filter CEs were categorized into 5 ecologically-based assemblages, 35 landscape species, 32 local species, and 1 species proposed to be treated through coarse-filter assessment. Landscape species included mammal, bird, and fish species. Local species included all focal plant taxa and six bird species. Prototypical models for both aquatic and terrestrial coarse-filter CEs and landscape CEs were presented as examples of our diverse approaches to addressing the management questions. We have described distributions and conceptual models for agents expected to alter the condition and distribution of CEs; the change agents included wildfire, anthropogenic activities, invasive species and nuisance species, and climate change. Additionally, we describe the potential interactions of CAs with CEs. Guidelines for assessing the condition of CEs are included. Condition assessments were similar among CEs and relied heavily on distribution of anthropogenic activities (e.g., numbers of culverts along streams). In general, our approach to assessing management questions related to the interaction of CEs with CAs uses a scenarios approach. The multiple approaches of modeling CE and their current and potential future interactions with CAs described here should be a robust way of addressing the management questions.

References

ADF&G. 2011. Fish Passage Inventory Database. http://www.adfg.alaska.gov/index.cfm?adfg=fishpassage.mapping.

AKEPIC. 2010. Alaska Exotic Plant Information Center Database. Alaska Natural Heritage Program, UAA. http://akweeds.uaa.alaska.edu/. Accessed May 15, 2010

Alaska Energy Authority. 2011. Renewable Energy Atlas of Alaska. www.aidea.org/publications/html. May.

Alexander, R.B., E.W. Boyer, R.A. Smith, G.E. Schwarz, and R.B. Moore. 2007. The role of headwater streams in downstream water quality. Journal of the American Water Resources Association 43: 41-59.

Bella, E.M. 2009. Predicting invasive plant species range expansion in Alaska. University of California Davis, dissertation 130 pp.

Berg, E.E., J. D. Henry, C. L. Fastie, A. D. De Volder, S. M. Matsuoka. 2006. Spruce beetle outbreaks on the Kenai Peninsula, Alaska, and Kluane National Park and Reserve, Yukon Territory: Relationship to summer temperatures and regional differences in disturbance regimes. Forest Ecology and Management 227: 219-232.

Berman, Matthew and Gary Kofinas. 2004.Hunting for models: grounded and rational choice approaches to analyzing climate effects on subsistence hunting in an Arctic community. Ecological Economics 49:31– 46.

Betts, E.F. and J.B. Jones. 2006. Impact of wildfire on stream nutrient chemistry and ecosystem metabolism in boreal forest catchments of Interior Alaska. Arctic, Antarctic, and Alpine Research 41: 407-417.

Broennimann, O. , U. A. Treier, H. Muller-Scharer, W. Thuiller, A. T. Peterson, and A. Guisan. 2007. Evidence of climatic niche shift during biological invasion. Ecological Letters 10:701-709.

Bryant, M.D., N.D. Zymonas, B.E. Wright. 2004. Salmonids on the fringe: abundance, species composition, and habitat use of salmonids in high-gradient headwater streams, Southeast Alaska. Transactions of the American Fisheries Society 133: 1529-1538.

Buckwalter, J.D., J.M. Kirsch, and D.J. Reed. 2010. Fish inventory and anadromous cataloging in the Lower Yukon River Drainage, 2008. Alaska Department of Fish and Game, Fishery Data Series No. 10-76. Anchorage, AK. 603 pgs.

Burnett, K.M., C.E. Torgensen, E.A. Steel, D.P. Larsen, J.L. Ebersole, R.E. Gresswell, P.W. Lawson, D.J. Miller, J.D. Rodgers, and D.L. Stevens, Jr. 2009. Data and modeling tools for assessing landscape influences on salmonid populations: examples from Western Oregon. American Fisheries Society Symposium 70: 873-900.

Carlson, M. L., I. V. Lapina, M. Shephard, J. S. Conn, R. Densmore, P. Spencer, J. Heys, J. Riley, and J. Nielsen. 2008. Invasiveness ranking system for non-native plants of Alaska. USDA, Forest Service, Gen. Tech. Rep. R10, R10-TP-143. 218 pp.

Carlson, M.L., and M. Shephard. 2007. The spread of invasive exotic plants in Alaska: is establishment of exotics accelerating? Harrington, T.B. and S.H. Reichard (tech. eds.). Meeting the Challenge: Invasive Plants in Pacific Northwestern Ecosystems. USDA Forest Service, Pacific Northwest Research Station, Gen. Tech. Rep. PNW-GTR-694.

Cote, D., D.G. Kehler, C. Bourne, and Y.F. Wiersma. 2009. A new measure of longitudinal connectivity for stream networks. Landscape Ecology 24: 101-113.

Chapin, F.S., III, T.S. Rupp, A.M. Starfield, L. DeWilde, E.S. Zavaleta, N. Fresco, J. Henkelman, and A.D. McGuire. 2003. Planning for resilience: modeling change in human-fire interactions in the Alaskan boreal forest. *Frontiers in Ecology and the Environment* 1(5):255-261.

Comer, P.J. and J Hak. 2009. NatureServe Landscape Condition Model. Technical documentation for NatureServe Vista decision support software engineering. NatureServe, Boulder CO.

Conn, J., K. Beattie, M. Shephard, M. L. Carlson, I. V. Lapina, M. Hebert, R. Gronquist, M. Rasy. 2008. Alaska *Melilotus* (Fabaceae) Invasions: Distribution, Origin, and Susceptibility of Plant Communities. Arctic, Antarctic, and Alpine Research 40:298-308.

Darwin, C. 1859. On the Origin of Species by Means of Natural Selection. Murray.

DeCicco, F. 2002. Fishery Management Plan for Arctic Grayling Sport Fisheries along the Nome Road System, 2001-2004. Alaska Department of Fish and Game, Fishery Management Report No. 02-03. Anchorage, AK. 24 p.

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.

Faber-Langendoen, D., J. Rocchio, M. Schafale, C. Nordman, M. Pyne, J. Teague, T. Foti, and P. Comer. 2006. Ecological Integrity Assessment and Performance Measures for Wetland Mitigation. Final Report to US EPA Office of Water and Wetlands. NatureServe, Arlington, VA.

Finstad G.L., Kielland K. and Schneider W.S. 2006. Reindeer herding in transition: historical and modern day challenges for Alaskan reindeer herders. *Nomadic Peoples 10*, 31–49.

Guisan, A. and W. Thuiller. 2005. Predicting species distribution: offering more than simple habitat models. Ecology Letters, 8:993-1009.

Hander, R.F., R.J. Brown, and T.J. Underwood. 2008. Comparison of inconnu spawning abundance estimates in the Selawik River, 1995, 2004, and 2005, Selawik National Wildlife Refuge. Alaska Fisheries Technical Report Number 99. U.S. Fish and Wildlife Service. 30 pg.

Higuera PE, Brubaker LB, Anderson PM, Brown TA, Kennedy AT, et al (2008). Frequent Fires in Ancient Shrub Tundra: Implications of Paleorecords for Arctic Environmental Change. PLoS ONE 3(3): e0001744.

Howell, P.J. 2006. Effects of wildfire and subsequent hydrologic events on fish distribution and abundance in tributaries of north fork John Day River. North American Journal of Fisheries Management 26: 983-994.

Hughes, N.F. 1999. Population processes responsible for larger fish upstream distribution patterns of Arctic grayling (*Thymallus arcticus*) in interior Alaskan runoff rivers. Canadian Journal of Fisheries and Aquatic Sciences 56: 2292-2299.

Johnson, J. and P. Blanche. 2010. Catalog of waters important for spawning, rearing, or migration of anadromous fishes – Arctic Region, effective June 1, 2010. Alaska Department of Fish and Game, Special Publication No. 10-04. 134 p.

Joly, K., T. Rupp, R. R. Jandt and F. S. Chapin III. 2009. Fire in the range of the Western Arctic Caribou Herd. Alaska Park Science. pp. 68-73.

Jorgensen, M.T. and T.E. Osterkamp. 2005. Response of boreal ecosystems to varying modes of permafrost degradation. Canadian Journal of Forest Research 35: 2100-2111.

Jorgenson, T., K. Yoshikawa, M. Kanevskiy, Y. Shur, V. Romanovsky, S. Marchenko, et al. 2008. Permafrost Characteristics of Alaska. Map presented at the Ninth International Conference on Permafrost. Fairbanks, Alaska.

Joy, P. and D.J. Reed. 2007. Estimation of Coho salmon abundance and spawning distribution in the Unalakleet River 2004-2006. Alaska Department of Fish and Game, Fishery Data Series No. 07-48. 54 p.

Kudryavtsev, V. A., Garagula, L. S., Kondrat'yeva, K. A. and Melamed V. G. (1974). *Osnovy merzlotnogo prognoza* (in Russian). MGU, 431 pp. [CRREL Translation: V. A. Kudryavtsev et al., Fundamentals of Frost Forecasting in Geological Engineering Investigations, CRREL Draft Translation 606, 1977, 489 pp.]

Lawler, J. P., S. D. Miller, D. M. Sanzone, J. Ver Hoef, and S. B. Young. 2009. Arctic Network vital signs monitoring plan. Natural Resource Report NPS/ARCN/NRR—2009/088. National Park Service, Fort Collins, Colorado.Liu C, Berry PM, Dawson TP, and Pearson RG (2005) Selecting thresholds of occurrence in the prediction of species distributions. Ecography 28**:**385-393.

Loya, W. 2011. Climate change implications for Western Alaska LCC. Western Alaska LCC Science Workshop. Anchorage, AK.

McClory, J. and T. Gotthardt. 2008. Non-native and invasive animals of Alaska: a comprehensive list and select species status reports. Alaska Natural Heritage Program. Anchorage, AK. 64 pgs.

McCune, B. and J.B. Grace. 2002. Analysis of ecological communities. MjM Software Design, Glenden Beach, OR.

McRae, B.H., and Shah, V.B. 2009. Circuitscape user's guide. ONLINE. The University of California, Santa Barbara. Available at: http://www.circuitscape.org.

Menard, J., J. Soong, and S. Kent. 2010. 2008 Annual Management Report for Norton Sound, Port Clarence, and Kotzebue. Alaska Department of Fish and Game, Fishery Management Report No. 10-49. Anchorage, AK. 227 p.

Murphy, K., Huettmann, F., Fresco, N. and J. Morton. (2010) *Connecting Alaska Landscapes into the future: Results from an interagency climate modeling, land management and conservation project*. Final Report.

Nemeth, M.J., B.C. Williams, R.C. Bocking, and S.N. Kineen. 2009. Freshwater habitat quantity and Coho salmon production in two rivers: an initial study to support the development of habitat-based escapement goals in Norton Sound, Alaska. American Fisheries Society Symposium 70: 73-96.

Northern Economics. 2009. Analysis of Future Offshore Oil and Gas Development: Beaufort Sea, Chukchi Sea, and North Aleutian Basin Prepared for Shell Exploration and Production. March.

Ogawa, A., H. Shibata, K. Suzuki, M.J. Mitchell, and Y. Ikegami. 2006. Relationship of topography to surface water chemistry with particular focus on nitrogen and organic carbon solutes within a forested watershed in Hokkaido, Japan. Hydrologic Processes 20:251–265.

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.

Phillips, S.J., R.P. Anderson, and R.E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modeling 190: 231-259.

Quinn, T.P. 2005. The Behavior and Ecology of Pacific Salmon and Trout. University of Washington Press. Seattle, WA. 378 p.

R Development Core Team. 2009. R: a language and environment for statistical computing. R package version 2.10.1 Vienna, Austria.
Racine, C.H., J.G. Dennis and W.A. Patterson III. 1985. Tundra fire regimes in the Noatak River Watershed, Alaska: 1956-83. Arctic 38:194-200.
Racine, C.H., L.A. Johnson and L.A. Viereck. 1987. Patterns of vegetation recovery after tundra fires in Northwestern Alaska, U.S.A. Arctic and Alpine Research, vol.19, no. 4. 461-469
Rattenbury, Kumi, Knut Kielland, Greg Finstad, and William Schneider. 2009. A reindeer herder's perspective on caribou, weather and socio-economic change on the Seward Peninsula, Alaska. *Polar Research 28: 71-88*.
Rieman, B. and J. Clayton. 1997. Wildfire and native fish: issues of forest health and conservation of sensitive species. Fisheries 22: 6-15.
Rupp, T.S., A.M. Starfield, and F.S. Chapin III. 2000a. A frame-based spatially explicit model of subarctic vegetation response to climatic change: comparison with a point model. *Landscape Ecology* 15: 383-400.
Rupp, T.S., F.S. Chapin III, and A.M. Starfield. 2000b. Response of subarctic vegetation to transient climatic change on the Seward Peninsula in northwest Alaska. *Global Change Biology* 6: 451-455.
Rupp, T.S., F.S. Chapin III, and A.M. Starfield. 2001. Modeling the influence of topographic barriers on treeline advance of the forest-tundra ecotone in northwestern Alaska. *Climatic Change* 48: 399-416.
Rupp, T.S., A.M. Starfield, F.S. Chapin III, and P. Duffy. 2002. Modeling the impact of black spruce on the fire regime of Alaskan boreal forest. *Climatic Change* 55: 213-233.
Rupp, T.S., X. Chen, M. Olson, and A.D. McGuire. 2007. Sensitivity of simulated land cover dynamics to uncertainties in climate drivers. *Earth Interactions*. 11(3):1-21.
Rzeczycki, T. Effects of *Melilotus alba* (Fabaceae) on Alaska floodplain plant communities and soils. Unpublished data. MS research, UAA.
Sax, D. F., J.J. Stachowicz, J.H. Brown, J. F. Bruno, M.N Dawson, S.D. Gaines, R.K. Grosberg, A. Hastings, R.D. Holt, M.M. Mayfield, M.I. O'Connor, and W.R. Rice. 2007. Ecological and evolutionary insights from species invasions. Trends in Ecology and Evolution 22:465-471.
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.
Schneller, L.C., and M.L. Carlson. 2011. Impacts of *Melilotus alba* on pollinator services, diversity and abundance in the boreal forest of Iinterior Alaska. Poster presentation, Classrooms for Climate, USFS-UAA symposium. http://www.uaa.alaska.edu/classroomsforclimate/upload/symposium-program.pdf.
Shaftel, R.S., R.S. King, and J.A. Back. 2010. Alder cover drives nitrogen availability in Kenai lowland headwater streams, Alaska. Biogeochemistry doi:10.1007/s10533-010-9541-3.
Sparrow, S.D., V.L. Cochran, and E.B. Sparrow. 1995. Dinitrogen fixation by seven legume crops in Alaska. Agronomy Journal 87:34-41.
Spellman, B.T. and T. Wurtz. 2010. Invasive sweetclover (*Melilotus alba*) impacts native seedling recruitment along floodplains of interior Alaska. Biological Invasions. Published online: January 6, 2011.
Sheer, M.B. and E.A. Steel. 2006. Lost watersheds: barriers, aquatic habitat connectivity, and salmon persistence in the Willamette and Lower Columbia River basins. Transactions of the American Fisheries Society 135: 1654-1669.
Sorenson, R., U. Zinko, and J. Seibert. 2005. On the calculation of the topographic wetness index: evaluation of different methods based on field observations. Hydrology and Earth Systems Sciences Discussions 2:1807–1834.
Therneau, T.M., B. Atkinson, B. Ripley, J. Oksanen, and G. De'Ath. 2011. Mvpart: Mutivariate partitioning. R package version 1.4-0. http://CRAN.R-project.org/package=mvpart.
USGS. 2008. Alaska Resource Data File. http://ardf.wr.usgs.gov/.
Unnasch, R.S., D.P. Braun, P. J. Comer, G. E. Eckert. 2008. The Ecological Integrity Assessment Framework: A Framework for Assessing the Ecological Integrity of Biological and Ecological Resources of the National Park System**.** Report to the National Park Service.
Viereck, L.A. 1979. Characteristics of treeline plant communities in Alaska. Holarctic Ecology. 2:228-238.
Viereck, L. A., C. T. Dyrness, A. R. Batten, and K. J. Wenzlick. 1992. The Alaska vegetation classification. U.S. Department of Agriculture, Forest Service, Portland, OR. General Technical Report PNW-GTR-286.
Villano, K. L. and C. P. H. Mulder. 2008. Invasive plant spread in burned lands of interior Alaska, final report. Prepared for the National Park Service—Alaska Region and the National Aeronautics and Space Administration. Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, AK. 25 pp.
Walker, C.W., S. Baird, R. King, and D. Whigham. 2007. Wetland geomorphic linkages to juvenile salmonids and macroinvertebrate communities in headwater streams of the Kenai Lowlands, Alaska. U.S. Environmental Protection Agency Wetland Program Development Grants Final Report. 83 p.

Weidmer, M. 2004. FY 2005 Operational Plan: Synoptic inventory of fish distribution in Seward Peninsula and middle Yukon River freshwaters. Alaska Department of Fish and Game. 118 pg.
Weidmer, M. 2011. Hierarchical analysis of headwater lotic fish species-environment relationships in northern Alaska, U.S.A. In prep.
Wipfli, M.S., J.S. Richardson, and R.J. Naiman. 2007. Ecological linkages between headwaters and downstream ecosystems: transport of organic matter, invertebrates, and wood down headwater channels. Journal of the American Water Resources Association 43: 72-85.
Yoshikawa, K., W.R. Bolton, V.E. Romanovsky, M. Fukuda, and L.D. Hinzman. 2002. Impacts of wildfire on the permafrost in the boreal forests of Interior Alaska. Journal of Geophysical Research 108: 8148.

Appendices

Appendix I. List of fine-filter CEs with assessment approach, known data gaps, and planned distribution modeling.

	Global Rank	State Rank	AK SWAPs	Federal Listing	BLM	Ecological Systems	Comments	Assessment Approach	Data gap	Distribution Model
SPECIES ASSEMBLAGES										
Critical Fish Habitats					*SOW*		*Subsistence importance -Likely unidentifiable*	Ecological-based Assemblages	Most data available for anadromous species	Yes - Existing data
Marine Mammal Haul-Out Sites					*SOW*		*Subsistence importance. Includes haul-out areas for ribbon, bearded, spotted, and ringed seals and Pacific walrus*	Ecological-based Assemblages	No	Yes - known mapped locations
Migratory Bird Habitats					*SOW*		*Important for rare species*		Yes	Need to define migratory habitats
Raptor Concentrations					*SOW*		*Important for rare species. Includes habitat for Peregrine Falcon, Golden Eagle, Gyrfalcon, Rough-legged Hawk, Bald Eagle, Northern Harrier, Merlin*	Ecological-based Assemblages	Surveyed area limited to one river and a few scattered locations.	Maybe -potentially model (riparian areas with cliffs, rocky outcrops away from water)
Seabird colony sites					*SOW*		*Important for coastal nesting species; e.g., coastal cliffs at Cape Deceit. Includes Aleutian Tern, Common Murre, Horned Puffin, auklets, and Black-legged Kittiwake.*	Ecological-based Assemblages	No	Yes - Known mapped locations
ANIMALS										
Birds										
Aleutian Tern (*Oncychoprion aleuticas*)	G4	S3B	Nominee Species			Estuary, Lagoon, and Coastal Cliffs; can be included in seabird colony sites	Uncommon breeder on Seward Peninsula; population declining	Ecologically-based assemblage – included within Seabird colony sites	Yes	Maybe - If lumped with seabird colony data, there is sufficient data to model. We do not have sufficient data to model this species individually.
Arctic Peregrine Falcon (*Falco peregrinus tundrius*)	G4T2	S3B	Nominee Species			Arctic Bedrock and Talus, Major River		Ecologically based assemblage – included within Raptor concentrations	Overall lack of spatial data; suggest lumping this species with Raptor Concentrations. Even so, we have very sparse and localized data for raptors.	Maybe- lump with Raptor Concentrations
Bar-tailed Godwit (*Limosa lapponica*)	G5*	S3B	Nominee Species			Arctic Polygonal Ground Wet Sedge Tundra, Arctic Dwarf-Shrubland	Common breeder in the region; declining *Global status debated.	Landscape	No	Yes
Black Scoter (*Melanitta nigra*)	G5	S3S4B SCS4N					USGS suggests declining population, furthest north nesting population, suggested by USGS reviewer to be included	Landscape	No	Yes
Bristle-thighed Curlew (*Numenius tahitiensis*)	G2	G2, S2B	Nominee Species		Sensitive Species	Arctic Shrub-Tussock Tundra	Small population, 40% global pop. Breeds on Seward Peninsula	Landscape	No	Yes
Common Eider (*Somateria mollissima*)	G5	S3S4B S3N					FWS species of concern, unique habitats at Espenburg; suggested by USGS reviewer to be included	Landscape	We potentially have sufficient data to model this species.	Yes

	Global Rank	State Rank	AK SWAPs	Federal Listing	BLM	Ecological Systems	Comments	Assessment Approach	Data gap	Distribution Model
Emperor Goose (*Chen canagica*)	G3G4	S3S4			Sensitive Species	Arctic Tidal Marsh	Uncommon breeder on Seward Peninsula, populations depressed	Local	Yes	Yes
Hudsonian Godwit (*Limosa haemastica*)	G4	S2S3B	Nominee Species		Watch List	Arctic Wet Sedge-Sphagnum Peatland	Rare breeder on Seward Peninsula; AK pop is small, and genetically distinct.	Local	Yes	Yes
King Eider (*Somateria spectabilis*)	G5	S3B, S3N	Nominee Species			Western North American Boreal Freshwater Emergent Marsh		Landscape	Yes	Yes
Kittlitz's Murrelet (*Brachyramphus brevirostris*)	G2	S2B, S2N	Nominee Species	Candidate for Listing	Sensitive Species	Arctic Bedrock and Talus	Relict population in Seward Peninsula, declining	Local	Yes	Yes
McKay's Bunting (*Plectrophenax hyperboreus*)	G3	S3	Nominee Species		Sensitive Species	Arctic Tidal Marsh, Arctic Marine Beach and Beach Meadow	One of NA's rarest birds, AK endemic; winters on Seward Peninsula.	Landscape	Yes	No
Red Knot (*Calidris canutus*)	G5*	S2S3B	Nominee Species		Sensitive Species	alpine tundra, bare ground	Subspecies *roselaari* declining; breeds on Seward Peninsula	Landscape	Yes	No
							*Global status debated			
Spectacled Eider (*Somateria fischeri*)	G2	S2B	Nominee Species	Listed as Threatened		Lowland stream, Arctic Coastal Brackish Meadow,	rare local breeder	Local	Yes	Yes
Yellow-billed Loon (*Gavia adamsii*)	G4	S2S3B, S3N	Nominee Species	Candidate for Listing	Sensitive Species	Lentic – shallow, closed basin, Arctic Polygonal Ground Wet Sedge Tundra	Candidate species for listing based on low populations and potentially declining trend; status on the Seward Peninsula is unknown.	Landscape	No	Yes
Cackling Goose (Branta hutchinsii)	*G5*	*S5B*				*Estuary and Lagoon, Western North American Boreal Freshwater Emergent Marsh, Arctic Coastal Brackish Meadow*	*Subsistence importance*	Landscape	No	Yes
Willow ptarmigan (Lagopus Lagopus)	*G5*	*S5*				*Arctic Mesic-Wet Willow Shrubland*	*Subsistence importance*	Coarse-filter	No	Yes
Mammals										
Alaskan hare (*Lepus othus*)	G3G4	S3S4	Nominee Species		Sensitive Species	Arctic Mesic-Wet Willow Shrubland	potentially declining	Landscape	No	Yes
Pacific walrus (*Odobenus rosmarus*)	G4	S3	Nominee Species			rocky shores, islands, beaches, coastal headlands - captured within sea mammal haul-out sites		Ecologically-based assemblage – to be included in marine mammal haulouts	No	Combine with marine mammal haulouts.
Polar Bear (*Ursus maritimus*)	G3	S3		Listed as Threatened		Sea ice-associated habitats		Landscape	Yes	Maybe a coarse scale terrestrial feeding areas model
Beaver (Castor canadensis)	*G5*	*S5*			*SOW*	*River, Headwater Stream, Slough/Pond, Freshwater Lakes*	*Ecologically important - range appears to be expanding*	Landscape	No	Yes

	Global Rank	State Rank	AK SWAPs	Federal Listing	BLM	Ecological Systems	Comments	Assessment Approach	Data gap	Distribution Model
Black Bear (Ursus americanus)	*G5*	*S5*			*SOW*	*Forested ecological systems*	*Subsistence species in Nulato Hills region.*	Landscape	Specific occurrence data are lacking, but can model based on habitat preferences and known range.	Yes
Brown Bear (Ursus arctos)	*G4*	*S5*			*SOW*		*Subsistence species.*	Landscape	Specific occurrence data are lacking, but can model based on habitat preferences and known range.	Yes
Moose (Alces americanus)	*G5*	*S5*			*SOW*	*rctic Mesic-Wet Willow Shrubland, Western North American Boreal Deciduous Shrub Swamp*	*One of the most used terrestrial mammals for subsistence, growing sport hunting in the region, charismatic species*	Landscape	No	Yes
Muskox (Ovibos moschatus)	*G4*	*S4*			*SOW*	*Arctic Shrub-Tussock Tundra, Arctic Polygonal Ground Wet Sedge Tundra*	*Rarely used subsistence species. Sport hunting occurs.*	Landscape	No	Yes
Western Arctic Caribou Herd (Rangifer tarandus)					*SOW*	*Arctic Acidic Dwarf-Shrub Lichen Tundra, Arctic Shrub-Tussock Tundra, Arctic Acidic Sparse Tundra??*	*One of the most used terrestrial mammals for subsistence, growing sport hunting in the region.*	Landscape	No	Yes
Fishes										
Alaska Blackfish (*Dallia pectoralis*)	G5	S5	Nominee Species			Lowland stream, Major river, Lentic - deep or shallow, open basin		Landscape	No	Yes
Arctic lamprey (*Lampetra japponica*)	G4	S4	Nominee Species			Major river		Landscape	Yes	No
Pacific lamprey (*Lampetra tridentata*)	G5	S4S5	Nominee Species					Landscape	Yes	No
Broad whitefish (*Coregonus nasus*)	G5	S4S5	Nominee Species			Major river, Estuary and Lagoon, Lentic - shallow and deep		Landscape	Information available for whitefish genus only	No
Humpback whitefish (*Coregonus pidschian*)	G5	S5	Nominee Species			Major river		Landscape	Information available for whitefish genus only	No
Round whitefish (*Prosopium cylindraceum*)	G5	S4	Nominee Species			Major river		Landscape	Information available for whitefish genus only	No
Bering cisco (*Coregonus laurettae*)	G4	S4	Nominee Species			Estuary and Lagoon		Landscape	Yes	No
Rainbow smelt (*Osmerus mordax*)	G5	S3S5	Nominee Species			Lentic - shallow, estuary and lagoon, major river		Landscape	Yes	No
Arctic char (Salvelinus alpinus)	*SNR*	*SNR*			*SOW*	*Lakes*		Landscape	No	No
Arctic grayling (Thymallus Arcticus)	*G5*	*S5*			*SOW*	*Major river*	*There is some sport fishing for grayling*	Landscape	No	Yes

	Global Rank	State Rank	AK SWAPs	Federal Listing	BLM	Ecological Systems	Comments	Assessment Approach	Data gap	Distribution Model
Pink salmon (Oncoyhynchus gorbuscha)	*G5*	*S5*			*SOW*	*Major river*	*Behind marine mammals salmon are the most consumed subsistence species in the region (Pinks and Chums appear most important)*	Landscape	No	No
Chum salmon (Oncorhynchus keta)	*G5*	*S5*			*SOW*	*Major river*	*Subsistence species*	Landscape	No	No
Chinook salmon (Oncorhynchus tshawytscha)	*G5*	*S4*			*SOW*	*Major river*	*Subsistence species*	Landscape	No	No
Coho salmon (Oncorhynchus kisutch)	*G4*	*S4*			*SOW*	*Major river*	*Subsistence species*	Landscape	No	Yes
Sockeye salmon (Oncorhynchus nerka)	*G5*	*S5*			*SOW*	*Major river*	*Subsistence species*	Landscape	No	No
Dolly Varden (Salvelinus malma)					*SOW*		*Subsistence species. There is some sport fishing for Dolly Varden*	Landscape	No	Yes
Lake trout	*G5*	*S5*			*SOW*	*Freshwater Lakes - Deep*	*Not in study area*	Landscape	Yes	No
Pike (Esox lucius)					*SOW*	*Freshwater Lakes, Major river*	*There is some sport fishing for pike*	Landscape	Yes	No
Sheefish (Stendous leucichthys)	*G5*	*S3S5*			*SOW*	*Major river*	*There is some sport fishing for sheefish*	Landscape	No	No
VASCULAR PLANTS										
Artemisia globularia ssp. lutea	G4T1T2Q	S1S2			Sensitive Species	Bedrock and Talus	Stony habitats	Local	Yes	No
Artemisia senjavinensis	G3	S2S3			Sensitive Species	Bedrock and Talus	Carbonate associate	Local	Yes	Maybe
Cardamine microphylla ssp. blaisdellii	G4T3T4	S3S4			Watch List	Mesic-Wet Willow Shrubland	Relatively common	Local	Yes (Previously modeled, but requires update, Cortés-Burns 2011)	Maybe
Carex heleonastes	G4	S2S3			Watch List	Boreal Freshwater Emergent Marsh		Local	Yes	No
Claytonia arctica	G3	S1			Sensitive Species	Acidic Sparse Tundra (?)	Wet graminoid-herbaceous tundra	Local	Yes	No
Douglasia alaskana	G3	S3			Sensitive Species	Bedrock and Talus	Stony habitats	Local	Yes	Maybe
Douglasia beringensis	G2	S2			Sensitive Species	Bedrock and Talus	Gravel slopes, outcrops	Local	Yes	Maybe
Gentianopsis detonsa ssp. detonsa	G3G5T3T5	S1			Sensitive Species	Bedrock and Talus	Beach ridges, saline meadows	Local	Yes	No
Lupinus kuschei	G3G4	S2			Watch List	Sand dunes, glacial rivers	Sandy habitats	Local	Yes	Maybe
Oxytropis arctica var. barnebyana	G4?T2Q	S2			Sensitive Species	Bedrock and Talus, Mesic-Wet Willow Shrubland		Local	Yes	No
Oxytropis kokrinensis	G3	S3			Watch List	Acidic Dwarf-Shrub Lichen Tundra	Specifically, "Dryas meadows"	Local	Yes	Maybe
Papaver walpolei	G3	S3			Sensitive Species	Bedrock and Talus	Stony habitats, often carbonates	Local	Yes	Maybe
Parrya nauruaq	G2	S2			Sensitive Species	Bedrock and Talus	Carbonate associated	Local	Yes	Maybe

	Global Rank	State Rank	AK SWAPs	Federal Listing	BLM	Ecological Systems	Comments	Assessment Approach	Data gap	Distribution Model
Pedicularis hirsuta	G5?	S1			Sensitive Species	Marine Beach and Beach Meadow, Coastal Sedge-Dwarf-Shrubland	Collection on Seward Peninsula is questionable	Remove species, single collection, probably not accurate identification		
Pleuropogon sabinei	G4G5	S1			Sensitive Species	Slough/Pond	Collection on Seward Peninsula is questionable	Remove species, single collection, probably not accurate identification		
Potentilla rubricaulis	G4	S2S3			Watch List	Bedrock and Talus, Acidic Sparse Tundra	Specifically, "Alpine meadows"	Local	Yes	Maybe
Potentilla stipularis	G5	S1			Sensitive Species	Mesic-Wet Willow Shrubland		Local	Yes	No
Primula tschuktschorum	G2G3	S2S3			Sensitive Species	Wet Sedge-Sphagnum Peatland, Polygonal Ground Wet Sedge Tundra	Impacted by goose and reindeer grazing, competition with *P. eximia*	Local	Yes (Previously modeled, but requires update, Cortés-Burns 2011)	Maybe
Puccinellia vahliana	G4	S2S3			Watch List	Acidic Dwarf-Shrub Lichen Tundra, Wet Sedge-Sphagnum Peatland	Specifically, "Dryas tundra, fens"	Local	Yes (Previously modeled, but requires update, Cortés-Burns 2011)	Maybe
Puccinellia wrightii	G3G4	S2S3			Sensitive Species	Arctic Dwarf-Shrubland	Specifically, "Alpine Dryas"	Local	Yes	Maybe
Ranunculus auricomus	G5	S2			Watch List	Mesic-Wet Willow Shrubland		Local	Yes	No
Ranunculus chamissonis	G3G4	S2S3			Sensitive Species	Sedge-grass meadows, marshlands		Local	Yes	No
Ranunculus glacialis var. 1	G4T2	S2			Sensitive Species	Alpine scree		Local	Yes	No
Rumex krausei	G2	S2			Sensitive Species	Bedrock and Talus	Carbonate associate	Local	Yes	Maybe
Saussurea triangulata	G1	S1			Watch List	Mesic-Wet Willow Shrubland		Local	Yes	No
Smelowskia johnsonii	G1	S1			Sensitive Species	Bedrock and Talus	Only 2 known locations. Carbonate associate	Local	Yes	Maybe
Symphyotrichum yukonense	G3	S3			Watch List	Large River Floodplain		Local	Yes	No
Taraxacum carneocoloratum	G3Q	S3			Watch List	Acidic Sparse Tundra		Local	Yes	No
Blueberry (Vaccinium uliginosum)	G5	SNR				*Arctic Scrub Birch-Ericaceous Shrubland, Arctic Dwarf-Shrubland*	*Inclusion as one of the regions important plant subsistence food. This species occurs on most acidic tundra and woodland habitats*	Coarse-filter	No	Yes
Cloudberry/Salmonberry (Rubus chamaemorus)	G5	SNR				*Arctic Dwarf-Shrubland, Arctic Wet Sedge-Sphagnum Peatland*	*Inclusion as one of the regions most important plant subsistence food*	Coarse-filter	No	Yes

	Global Rank	State Rank	AK SWAPs	Federal Listing	BLM	Ecological Systems	Comments	Assessment Approach	Data gap	Distribution Model
Crowberry/Blackberry (Empetrum nigrum)	G5	SNR				*Arctic Scrub Birch-Ericaceous Shrubland, Arctic Acidic Dwarf-Shrub Lichen Tundra, Arctic Non-Acidic Dwarf-Shrub Lichen Tundr, Arctic Dwarf-Shrubland*	*Inclusion as one of the region's most important plant subsistence food*	Coarse-filter	No	Yes

Appendix II. Conceptual Model for Bristle-thighed Curlew

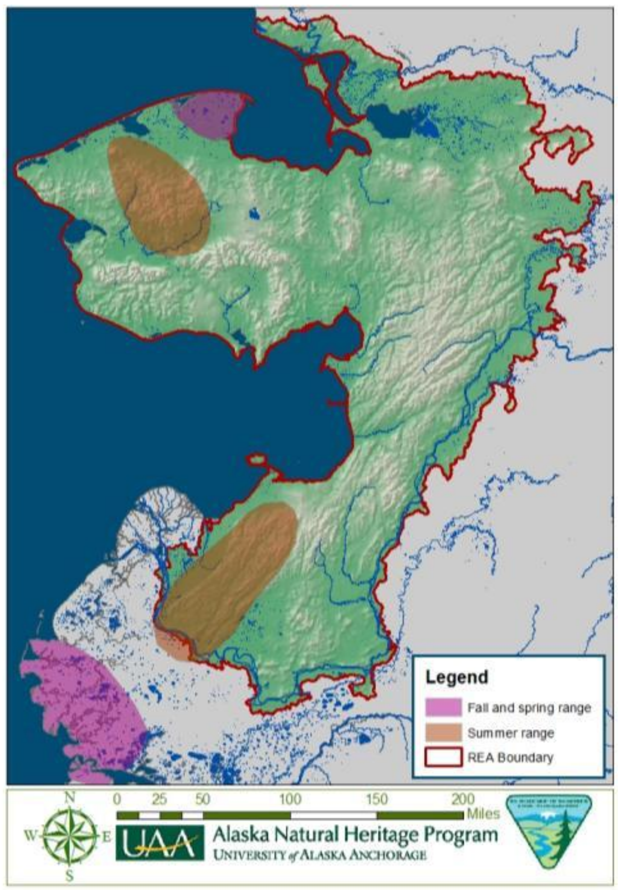
Conservation Element (CE) Characterization

Summary

The entire breeding range of the Bristle-thighed Curlew (*Numenius tahitiensis*) is restricted to two remote mountainous regions of western Alaska: the Andreafsky Wilderness Area northeast of the Yukon River mouth, and on the north central Seward Peninsula (Marks et al. 2002). Non-breeding individuals occur on coastal tundra from Kotzebue Sound south to Hooper Bay (Figure 1). The breeding areas are not contiguous (Marks et al. 2002). The breeding population on the Seward Peninsula accounts for about 40% of the species global population, which is estimated at less than 3,200 pairs (Wetlands International 2002, Brown et al. 2001, Morrison et al. 2001).

The U.S. Shorebird Conservation Plan lists Bristle-thighed Curlew as a "Species of High Concern," based on relative abundance, threats on non-breeding grounds, and restricted breeding distribution. Its reliance on a small area for breeding in western Alaska places it at high risk to potentially disruptive activities such as gold mining.

Figure 1. Coarse-level breeding range extent of the Bristle-thighed Curlew (*Numenius tahitiensis*) in Alaska.



Habitat Preferences

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 subarctic 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.

Migration/Mobility

This species flies at least 4,000 km nonstop between Alaska and the northern end of the non-breeding range in the northwestern Hawaiian Islands. Most northbound migrants arrive at breeding areas in Alaska during first three weeks of May (Marks et al. 2002). From June to August, curlews gather 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).

Reproduction Comments

Spring migrants usually arrive singly or in groups of two, occasionally in flocks. Nest building begins within 1-3 days of arrival. At Nulato Hills (1987-1991), most nests were initiated during last two weeks of May with successful nests hatching from 15-30 June. 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). When 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 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).

Food Preferences

Diet consists of crowberries (*Empetrum nigrum*), lingonberries (*Vaccinium vitis-idaea*), and bog cranberries (*Vaccinium oxycoccus*), less frequently bog blueberries (*Vaccinium uliginosum*) and alpine bearberries (*Arctostaphylos alpina*). Will also take invertebrates including spiders, beetles, moths, and butterflies (Mark et al. 2002).

Ecology

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 the 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, and0.6-1.0 km (up to 2.6 km) in fourth and fifth weeks (Lanctot et al.1995).

On staging grounds, birds gather 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).

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 (Marks et al. 2002).

Forms temporary associations with American and Pacific Golden Plover (*Pluvialis dominica* and *P. fulva*), Whimbrel (*Numenius phaeopus*), Bar-tailed Godwit (*Limosa lapponica*), Western Sandpiper (*Calidris mauri*) 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).

Change Agent (CA) Characterization

Altered Dynamics

On their breeding grounds the Bristle-thighed Curlew suffers predation by Parasitic Jaeger, Common Raven and several raptor species, as well as foxes. Activities associated with the expanding development of gold mines and mining roads on the Seward Peninsula is an increasing threat that could have a significant impact on this species, due to its reliance on this small area for breeding. There is also concern regarding disturbance on breeding ground regarding future oil and gas exploration. Livestock grazing may also alter dynamics due to trampling or OHV use associated with herding. Humans also have an effect by off-road hunting of other species.

Gold Mining

Avian species are particularly vulnerable to disturbance during stressful periods during their life history such as nesting and molting. Small scale placer mining is widespread throughout the region and could negatively impact Bristle-thighed Curlew during the breeding and post-breeding season. Impacts to the species and other ground nesting birds in the area include temporary disturbance or displacement in localized areas, temporary loss of habitat, long-term degradation of habitat, and possible direct mortality of nestling birds or eggs during clearing of land.

Gas and Oil Exploration and Development

The Cape Espenberg oil and gas well sits at the perimeter of the species spring/fall staging grounds on the northern Seward Peninsula. There is also an oil and gas basin that completely surrounds this staging area, although it is not actively being explored (Kobuk-Seward Peninsula Proposed RMP/Final EIS 2005). Potential effects of oil-development activities include both direct and indirect habitat loss. Direct loss of habitat would result from gravel mining and gravel deposition on the tundra for roads, pads, and airstrips. Roads and pads are constructed using gravel, and tundra covered by gravel would no longer be available for nesting, brood-rearing, or foraging. This loss of habitat would continue for as long as the proposed development was in operation. If abandonment plans call for allowing gravel pads and roads to "bed" naturally, loss of habitat may extend considerably longer than the end of the operational life of the field. There could also be indirect habitat loss through reduced access caused by physical or behavioral barriers created by roads, pipelines, and other facilities (Kobuk-Seward Peninsula Proposed RMP/Final EIS 2005).

Current concern is the existing oil and gas site situated near the species staging area. There is currently no known exploration or development within species breeding range.

Urbanization and Road Construction

Habitats subject to intensive urbanization do not provide suitable Bristle-thighed Curlew habitat and would likely eliminate curlew populations from affected areas. Urbanization in the region is generally small-scale and not considered a significant threat. However, activities associated with road construction could result in long-term degradation of habitat and alteration, disturbance at nest sites, trampling and possible mortality of nesting birds. Roads also provide increased access into formerly remote habitats due to the proliferation of trails that usually follow improved road access. Increased urbanization may also indirectly result in an increase in nest predators. Common Ravens and Arctic foxes are both associated with human habitation - especially around refuse sites. Both of these species are known predators of Bristle-thighed Curlew on the breeding grounds.

Subsistence Hunting

Subsistence hunting for caribou, moose and waterfowl is widespread throughout the region. Humans may have a direct effect to nesting birds through disturbance and trampling at breeding sites when off-road hunting for other species.

Reindeer Grazing

The Bristle-thighed Curlew could potentially be negatively impacted by reindeer grazing activities on the Seward Peninsula. There are numerous reindeer grazing allotments throughout the Seward Peninsula – many of which overlap with the breeding range of Bristle-thighed Curlew. Reindeer grazing activities could result in minor impacts to habitat due to cratering and exposure of mineral soils. In rare cases, there could potentially be direct mortality of nestling birds or eggs (as this is a ground nesting species) due to trampling by reindeer or OHV use associated with herding activities (Kobuk-Seward Peninsula Proposed RMP/Final EIS 2005).

Ecological Status Assessment Criteria

This analysis will be based on a habitat distribution spatial model (or habitat probability surface model), which is a required input for assessing habitat integrity. We will build upon the habitat distribution models developed by the AKGAP program for Bristle-thighed Curlew. Our models will include a predicted current habitat distribution (factoring in current land use variables. The status assessment criteria are organized by the rank factors Landscape Context and Condition and assessed using indicators that can be evaluated at the appropriate spatial scale. For conservation elements the reporting unit is at the Watershed 5th Level (HUC – 10).

Landscape Context

Landscape Condition model (LCM) index - This example indicator is measured in a GIS by intersecting the habitat distribution map for Bristle-thighed Curlew with the NatureServe LCM layer as adapted for the SNK (Comer and Hak 2009, Appendix IV) and reporting the overall LCM index for the habitat. The program results are an index of Landscape Condition from 0 to 1 with 1 being very high landscape condition and 0 having very poor condition.

Condition

Abundance of invasive species – This indicator is measured in a GIS by intersecting the habitat distribution map for Bristle-thighed Curlew with a layer of invasive animal species (e.g., rates) developed specifically for the REA. The results are an index of landscape condition from 0 to1 with 1 indicating a sustainable system with no non-native infestations and 0 being a very degraded system due to numerous infestations.

Table 1. Ecological Status Assessment Scorecard for Bristle-thighed Curlew.

Indicator	Justification	Rating			Index Score
		Sustainable	Transitioning	Degraded	
Rank Factor: LANDSCAPE CONTEXT					
Key Ecological Indicator: *Landscape Condition*					
Landscape Condition Model Index	Land use impacts vary in their intensity, affecting ecological dynamics that support species habitat.	Cumulative level of impacts is sustainable. Landscape Condition Model Index > 0.8	Cumulative level of impacts is transitioning habitat between sustainable and degraded state. Landscape Condition Model Index 0.75 – 0.5	Cumulative level of impacts has degraded habitat. Landscape Condition Model Index < 0.5	**0.7**

Indicator	Justification	Rating			Index Score
		Sustainable	Transitioning	Degraded	
Rank Factor: CONDITION					
Key Ecological Indicator: *Native Species Composition*					
Invasive Species Index	Invasive species can impact ecological systems and species.	System is sustainable with no non-native species infestations. Invasive Species Index is 1.	System transitioning to degraded state by presence of non-native species with 1-24 infestations of non-native species. Invasive Species Index is 0.5-0.9.	System is degraded by invasive species. One or more infestations of highly invasive species or > 24 total infestations. Invasive Species Index is <0.5.	**0.9**
Rank Factor: Relative Extent					
Overall Ecological Integrity Rank					
				Mean Index Score	**0.8**

References

Brown, S., C. Hickey, B. Harrington, and R. Gill (Eds). 2001. United States shorebird conservation plan, 2nd edition. Manomet Center for Conservation Sciences, Manomet, MA. Available online at: http://www.manomet.org/USSCP/files.htm

Comer, P.J. and J Hak. 2009. NatureServe Landscape Condition Model. Technical documentation for NatureServe Vista decision support software engineering. NatureServe, Boulder CO.

Gill, R.E. Jr. 1998. Trouble in paradise: the Bristle-thighed Curlew. World Wildlife Fund. Arctic Bull. 4:12-13

Gill, R.E., Jr. and C.M. Handel. 1987. The status of the Bristle-thighed Curlew (*Numenius tahitiensis*): Should we be concerned? U.S. Fish and Wildlife Service paper presented at the Alaska Bird Conference and Workshop, 3-4 April 1987 Centennial Hall, Juneau, AK.

Gill, R.E., Jr., R.B. Lanctot, J.D. Mason, and C.M. Handel. 1990. Observations on habitat use, breeding chronology, and parental care in Bristle-thighed Curlews on the Seward Peninsula, Alaska. Wader Study Group Bulletin 61:28-36.

Handel, C.M., and C.P. Dau. 1988. Seasonal occurrence of migrant Whimbrels and Bristle- thighed Curlews on the Yukon-Kuskokwim delta, Alaska. Condor 90:782-790.

Kyllingstad, H.C. 1948. The secret of the Bristle-thighed Curlew. Arctic 1(2):113-118.

Lanctot, R.B., R.E. Gill, Jr., T.L. Tibbits, and C.M. Handel. 1995. Brood amalgamation in the Bristle-thighed Curlew, *Numenius tahitiensis*: process and function. Ibis 137: 559-569.

Marks, J.S., T.L. Tibbits, R.E. Gill, and B. J. McCaffery. 2002. Bristle-thighed Curlew (*Numenius tahitiensis*). In: A. Poole and F. Gill, (eds.). The Birds of North America, No.705. The Birds of North America, Inc., Philadelphia, PA.

McCaffery, B.J. and G. Peltola, Jr. 1986. The status of the Bristle-thighed Curlew on the Yukon Delta National Wildlife Refuge. Wader Study Group Bull. 47:22-25.

McCaffery, B.J. and R.E. Gill, Jr. 1992. Antipredator strategies in breeding Bristle-thighed Curlews. Amer. Birds 46(3):378-383.

McRae, B. H. 2006. Isolation by resistance. Evolution 60:1551-1561.
McRae, B. H., B. G. Dickson, T. H. Keitt, and V. B. Shah. 2008. Using circuit theory to model connectivity in ecology and conservation. Ecology 10: 2712-2724.
Morrison, R.I.G., R.E. Gill, B.A. Harrington, S. Skagen, G.W. Page, C.L. Gratto-Trevor, and S.M. Haig. 2001. Estimates of shorebird populations in North America. Occasional Paper, Number 104, Canadian Wildlife Service, Environment Canda, Ottawa, ON. 64 pp.
Tibbitts, L. 1990. Phenology and habitat use during ground surveys of the Yukon-Kuskokwim River Delta. Pp. 11-13 in: Summary of the proceedings from the workshop on Bristle-thighed Curlews (R.E. Gill, Jr., and C.M. Handel, compilers). U.S. Fish and Wildlife Service, Anchorage, AK.
USDI BLM. 2006. Kobuk-Seward Peninsula Resource Management Plan and Environmental Impact Statement. Prepared by the Fairbanks District Office and Anchorage Field Office.
Wetlands International. 2002. Waterbird population estimates - Third edition. Wetlands International Global Series No. 12, Wageningen, The Netherlands.

Appendix III. Management Questions: Referenced to Data Inputs and Modeling Categories

Number	Group	Management Question (proposed form)	Original MQ if different	MQ Status	Data Sources and Recommendation	Applicable Models	Data Needs and Evaluation Comments
2	Subsistence	How could changes in sea mammal harvests potentially affect land based hunting and fishing?	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.)	ACCEPT	ADFG harvest data.	Intersect subsistence species range maps (caribou, walrus, seals, bowhead whales) with communities. Indentify proximity of terrestrial and marine species to communities. Assess population changes for subsistence species intersecting scenario + condition model	baseline, table data to map
3	Subsistence	(A) What is the current population and range of moose? (B) What are moose harvest levels? (C) Are there reports of use conflicts among user groups?	At what point should we be thinking about managing for moose rather than caribou?	ACCEPT Part A. Parts B and C are OUT OF SCOPE	Moose distribution model (GAP), moose range map (AKNHP), moose survey data (FWS). ADFG general hunting and subsistence harvest data. Reports about user conflicts. Map moose harvests by community.	Existing data or distribution model + intersect scenarios, Identify current moose harvest levels, Identify reports about user conflicts.	Baseline table to map, regs
4	Subsistence	How much have harvests (lbs.) changed over the past 20 years?	Are peoples' subsistence needs being met? How, where, how many, etc.? and how will change affect?	ACCEPT	ADFG harvest data.	Compare current harvest data to historical use	Baseline table to map
6	Subsistence	Which species make up the largest share (lbs.) of subsistence harvests? How is this changing?	We need to know more about what the subsistence species are and their use patterns. And how is this changing? How could access to subsistence resources change?	ACCEPT	ADFG harvest data.	Current harvest data + intersect scenarios	Baseline table to map.
7	Subsistence	Given current and estimates of future subsistence species populations, are harvest regulations adequate to protect subsistence species populations?	How will harvest regulations reflect species availability?	ACCEPT	ADFG harvest data.	Current harvest data + intersect scenarios + harvest regulations. Also estimate relationship between fuel price and harvest.	
9	Subsistence	How have hunting and fishing regulations affected general hunting and fishing harvests?		ACCEPT	Need to get copies of regulations - reports not data.	Current harvest data + harvest regulations	past
10	Subsistence	What are the current ranges of subsistence species? Where are the subsistence communities?	With climate change, what will the impacts be to subsistence spp. (specific species, habitat) and what is the time frame that villages need to be aware of regarding subsistence species that they rely upon?	ACCEPT	Subsistence species range maps. BLM map from EIS has subsistence use areas - cites ADFG as source. We should ask BLM. Caribou range data come from ADFG but BLM might have copies.	Subsistence species range maps + subsistence use areas	current, census maps
11	Subsistence	In which locations are climate change events likely to affect subsistence species?		ACCEPT	Subsistence species range maps + SNAP climate change scenarios	Subsistence species range maps + CA scenarios	
12	Subsistence	Given likely scenarios for changes in hydrological systems, what changes can be expected in subsistence species.	How will the changes to hydrological systems affect subsistence species?	REDUNDANT	SNAP can provide climate projections and possibly P-PET (summer precipitation - potential evapotranspiration) model outputs.	Subsistence species range maps + CA scenarios	This question is the same as MQ 116 (hydrologic regime) and subsistence fish species will be covered in that MQ.
13	Subsistence	How could changes in snowfall, rain and icing events potentially impact subsistence species?	What snowfall changes will occur and what affect will it have on subsistence?	OUT OF SCOPE	SNAP can provide climate projections and possibly P-PET (summer precipitation - potential evapotranspiration) model outputs.	Subsistence species range maps + CA scenarios	

Number	Group	Management Question (proposed form)	Original MQ if different	MQ Status	Data Sources and Recommendation	Applicable Models	Data Needs and Evaluation Comments
15	Socioeconomic and population demographics	What are patterns of current tourism including hunting and fishing (e.g., total revenue, total visitors, and types of ecotourism)?	What is the current ecotourism industry and what is forecast?	ACCEPT	ISER tourism database, hunting permits.	Map of tourist counts at destinations.	
16	Socioeconomic and population demographics	(A) What is the current socio-economic profile for each community? (B) How are they likely to change under development and climate scenarios?	What are the predicted socioeconomic changes in the different villages? Are shoreline communities likely to be more or less affected? Compared to villages not on the ocean shoreline?	ACCEPT	Community planning documents. Population projections from Alaska Department of Labor (modified by ISER).	Socio-economic profile + CA scenario. Including locations of prospective sites for village relocations.	
18	Socioeconomic and population demographics	How are changes in climate likely to affect tourism destination sites, numbers of tourists and revenues?		ACCEPT	ISER tourism database.	Tourism sites + CA scenarios	
20	Socioeconomic and population demographics	Where will relevant infrastructure potentially experience significant changes in soil thermal regime?	What are the implications for infrastructure given permafrost melt?	REDUNDANT	SNAP can provide GIPL model outputs for projected changes in soil thermal dynamics (mean annual ground temperature at the base of the active layer and maximum active layer thickness)	Infrastructure + CA scenarios	recommend deletion - SNAP agrees as it is redundant with MQ # 159
23	Socioeconomic and population demographics	Based on output from storm surge models, which communities and infrastructure are most at risk for damage?	How will storm surges affect infrastructure? (Road to Council significantly eroded due to surges.)	OUT OF SCOPE	Storm surge data not currently available	Communities + Storm Surge Models	ISER will need to reframe this question if they wish to retain it. ISER agrees.
24	Socioeconomic and population demographics	How is climate change likely to affect community water supply and quality? Sewage disposal?	How will Moonlight springs—be affected by climate change (main water supply to Nome)?	OUT OF SCOPE		???	Do not have specific Climate change data at such as small scale. Only location of water and sewer. Not enough information to model. Recommend delete.
26	Socioeconomic and population demographics	Where are sewage lagoons and dumps? Which are at risk by climate related ecological change?	How do sewage lagoons, wastewater systems, dumps, FUDS/Dewline, other hazardous sites, and air pollution impact species/habitats?	OUT OF SCOPE		Sewage lagoons and dumps + intersect scenarios	Check with DEC about local problems with dumps and sewage lagoons.
28	Socioeconomic and population demographics	What types of traditional and local knowledge data exist for the region and then how can these data be best incorporated into management decisions?	Customary and Traditional Knowledge-elders are commenting they are no longer able to accurately predict/interpret weather, freeze /thaw dates, fire behavior, and regional temperatures – how will changes affect traditional knowledge delivery?	ACCEPT	LTER project at UAF	This is part of the report. It could also inform scenarios. Some rule based models (moose in the interior region) are being developed based on TEK but are not ready for use yet.	Reports from LTER project
29	Socioeconomic and population demographics	Among areas at risk of river erosion, which threaten relevant CEs?		ACCEPT	SNAP - To assess risk, we could overlay fire scenarios, hydrology and topography (DEM) spatial data for the ecoregion	fire regime projections, hydrology and topography + intersect CE distributions	
30	Socioeconomic and population demographics	Where will losses of lakes potentially affect water supply to villages?		ACCEPT	SNAP - To assess the affect of loss of lakes on water supply to villages, we could overlay community water sources (lakes) projected changes in soil thermal regime and possibly P-PET (summer precipitation - potential evapotranspiration)	soil thermal regime projections and possibly P-PET + intersect with community water sources	

Number	Group	Management Question (proposed form)	Original MQ if different	MQ Status	Data Sources and Recommendation	Applicable Models	Data Needs and Evaluation Comments
33	Development	Will the changes to permafrost and hydrological resources affect mining practices or opportunities (i.e. the NPDES permits for waste water)?	Will the changes to permafrost and hydrological resources affect mining practices or opportunities (i.e. the NPDES permits for waste water)?	REVIEW AT AMT3	SNAP can provide projected changes in soil thermal regime and possibly P-PET (summer precipitation - potential evapotranspiration) model outputs	soil thermal regime projections and possibly P-PET + intersect with mining data	ISER will need to reframe this question if they wish to retain it. SNAP can only evaluate it from the perspective of potential future scenarios of soil thermal regime and climate. ISER agrees.
36	Development	Where are lands that are and are not available for development?	Are we striking a good balance between development activities and habitat protection? and how do we do that?	OUT OF SCOPE	Land ownership map.	Map	
37	Development	Where are areas that experience significant plastic on beaches?	How is all the plastic on the beaches of Kobuk Lake (and elsewhere) affecting species?	OUT OF SCOPE		???	
39	Development	Is there evidence of contaminants in subsistence foods? In which species/locations?	Unexplained potential anthropogenic impacts: milk production in male caribou; lesions on fish; persistent organic pollutant impacts, thickness of seagull eggshells?	OUT OF SCOPE	EPA data - do not have yet.	???	EPA data.
44	Development	How are transporters/tourism/sport hunt and fishing affecting the migration patterns of caribou?	How are transporters/tourism/sport hunt and fishing affecting the migration patterns of caribou?	ACCEPT	Reports.	Caribou range maps + intersect transportation/tourism/sport hunting	Literature review. Map instances of human intervention shifting migration.
45	Development	Where are current and planned oil/gas activities located and where do they overlap with CEs or other relevant habitats?	What is the extent and impact of Oil/Gas activities?	ACCEPT	Have reports of Socio-economic impacts of off shore oil development on local communities.	Oil/gas + intersect CE distribution model	Have oil and gas potential map. Have reports of on-shore impacts of Chukchi Sea development.
46	Development	Where are historic, current and potential mining activities located, and where do they overlap with CEs or other relevant habitat?	What is the current status and impacts from mining, including past mining?	ACCEPT	Have digital maps.	Mining + intersect CE distribution models	Have map.
49	Development	Where are current and potential recreational use areas located, and where do they overlap with CEs or other relevant habitat?	Where the concentrated areas of recreation are and what is the forecast or potential for future areas? Impacts sport and trophy industry?	ACCEPT	Map of recreation areas, have digital	Recreation + intersect CE distribution models	Have map of recreation areas.
50	Development	Where are current and planned roads located, and where do they overlap with CEs or other relevant habitat?	Where are the travel corridors located and what are the related impacts and what is forecast?	ACCEPT	Nome road proposed route, have hardcopy	Roads + intersect CE distribution models	Have hard copy map. Need to get digital.
51	Development	Where are historic, current and planned military sites located, and where do they overlap with CEs?	What is the current status and impacts if any from military lands and what is forecast?	ACCEPT	Contained in DEC contaminated sites map.	Military sites + intersect CE distribution models	Have DEC map.
52	Development	Where potential renewable energy sites located and where do they overlap with CEs or other relevant habitats?	Will there be a change in renewable energy opportunities? For example: Biomass, geothermal, wind farms, etc. And to what extent and where are these areas?	ACCEPT	Have digital map, reports.	Renewable energy sites + intersect CE distribution models	Have map (ISER)

Number	Group	Management Question (proposed form)	Original MQ if different	MQ Status	Data Sources and Recommendation	Applicable Models	Data Needs and Evaluation Comments
60	Species	What is the current distribution of each CE?	What is the current distribution of each CE?	ACCEPT	Matt-Biotics Plants and Arctos (for desired plant CE) data available. Tracey - GAP distribution models for terrestrial animals as well as occurrence and survey data for many individual species.	Existing data or distribution model	
61	Species	What areas have been surveyed (i.e., inventoried) for each CE and what areas have not been surveyed (i.e., data gap locations)? How does survey intensity vary across the region?		ACCEPT	Matt-Biotics Plants and Arctos (for desired plant CE) data available, Keith/Monica -Vegetation plot database. Tracey - for desired animal CEs, GAP occurrence database which is comprised of numerous surveys datasets, plus additional survey data obtained for this project specifically.	Existing data + intersect with distribution model	
62	Species	Where do current CE distributions overlap with CA?		ACCEPT	Matt-Biotics Plants, + Arctos (des CE), + AKEPIC (non-native plants CA) in Master Data List, Tracey - Terrestrial CE GAP Distribution models and individual species range maps, SNAP - climate models	Existing data or distribution model + intersect scenarios + condition model	
63		Where will the distribution of CEs and wildlife ranges likely experience significant change in climate?		ACCEPT	same data as MQ#62	Existing data or distribution model + intersect scenarios + condition model	
64	Species	Where are CEs whose habitats are systematically threatened by CAs (other than climate change)?		ACCEPT	same data as MQ#62	Existing data or distribution model + intersect scenarios + condition model	
65	Species	What is the current distribution of the suitable habitats for each CE? *[A subset of CE to de proposed in Tasks 2 and 3]*	What is the current status of occupied habitat, including seasonal habitat and specialty habitat (calving, insect relief, etc.), and movement corridors? Current status compared to historical?	REDUNDANT	Answered in MQ# 86 - **REMOVE**	Existing data or distribution model (potential habitat)	
66	Species	What habitats are critical for species sustainability?	Where are habitats that may be limiting species sustainability?	REDUNDANT	Answered in MQ# 86 - **REMOVE**	Existing data or distribution model (potential habitat)	

Number	Group	Management Question (proposed form)	Original MQ if different	MQ Status	Data Sources and Recommendation	Applicable Models	Data Needs and Evaluation Comments
68	Species	What CE populations and movement corridors overlap with CA?	Where are change agents affecting this habitat and movement corridors?	ACCEPT	SNAP can provide climate projections and model outputs for fire (ALFRESCO model) and soil thermal dynamics (GIPL model). Tracey can provide species range maps, and distribution models for each species. Matt has Arctos (des CE), + AKEPIC (non-native plants CA) in Master Data List. We have seasonal range maps for caribou and some information on seasonal movements. We do not have this information for muskox. We have a lot of information on moose, but only for a limited area (Selawik NWR). Therefore, we can try to answer this question, but it may be limited to only one or 2 terrestrial CEs.	Existing data or distribution model (potential habitat) + intersect scenarios	
72	Species	Where are moose, caribou and musk ox habitats likely to experience significant changes due to climate change?	What are the predicted effects to moose habitat, specifically willow browse and what are the predicted trends?	REDUNDANT	Tracey can provide information on current habitat preferences and locations. SNAP can provide climate projections and model outputs for fire (ALFRESCO model) and soil thermal dynamics (GIPL model).	Existing data or distribution model + intersect scenarios + condition model	REDUNDANT with MQ#63
73	Species	Is there a predicted increase in mosquito/insect populations and how will this affect the wildlife resources (insect relief areas)?	Is there a predicted increase in mosquito/insect populations and how will this affect the wildlife resources (insect relief areas)?	OUT OF SCOPE	We have current information on insect relief areas, but whether or not there is going to be predicted increase is likely to come from the literature, not a model.	Insect relief areas + intersect existing data or distribution models	
74	Species	Will climate change cause increased chance of disease in wildlife populations? What disease(s) are likely to be introduced or increase?	Will climate change cause increased chance of disease in wildlife populations? What disease(s) are likely to be introduced or increase?	ACCEPT	This question cannot be modeled spatially. Research questions beyond the scope of this work - answers may be available in the literature, but we don't have sufficient data to model this.		
75	Species	What snowfall changes will occur and what affect will it have on wildlife (mobility, predation, habitat shifts)?	What snowfall changes will occur and what affect will it have on wildlife (mobility, predation, habitat shifts)?	OUT OF SCOPE	SNAP can provide climate projections for precipitation. These data are snow water equivalent (SWE)	climate projections	The future scenarios SNAP can provide are crude and AKNHP does not think this will provide much insight into the question as stated.
78	Species	Which CE's are likely to be more vulnerable due to dispersal barriers?	Where are potential areas to restore connectivity?	ACCEPT	Tracey can answer this question using basic topographical data. These questions may be difficult to address, but the proposed model type and topographical analyses seems like a logical approach and worth a try.	Future distribution models + Existing data or distribution models	

Number	Group	Management Question (proposed form)	Original MQ if different	MQ Status	Data Sources and Recommendation	Applicable Models	Data Needs and Evaluation Comments
79	Species	Given current and anticipated future locations of change agents, not including climate change, where will potential habitat enhancement/restoration locations likely occur?	Where are potential habitat restoration areas?	ACCEPT	Conceptual models, EIA scorecards, landscape condition models, landscape connectivity models. Criteria for evaluating ecological integrity exist in some form for most Coarse Filter CEs. These conceptual models will be customized for fine-filter CEs among the landscape species and species assemblages. These form the conceptual foundation for ecological integrity scorecards, and spatial models that link CAs to CE integrity. For example, possibly streams impacted by placer mining.	Existing data or distribution model + intersect scenarios + restoration model	
80	Species	How will icing events affect habitat availability?	How will icing events affect habitat availability?	OUT OF SCOPE			Icing events are not predictable with the current SNAP down-scaled climate models. Subsume with other extreme events issues, capture in conceptual models, and pursue as far as possible with any spatial modeling. Or look within the weather section. Include this in the planned list of RESEARCH ISSUES
84	Species	With recent science concluding that musk ox are eating lichens now, how is this going to affect winter range availability for reindeer and caribou?	How will these changes affect caribou and reindeer populations/migration patterns that rely on the lichens for winter habitat? With recent science concluding that musk ox are eating lichens now, how is this going to affect winter range availability for reindeer and caribou?	ACCEPT	We have winter range maps for caribou and seasonal grazing data for reindeer. Lichen data is available through some of the ecological systems.	Literature review only	
86	Native Plant Communities	What habitats support terrestrial species of concern (rare plants, rare animals, and subsistence species)?		ACCEPT	Distribution Models (GAP analysis) + EO data (Matt- Biotics Plants, + Arctos (des CE) in Master Data List) + Ecological Systems map + Finer scale land cover map	Overlay Distribution Models (GAP analysis) + EO data + Ecological Systems map + Finer scale land cover map + Plant Associations	
87	Native Plant Communities	How will habitats that support terrestrial species of concern likely change due to disturbance or climate change over the next 15 and 50 years?		ACCEPT	SNAP can provide climate projections and model outputs for fire (ALFRESCO model) and soil thermal dynamics (GIPL model).	Ecological systems (Healy) - species climate envelope models + SNAP models + intersect landscape condition model	
88	Native Plant Communities	Evaluate whether all species and ecosystems are conserved within the conservation network of the study area currently and over the next 15 and 50 years given climate change.		ACCEPT	GAP data, Ecological Systems map - maybe SNAP models, aquatic coarse filter, Protected Areas database, Species climate envelope models	GAP data + Ecological Systems Map + Species Assemblage Data + Protected Areas Database + Apply conservation requirement criteria to assess conservation status + use similar methods to look at future CE distribution (standard GAP products)	

Number	Group	Management Question (proposed form)	Original MQ if different	MQ Status	Data Sources and Recommendation	Applicable Models	Data Needs and Evaluation Comments
90	Native Plant Communities	Where are high priority native plant associations and ecological systems? (i.e. rare associations/ecological systems or associations that support species of concern)	Where are intact CE vegetative communities located?	REDUNDANT	**REMOVE** Answered in MQ#86 - combine with above	Answered in MQ#86	
100	Native Plant Communities	Which native plant communities will likely experience climate completely outside their normal range?	How will the distribution of native flora and fauna communities change with climate change (shrub habitat replacing sedge/lichen communities, extent of anadromy, diversity, areas with highest potential to change)?	REDUNDANT	**REMOVE** Answered in MQ#87 - combine with above	Answered in MQ#87	
102	Livestock (Reindeer Grazing)	Where are the current populations of Reindeer? What is the current and historic herd size?	Where are the current populations of Reindeer?	ACCEPT	Reindeer grazing allotments and location information.	Existing data, range map	
103	Livestock (Reindeer Grazing)	Will suitable habitat for caribou be available with climate change?	Will Reindeer grazing grow if caribou decline due to climate and other change agents?	ACCEPT	Tracey-current habitat, SNAP - climate projection, ISER - Teller herd collar data.	Future distribution models + future vegetation models (CA Scenarios)	
104	Livestock (Reindeer Grazing)	Where will current Reindeer grazing areas experience climate completely outside their normal range?	With climate change, what may affect the reindeer grazing viability?	ACCEPT	Reindeer grazing allotments and existing data, predicted distribution model derived from habitat preferences.	Current distribution model or grazing allotments + CA Scenarios	
105	Livestock (Reindeer Grazing)	Where will current populations of Reindeer experience overlap with Change Agents?		ACCEPT	Tracey-current habitat, SNAP - climate projection, fire, soils models, ISER - Teller herd collar data. Western Arctic herd collar data (ADFG) + development data	Current distribution model or grazing allotments + CA Scenarios	
106	Livestock (Reindeer Grazing)	How have the reindeer herds changed over time? How do herds affect grazing areas?	What are the impacts on the ecoregion from reindeer grazing (ecosystem, socioeconomic,)?	ACCEPT	ISER - Reports on Teller and Western Arctic herds.	Map of grazing allotments with information about herd size.	
109	Aquatic ecological function and structure	How may climate change affect barge transportation to rural villages?	How may this affect barge transportation to rural villages?	OUT OF SCOPE	ISER - Reports on current difficulties.		
111	Aquatic ecological function and structure	Where are hazardous waste sites?	Where are hazardous waste sites and how will climate change exacerbate pollution entering the environment?	ACCEPT	Map of sites from AK Department of Environmental Conservation.		
113	Aquatic ecological function and structure	Where are the important aquatic resources, such as spawning grounds and other fish habitats? (herring spawning grounds and areas used by waterfowl?)	Where are the regionally important aquatic values?	ACCEPT	USFWS report on sheefish spawning ground on Selawik, AWC for salmon spawning areas, and other ADF&G reports	Existing data	
114	Aquatic ecological function and structure	What is the condition of these various aquatic systems?		ACCEPT	See Memo 2-3, Volume 3 for datasets to be used in the ecological integrity assessment	Ecological integrity assessment for aquatic resources	

Number	Group	Management Question (proposed form)	Original MQ if different	MQ Status	Data Sources and Recommendation	Applicable Models	Data Needs and Evaluation Comments
116	Aquatic ecological function and structure	Where are predicted changes in hydrologic regime associated with important aquatic resources?	Where are aquatic resources that will likely experience significant and abrupt deviations from normal flow regime or mean water levels?	ACCEPT	SNAP can provide climate projections and P-PET (summer precipitation - potential evapotranspiration) model outputs. We also have access to SWE (snow water equivalent) historical data.	Hydrologic regime change will be based on the P-PET model (summer precipitation - potential evapotranspiration). The P-PET model output will be intersected with the aquatic resource distribution models to locate areas of potential change.	
117	Aquatic ecological function and structure	Where are predicted changes in air temperature associated with important aquatic resources?		ACCEPT	SNAP- climate projections. Dan/Becky-To model effect on water temperature, we need contributions of surface versus groundwater for rivers/streams because groundwater will buffer changes in air temperature. It is very likely gw/sw data does not exist.	Predicted air temperature will come from SNAP climate models and outputs will be intersected with the aquatic resource distribution models to locate areas of potential change.	
118	Aquatic ecological function and structure	Where will Essential Fish Habitat likely experience significant and abrupt deviations from normal temperature regime?	Essential Fish Habitat - How will these areas be affected by the predicted changes, and within what timeframes?	REDUNDANT	same as #117		This question is the same as MQ 117. Essential Fish Habitat is any habitat used by salmon, which are included on the list of aquatic conservation elements.
120	Fire	How is the potential future fire regime anticipated to impact permafrost?	How will fires impact the permafrost?	ACCEPT	Literature review	Literature review	
122	Fire	Where are predicted changes in future fire regime associated with rivers?	How will fires affect sedimentation into nearby rivers?	ACCEPT	SNAP can assess effect of fire on sedimentation by overlaying model outputs for fire (ALFRESCO model), topography (DEM) and river localities	fire regime projections and topography + intersect with river localities	
126	Fire	What is the known lightning strike frequency in the ecoregion? Do these data show a significant trend over time?	What is the change in lightning strike frequency and distribution and subsequent ignition?	ACCEPT	SNAP will compile the known lightning strike frequency (from Alaska Fire Service) in the ecoregion and determine if there is a trend over time.)	Linear regression analysis of year x number of lightning strikes	
129	Fire	What is the known fire history of the ecoregion and what is the potential future fire regime? What are the implications for vegetation?	Fire Potential – where are the areas of highest potential to change from historic and/or predicted wildfire patterns?	ACCEPT	SNAP can provide historical fire data (from Alaska Fire Service) and model outputs for future fire regime and resulting vegetation (ALFRESCO model).	compare historical and future fire regime using the existing ALFRESCO model	
129.5	Fire	What does the paleontological record reveal about fire history within the ecoregion?		ACCEPT	Literature review	Literature review	
130	Fire	Where are areas of predicted high future fire risk associated with current caribou habitat, winter range, and calving sites?	Where are the areas with highest risks to caribou habitat? Calving sites/wintering range for caribou/musk ox/moose	REVIEW AT AMT 3 REFRAME/POSSIBLE REDUNDANT	SNAP can provide model outputs for future fire regime (ALFRESCO model). Tracey - current data for caribou habitat, winter range and calving sites.	fire regime projections + intersect with caribou distribution	AKNHP will need to determine if we should retain this question given the available caribou data. We can also refer to Kyle Joly's work and cite his dissertation as he defended last month.
132	Fire	What is the probability of fire, based on model scenarios, near existing communities?	What is the risk to communities for wildfire and smoke?	ACCEPT	SNAP can provide historical fire data (from Alaska Fire Service) and model outputs for future fire regime.	future fire regime projections + intersect with communities	
134	Invasive species	Where have recent beetle outbreaks occurred?	What affect will beetle populations have on fire regime and vice versa?	ACCEPT	State and Private Forestry	Existing maps	

Number	Group	Management Question (proposed form)	Original MQ if different	MQ Status	Data Sources and Recommendation	Applicable Models	Data Needs and Evaluation Comments
138	Invasive species	What is the current distribution of invasive species included as CAs?	What is the extent of specific introduced and/or invasive species and what are the expected trends and forecast for invasive plant occurrence?	ACCEPT	Matt-AKEPIC (non-native plants) data in Master Data List. Dan and Becky will evaluate *Elodea* (aquatic invasive plant).	Existing AKEPIC distribution data for all species, summarize Bella 2009 and Murphy et al. 2010, select four species for current predictive distribution models	
139	Invasive species	Given current patterns of occurrence, what is the potential future distribution of invasive species included as CAs? [From narrow list of species that are CA.]		ACCEPT	Matt-IC (non-native plants) data in Master Data List, Dan and Becky will evaluate *Elodea* (aquatic invasive plant), SNAP can provide climate projections and model outputs for fire (ALFRESCO model) and soil thermal dynamics (GIPL model).	Summarize Bella 2009 and Murphy et al. 2010, select four species for future predictive distribution models	
139.5	Invasive species	Which CE's are likely to be most affected by invasive species		ACCEPT	Matt-Biotics Plants, + Arctos (des CE), + AKEPIC (non-native plants CA) in Master Data List	Overlay current and future distributions of invasive plants with CEs	
143	Invasive species	What are the known and likely introduction vectors of invasive species?	What is the current status and forecast of invasives via straw and other use including river drainages? Subsequent impacts to moose wintering habitat	ACCEPT	Matt-AKEPIC data in Master Data List, Review Jeff Conn's publications for weed vectors, Flagstad and Cortes-Burns, etc., Dan/Becky - Dan and I will evaluate *Elodea* (aquatic invasive plant).	Summarize literature	
146.3	Invasive species	What is the historic and current range of beaver?		OUT OF SCOPE	No existing spatial datasets available. Unable to answer.		
146.4	Invasive species	What are the potential impacts of beaver establishment on CEs, including subsistence species??		OUT OF SCOPE	No existing spatial datasets available. Unable to answer.		
146.6	Invasive species	What is the historic and current range of coyotes?		OUT OF SCOPE	No existing spatial datasets available. Unable to answer.		
146.7	Invasive species	What are the potential impacts of coyotes on CEs, including subsistence species?		OUT OF SCOPE	No existing spatial datasets available. Unable to answer.		
147	Hydrology, Sea Ice, Weather, Permafrost, Soils	What are the potential future climate scenarios in the ecoregion for temperature and precipitation?		ACCEPT	SNAP can provide climate projections.	climate projections	
148	Hydrology, Sea Ice, Weather, Permafrost, Soils	What is the annual extent of sea ice and changes in proximity to shore by date and how is this changing?	What is the annual extent of sea ice and changes in proximity to shore by date and how is this changing?	OUT OF SCOPE			From SNAP's perspective, this question is un-answerable for the specific ecoregion given the available models/data. We may be able to address the question in a more general sense from a literature review.
154	Hydrology, Sea Ice, Weather, Permafrost, Soils	How would the villages/communities deal with the effects of coastal erosion – what areas are in high risk for coastal erosion and sea level rise and what are the effects to coastal communities?	How would the villages/communities deal with the effects of coastal erosion – what areas are in high risk for coastal erosion and sea level rise and what are the effects to coastal communities?	OUT OF SCOPE	Army Corp of Engineers and other federal and state assessments of erosion and its effect on villages.	Map of villages identified to need to relocate over 10 and 50 year time horizon. Map will include alternative sites, where they have been identified.	ISER will need to reframe this question if they wish to retain it. ISER portion is contained in community profiles (q16). Agree that it is out of scope.

Number	Group	Management Question (proposed form)	Original MQ if different	MQ Status	Data Sources and Recommendation	Applicable Models	Data Needs and Evaluation Comments
156	Hydrology, Sea Ice, Weather, Permafrost, Soils	What are the current soil thermal regime dynamics for the ecoregion and how are these predicted to change in the future?	What is the depth and extent of permafrost and how is this changing?	ACCEPT	SNAP can provide GIPL model outputs for projected changes in soil thermal dynamics (mean annual ground temperature at the base of the active layer and maximum active layer thickness).	soil thermal regime projections	
157	Hydrology, Sea Ice, Weather, Permafrost, Soils	Where are predicted changes in soil thermal regimes associated with aquatic communities?	How will permafrost degradation and function affect vegetative and aquatic communities and to what extent? What will be permeability changes effects on water quality?	ACCEPT	SNAP can provide GIPL model outputs for projected changes in soil thermal dynamics (mean annual ground temperature at the base of the active layer and maximum active layer thickness).	Predicted soil thermal dynamics will come from SNAP GIPL model and outputs will be intersected with the aquatic resource distribution models to locate areas of potential change.	
159	Hydrology, Sea Ice, Weather, Permafrost, Soils	Where are predicted changes in soil thermal regimes associated with communities/villages?	What communities/villages are at risk from permafrost melt?	ACCEPT	SNAP can provide GIPL model outputs for projected changes in soil thermal dynamics (mean annual ground temperature at the base of the active layer and maximum active layer thickness). ISER: Overlay permafrost maps and community location maps.	climate and soil thermal regime scenarios + intersect with village localities	
170	General questions or applicable to several MQs	What areas have been surveyed and what areas have not been surveyed (i.e., data gap locations)?	What areas have been surveyed and what areas have not been surveyed (i.e., data gap locations)?	REDUNDANT	Biotics Plants, + Arctos (des CE), + AKEPIC (non-native plants CA) in Master Data List	REMOVE - Answered in MQ 61	
172	General questions or applicable to several MQs	What are the attributes and indicators of status?	What are the attributes and indicators of status?	REMOVE - Part of the Assessment			
176	General questions or applicable to several MQs	What are the information/data gaps? What are the science needs? What are important research issues?	What are the information/data gaps? What are the science needs?	REMOVE - Part of the Assessment			

Appendix IV. NatureServe Landscape Condition Model

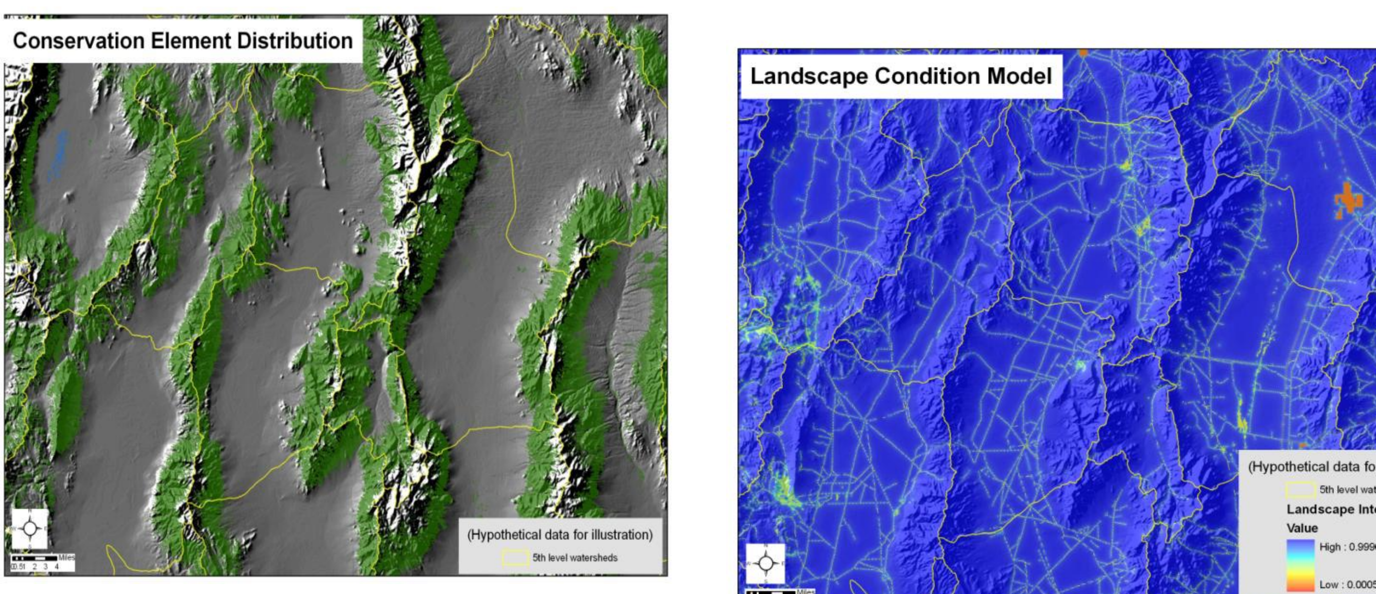
Danz et al. (2007) noted that “Integrated, quantitative expressions of anthropogenic stress over large geographic regions can be valuable tools in environmental research and management.” When they take the form of a map, or spatial model, these tools initially characterize ecological conditions on the ground; from highly disturbed to apparently unaltered conditions. This conceptual approach, documented in Comer and Hak (2009), is very similar to Theobald’s (2008) *Natural Landscapes* model and the USGS *Human Footprint in the West* (Leu et al. 2008). For BLM REAs, CA effects can be summarized through a spatial model of relative landscape condition. When assessing ecological status of CEs, we can address attributes of the CE itself using indicators that best distinguish a degraded state from an intact state. The CAs in a given ecoregion come in many forms, from non-native species effects to local-scale patterns of land-conversion, and infrastructure corridors, among others. Our landscape condition model incorporates multiple stressors of varying individual intensities, the combined and cumulative effect of those stressors, and some measure of distance away from each stressor where negative effects remain likely. For this regional model, we have selected a set of CAs for inclusion (see Table 1).

Inputs: All development and terrestrial invasive species CAs

Analytic process and tools: NatureServe will establish site and distance intensity scores for CAs (Table 2) which may be reviewed and modified by AMT science members and partners. The source of information for the scores will accompany the process documentation and the output metadata. The mapped or modeled CA distributions will be combined and transformed into a single raster surface. We will use the Landscape Condition Modeler, a Python-based toolbox for ArcGIS 10 written by NatureServe. We investigated using NatureServe Vista which is designed specifically for this type of assessment and incorporates the Condition Modeler tool. We built a current (2010) scenario of CAs and attempted to run a condition assessment for a broadly distributed ecoregion. Unfortunately as an ArcView extension, Vista does not have sufficient computing power for ecoregion-wide assessment and modeling at the required 30 m resolution. We believe, however, that Vista will be ideal for downscaling assessments and planning work to subregions (e.g., Field Offices).

Outputs: A continuous raster surface with values from 0-1 representing relative CA induced stress on the landscape. When assessing ecological integrity of CEs, we can address attributes of the CE itself using indicators that best distinguish a degraded state from a sustainable state. For CAs, we will identify attributes that reflect the types and degrees of stressors that may be impacting the condition of the system which may be driving changes. Figure 1 includes an example of an existing landscape condition model (at a 90m pixel surface) applied to a landscape in Nevada. Yellow lines are 5th level watersheds.

Figure 1. Conservation Element Distribution (left) and landscape condition model (right) across 5th level watersheds.



Issues: The concept of landscape condition modeling is highly simplified resulting in relative indices of condition that take into account a fairly narrow set of considerations. The model does not calculate synergistic effects among CAs but instead utilizes the most intense CA where they co-occur. Distance (offsite) effects from neighboring CAs are additively included however. Table 2 depicts the distance effects from different intensity scores. The model does not incorporate the shielding effect of features such as topography that may reduce the distance effects. The model may not reflect observed condition levels for features on the landscape and does not directly incorporate field observations of condition although these can be used to calibrate the model. It is also important to note that the model will only reflect the inputs stated here; there are stressors on the landscape that are not included, namely environmental conditions such as erosion, drought, etc. The model scores are provided in Table 2 so that the AMT may provide feedback. During the next two phases of the REA process we will continue to adjust the site and distance intensity weights with specific input from the AMT as desired. The condition model is a relative scoring model and thus does not incorporate a number of issues related to habitat or species viability.

The CA stressors in the ecoregion come in many forms, from non-native annual grasses or climate induced ecosystem stress, to local-scale patterns of urban land-conversion and transportation corridors, among others. For this regional model, we have selected a set of CAs for inclusion (see Table 1). Each CA was given a **relative site intensity** score, between 0.0 and 1.0 to represent our assumptions of stress induced by each CA on CEs. As depicted in Table 2, a relative site intensity score near 0.0 indicates our assumption that the CA induces very high levels of stress on nearby ecosystems (i.e., removes nearly all condition value). Scores closer to 1.0 are assumed to induce a minimal amount of stress (i.e., retains nearly all condition value). Typically, only one CA occurs at each pixel, but where more than one can occur, the lowest score is applied (e.g. the highest-impact use determines the pixel value).

Table 1. CA inputs to the Landscape Condition Model for the lower 48 USA, their sources, and approximate resolutions.

CA Category	Change Agent	Source	Spatial resolution
Infrastructure - Roads	Primary Highways	2009 Tiger/Line or BLM linear features	1:100,000
	Secondary and connecting roads	2009 Tiger/Line or BLM linear features	1:100,000
	Local roads, jeep trails	BLM linear features	Unknown/Pending
	Trails and other non motorized routes	BLM linear features	Unknown/Pending

CA Category	Change Agent	Source	Spatial resolution
Infrastructure – Transmission lines	Transmission lines	BLM linear features, USGS SAGEMAP, West-wide Energy Corridor Programmatic EIS	1:100,000 or finer
	Communications towers	FCC point locations	1:100,000 or finer
Infrastructure- Pipelines	Pipelines	National Pipeline Mapping System (NPMS) or BLM linear features	1:24,000
Infrastructure- Water Transmission	Canals, ditches	USGS NHD Plus	1:24,000
Infrastructure - Railroads	Railroads	NTAD	1:100,000
Developments - Urbanization	High Density Development	ICLUS/SERGoM	30m pixel/ 1:100,000
	Medium Density Development	ICLUS/SERGoM	30m pixel/ 1:100,000
	Low Density Development	ICLUS/SERGoM	30m pixel/ 1:100,000
Energy Development	Wind	Operating and authorized wind facilities	1:100,000
	Solar	Solar Energy Study Areas	1:100,000
	Geothermal	Operating and authorized geothermal facilities	1:100,000
	Biomass	No current facilities known; save for future REAs	NA
	Oil and Gas Wells	Detailed oil and gas maps	30m pixel/ 1:100,000
Mining	Active Mines	Mines and refuse management model	Unknown/Pending

CA Category	Change Agent	Source	Spatial resolution
	Historical (inactive) mines	Mines and refuse management model	Unknown/Pending
Military Use	Urbanized areas	National Land Cover Data/ LANDFIRE Existing Vegetation/Gap Analysis Program 2001-2003 United States	30m pixel/ 1:100,000
	Heavily disturbed areas	National Land Cover Data/ LANDFIRE Existing Vegetation/Gap Analysis Program 2001-2003 United States	30m pixel/ 1:100,000
Refuse Management	Landfills, industrial lagoons	Mines and refuse management model	Unknown/Pending
Agriculture	Crops and irrigated agriculture	National Land Cover Data/ LANDFIRE Existing Vegetation/Gap Analysis Program 2001-2003 United States	30m pixel/ 1:100,000
Terrestrial Invasives	Impacted areas (5-15% cover exotic non-native species)	Terrestrial invasive species model	30m pixel/ 1:100,000
	Degraded areas (>15% cover exotic non-native species)	Terrestrial invasive species model	30m pixel/ 1:100,000
Recreation	Designated motorized recreation area or natural landscape score <0.3	Natural Landscapes model, existing data	30m pixel/ 1:100,000

CA Category	Change Agent	Source	Spatial resolution
	Recreation class medium	Natural Landscapes model	30m pixel/ 1:100,000

For the condition model, each CA is also given a **distance decay function**, scaled between 0.0 and 1.0, to represent our assumptions of decreasing stress-effects of each CA with distance away from each impacting feature (Table 2). When combined with site intensity, the decay function may be adjusted to represent CA types such as 4-lane highways where the assumed stress at the site is high and the distance effect from the feature is long vs. a single track dirt road. For example, if the site intensity score is low indicating a high stress site (e.g., 0.3) and the distance decay function is relatively high (e.g., 1.0), the resulting spatial model would depict the circumstance where the effect of the high stress CA is expected to decrease rapidly over short distances. A lower distance decay value would extend the effect further away from the site. This effect decays to zero within distances ranging from 200-800 meters from the impacting land cover.

Table 2. Proposed site intensity and distance decay values for ecoregion change agents.

CA Category	Change Agent	Relative Site Intensity	Relative Stress at Site	Distance Decay Function (meters)	Distance Decay (function)
Infrastructure - Roads	Primary Highways	0.05	Very High	2000	0.05
	Secondary and connecting roads	0.2	High	500	0.2
	Local roads, jeep trails	0.5	Medium	200	0.5
	Trails and other non motorized routes	0.9	Low	111	0.9
Infrastructure – Transmission lines	Transmission lines	0.5	Medium	200	0.5
	Communications towers	0.5	Medium	200	0.5
Infrastructure- Pipelines	Pipelines	0.5	Medium	200	0.5
Infrastructure- Water Transmission	Canals, ditches	0.8	Low	125	0.9
Infrastructure - Railroads	Railroads	0.2	High	500	0.2
Developments - Urbanization	High Density Developed	0.05	Very High	2000	0.05
	Medium Density Development	0.2	High	500	0.5
	Low Density Development	0.5	Medium	200	0.5
Energy Developmen	Wind	0.05	Very High	2000	0.2

CA Category	Change Agent	Relative Site Intensity	Relative Stress at Site	Distance Decay Function (meters)	Distance Decay (function)
t	Solar	0.05	Very High	2000	0.2
	Geothermal	0.05	Very High	2000	0.2
	Oil and Gas Wells	Unknown			
	Active Mines	0.2	High	500	0.5
Mining	Historical (inactive) mines	0.05	Very High	2000	0.05
	Urbanized areas	0.8	Low	125	0.5
Military Use	Heavily disturbed areas	0.05	Very High	2000	0.05
	Landfills, industrial lagoons	0.5	Medium	200	0.5
Refuse Management	Crops and irrigated agriculture	0.05	Very High	2000	0.05
Agriculture	Impacted areas (3-10% cover exotic non-native species)	0.8	Low	125	0.5
Terrestrial Invasives	Degraded areas (>10% cover exotic non-native species)	0.8	Low	125	0.8
	Designated motorized recreation area or natural landscape score <0.3	0.5	Medium	200	0.5
Recreation	Recreation class medium	0.3	High	333	0.5
	Recreation class low	0.5	Medium	200	0.8
		0.8	Low	125	0.8

As depicted in Table 3, the distance intensity score determines the rate of decay in condition values for each CA to a given distance where that effect reaches zero. This table serves as a basic guide to distance decay effects, especially where documented experience has indicated a specific distance where effects can be presumed to have reached zero. A clear example of this has been identified for ground-nesting birds where research has identified clear patterns of avoidance and higher predation near the presence of development, especially power lines (Braun 1998, 2002, Ellis 1984, Hagen et al. 2004, Pruett et al. 2009).

Table 3. Distance Intensity Scores and the maximum distance where distance effects reach zero.

Distance Intensity Score	Distance Decay to Zero (meters)	Km
1	0	0
0.9	111	0.1
0.8	125	0.1
0.7	143	0.1
0.6	167	0.2
0.5	200	0.2
0.4	250	0.3
0.3	333	0.3
0.2	500	0.5
0.1	1000	1
0.05	2000	2
0.04	2500	2.5
0.03	3333	3.3
0.02	5000	5
0.01	10000	10
0.003	33333	33.3
0.004	25000	25
0.005	20000	20
0.006	16667	16.7
0.007	14286	14.3
0.008	12500	12.5
0.009	11111	11.1
0.002	50000	50
0.001	100000	100

References

P. J. Comer and J Hak. 2009. NatureServe Landscape Condition Model. Internal documentation for NatureServe Vista decision support software engineering, prepared by NatureServe, Boulder CO.

Danz, N.P., G.J. Neimi, R.R. Regal. et al. 2007. Integrated measures of anthropogenic stress in the

Great Lakes Basin. Environmental Management 39:631-647.

Farig, L. and T. Rytwinski. 2009. Effects of Roads on Animal Abundance: an Empirical Review

Synthesis. Ecology and Society 14(1): 21(online).

NatureServe Vista version 2.0. 2009. www.natureserve.org/vista. NatureServe, Arlington, VA.