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activities, but because they occur over international waters, there are no restrictions on nonmilitary aircraft. The purpose of such areas is to warn nonparticipating pilots of the potential danger. When in use for military exercises, the controlling agency notifies civil, general, and other military aviation through notice-to-airmen and notice-to-mariner advisories, which specify the current and scheduled status of the area and warn other aircraft (Department of the Navy, 2004). Warning areas and military operating areas are generally used for air-to-air training operations and aerobatic flight (Department of the Navy, 2002).

Within the Mid-Atlantic Planning Area, warning areas W-72, W-122, and W-386 extend from the mouth of the Chesapeake Bay south to Pamlico Sound in North Carolina and offshore. The primary users of these areas include aircraft squadrons stationed at NAS Oceana (Department of the Navy, 2002) and MCAS Cherry Point. Aircraft operations conducted in warning areas primarily involve air-to-air combat training, such as air combat maneuvers and air intercepts, and are rarely conducted at altitudes below 5,000 feet (Department of the Navy, 2002). These areas are controlled by the Fleet Area Control and Surveillance Facility, Virginia Capes, Virginia Beach.

2. Global Climate Change

The temperature of the earth's atmosphere is regulated by a balance between the radiation received from the sun, the amount reflected by the earth's surface and clouds, and the amount of radiation absorbed by the earth and atmosphere. The so-called greenhouse gases, which include carbon dioxide (CO_2) and water vapor, keep the earth's surface warmer than it would be otherwise because they absorb infrared radiation from the earth and, in turn, radiate this energy back down to the surface. While these gases occur naturally in the atmosphere, there has been a rapid increase in concentrations of greenhouse gases in the earth's atmosphere from anthropogenic sources since the start of industrialization, which has caused concerns over potential changes in the global climate. The primary anthropogenic greenhouse gases are CO_2, methane (CH_4), nitrous oxides (N_2O), and halocarbons.

The atmospheric concentration of CO_2 has increased from a pre-industrial value of about 280 parts per million (ppm) to 379 ppm in 2005, which is an increase of about 35 percent. During the last 10 years, the rate of increase of CO_2 since 1980 was about 1.9 ppm (0.5%) per year. Most of the anthropogenic CO_2 emissions are primarily attributed to fossil fuel burning, with land-use changes, especially deforestation, providing another significant contribution (Intergovernmental Panel on Climate Change [IPCC], 2007). The level of CO_2 in the atmosphere is determined by a complex cycle that involves the exchange of carbon between the atmosphere, the biosphere, and the oceans. It is estimated that the oceans and terrestrial biota absorb about half of all CO_2 emissions, while the rest accumulates in the atmosphere (IPCC, 2001a).

Atmospheric CH_4 concentrations have increased from a pre-industrial value of about 715 parts per billion (ppb) to 1774 ppb in 2005 (IPCC, 2007). Growth rates have declined since the early 1990's, indicating that total emissions were nearly constant in the last decade. The IPCC states that the observed increase in methane concentration is due to anthropogenic activities, predominantly agriculture and fossil fuel use, but relative contributions from different source types are difficult to determine (IPCC, 2007).

Concentrations of N_2O have risen about 270 ppb in the pre-industrial age to a year 2005 level of 319 ppb. The growth rate has been approximately constant since 1980. More than a third of all N_2O emissions are anthropogenic and are primarily due to agriculture (IPCC, 2007). Anthropogenic sources of N_2O are agricultural soil management, animal manure management, sewage treatment, mobile and stationary sources of fossil fuel, adipic acid production, and nitric acid production. Nitrous oxide is also produced naturally from a wide variety of biological sources in soil and water, particularly microbial action in wet tropical forests (http://www.epa.gov/nitrousoxide/).

Global concentrations of halocarbons (carbon compounds that contain fluorine, chlorine, bromine, or iodine) have generally peaked as a result of the implementation of regulations under the Montreal Protocol. The most important of the halocarbons, both in terms of global warming and ozone-depleting potential, are the chlorofluorocarbons (CFC's). However, the observed concentrations of the substitutes for CFC's, which include hydrochlorofluorocarbons and hydrofluorocarbons, are rising; these are also greenhouse gases. At present, their concentrations are relatively low, and future emissions of these gases are limited by the Montreal Protocol (IPCC, 2001a). Perfluorocarbons (e.g., carbon tetrafluoride [CF_4] and hexafluoroethane [C_2F_6]) and sulfur hexafluoride are other sources of anthropogenic emissions and have extremely long residence times (CF_4 resides in the atmosphere at least 50,000 years) and a high greenhouse gas potential. Current atmospheric concentrations are small, but they have a significant growth rate. Ozone (O_3) is also one of the greenhouse gases. The observed losses of O_3 in the stratosphere as a result of CFC's have caused some cooling of the atmosphere, which offsets to some extent the warming due to greenhouse gases (IPCC, 2001a). On the other hand, an observed increase in global O_3 concentrations in the lower atmosphere since pre-industrial times tends to lead to warming.

Scientists continue to assess and estimate the total global effects on warming or cooling from the various greenhouse gases and other impacting agents. These estimates consider the radiative properties of the gas, the emission rate, and their residence time in the atmosphere. Based on the latest scientific data, the largest effect on global warming is from CO_2 emissions. The others, ranked in order of importance, are CH_4, O_3, halocarbons, and N_2O. Stratospheric ozone has a slight cooling effect. Anthropogenic aerosols in the atmosphere (which include sulphate particles, organic carbon and carbon black from fossil fuel burning, biomass burning, and mineral dust) also have a net cooling effect, but there is a significant uncertainty in the figures. Secondary effects from aerosols (which may affect cloud properties and cloud cover) could also result in surface cooling. Changes in solar radiation may also have contributed to global temperature increases in the early part of the twentieth century, but the importance has been difficult to evaluate (IPCC, 2001a). The advent of space-borne measurements of total solar irradiance in the late 1970's has now made it possible to quantify the natural variations in solar output.

The global averaged surface temperature in the 1906-2005 time period has increased by 0.74 ± 0.18 degrees Celsius (°C) (1.3 ± 0.32 °F) (IPCC, 2007). Eleven of the last 12 years (1995-2006) rank among the 12 warmest years globally since about 1850. The largest increases in temperature have occurred over the mid- and high latitudes of the Northern Hemisphere. New analyses of balloon-borne and satellite measurements of lower- and mid-tropospheric temperature show warming rates that are similar to those of the surface temperature records (IPCC, 2007). The diurnal temperature range over land has been decreasing, with average minimum temperatures increasing at about twice the rate of the maximum temperatures (IPCC, 2001a). Annual precipitation has increased in many areas in the middle and high latitudes of the Northern Hemisphere, while drying has been observed in portions of the subtropics (IPCC, 2007). It also appears that there has been an increase in the frequency of heavy precipitation events in the mid- and high latitudes of the Northern Hemisphere. Observations show a decrease in snow cover and land-ice extent. The annual average Arctic sea-ice extent has shrunk by about 2.7 percent per decade since 1978, with decreases of 7.4 percent per decade in the summer. The Antarctic sea-ice extent has not changed significantly (IPCC, 2007).

Hansen et al., 2005, have estimated the amount of excess energy that is now being absorbed by the earth as a result of the increase in greenhouse gases. This imbalance was correlated with precise measurements of the increasing heat content of the oceans. This confirmed the existence of a lag time between atmospheric forcing by greenhouse gases and effects on climate. The authors estimated that an additional warming of 0.6°C would be realized without any further changes in greenhouse gas levels. These findings were corroborated by Barnett et al., 2005, who observed a warming signal in the world's oceans which they found to be well simulated by two different climate models.

A number of different naturally occurring climate forcing agents can affect the global climate. These include changes in solar radiation, volcanic eruptions, and feedbacks from the ocean. The IPCC examined each of these factors over large time scales and determined that natural variability could not account for all of the warming observed in the 20th century. The IPCC in their Fourth Assessment Report published in 2007 made the following conclusion: "Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations". The IPCC defines the term "very likely" as meaning a probability of occurrence of greater than 90 percent.

Future projections of greenhouse gas emissions over the 21st century have been made using a number of emission scenarios reflecting different assumptions about economic growth, population, and technological emphasis (IPCC, 2007). The various projections provide a large range in projected emissions of greenhouse gases for the 21st century. The climate system response to increases in greenhouse gases is investigated by the use of computer models of the earth's climate system, known as atmosphere-ocean global climate models. The ability of the models to predict future climate is limited by their relatively coarse resolution (about 250 kilometers [km] in the horizontal for the atmospheric component). The effects on a finer scale, such as those caused by clouds, cannot be modeled directly, but have to be approximated on a grosser scale. Furthermore, clouds introduce significant uncertainties because they can result in either warming or cooling depending upon cloud height, thickness, and other properties. The effects of sulphate aerosols are also difficult to quantify.

Based on model simulations applied to six different greenhouse gas emission scenarios, the IPCC projected an increase of the globally averaged surface temperature of 1.8-4.0 °C (3.2-7.2 °F) for the end of the 21st century relative to the 1980-1999 period (IPCC, 2007). There is a range of outcomes for each emissions scenario such that, for the lowest impact scenario, the likely range is 1.1-2.9°C (2.0-5.2 °F), and for the highest impact scenario, the likely range is 2.4-6.4 °C (4.3-11.5 °F) (IPCC, 2007). The models showed that land areas will warm more rapidly than the global average, especially in the northern high latitudes in the cold season. Globally average precipitation is predicted to increase, with some differences by region as well as season. There is also evidence that an increase in precipitation would correlate with greater variability from year to year. It also appears likely that the continental interiors would experience more frequent and intense summer droughts. The global mean sea level is projected to rise by 0.18 to 0.59 meters (m) due to thermal expansion and melting from glaciers and ice caps. These estimates do not include any future rapid dynamical changes in ice flow.

While most analyses of climate change focus on scenarios of steady warming of the climate, there is also the possibility that gradual warming could trigger an abrupt change in climate resulting from non-linear processes in the climate system (National Research Council [NRC], 2002; Arctic Climate Impact Assessment [ACIA], 2004). Such a change could be triggered when a critical threshold is passed. The mechanisms are not adequately represented in current climate models; thus, there is the possibility of surprises. In the arctic, very large shifts in climatic patterns have occurred over short timescales in the past. Ice core records indicate that temperatures over Greenland dropped by as much as 5 °C within a few years during the period of warming that followed the last ice age, before abruptly rising again (ACIA, 2004).

a. Potential Consequences of Global Climate Change

The IPCC has assessed the potential consequences of global climate change (IPCC, 2001b). The report includes discussions on the sensitivity, adaptive capacity, and vulnerability of natural and human systems to climate change. According to the IPCC projections, crop yields in most tropical and subtropical regions would decrease, as would water availability for populations in water-scarce regions, particularly in the subtropics. The exposure to vector-borne and water-borne diseases would expand, and the risk of flooding due to higher incidences of heavy precipitation and sea-level rise would increase. If the global temperature increase were to rise by more than a few degrees Celsius, reduced crop yields would be likely in the mid-latitudes as well. There would also be some beneficial aspects to climate change. The increase in CO_2 levels may increase crop yields in the mid-latitudes if the increase in temperature stays relatively small. The global timber supply may increase from appropriately managed forests. There would be a reduction in winter mortality from cold weather stress in the mid and high latitudes.

The developing countries would be more vulnerable to climate change because more of the economy is sensitive to climatic variations. Many areas are prone to destructive droughts and floods. Population and agricultural centers in the tropics are often located in low-lying coastal areas, which are vulnerable to sea-level rise. Nutrition is deficient, and the health infrastructure is relatively poor. There is less capacity to adapt because of limited technological, financial, and institutional resources.

The IPCC investigated various strategies for reducing greenhouse gas emissions (IPCC, 2001c). Costs depend strongly on technological development and the timing and level of greenhouse gas stabilization. Lower emissions will require switching to lower-carbon fuels and increasing the energy efficiencies of buildings, transportation, energy production, and manufacturing. Appropriate management of forests, agricultural lands, and ecosystems could be used to sequester carbon. Progress is being made in the technological development of wind turbines, hybrid vehicles, and fuel cells. Some emission reductions, such as those resulting from increased energy efficiencies, could result in net cost savings. Other measures would have varying degrees of cost. The reduction in greenhouse gas emissions would have some other direct benefits, such as improved air quality. The use of emissions trading would likely reduce the cost of reaching emission reduction goals.

The National Assessment Synthesis Team (NAST, 2000) has summarized the consequences of climate change for the various regions in the United States. The report presents impacts by geographical regions as well as by resource (i.e., water resources, agriculture, ecosystems, coastal resources, human health). More recently, a report on the impacts of climate change in the Arctic was released (ACIA, 2004). We use these reports and others as a guide in describing qualitatively any potential regional climate change impacts. There are considerable uncertainties in the magnitude of any future climate change and even greater uncertainties about impacts in specific regions. Moreover, the IPCC, NAST, and ACIA make future projections over a 100-year period, while the activities associated with the Proposed Program span only about 30-40 years. Nevertheless, if the IPCC future climate change projections are accurate, a certain degree of climate change and their related impacts could occur within the period of the proposed 5-year program activities. The following sections describe some plausible environmental effects by region. It must be noted that climate change is one of a number of anthropogenic and natural impacting agents. Significant stresses on the environment will occur with or without climate change. However, climate change may exacerbate a variety of environmental problems.

Jorgensen et al. (2004) evaluated the economic impacts of global climate change on the United States. Various scenarios were considered taking into account sensitivity of the different sectors to climate shifts and ability to adapt. Under the "pessimistic scenario" the real U.S. Gross Domestic Product (GDP) in the year 2100 is reduced by 0.6-3.0 percent relative to the baseline. Under the "optimistic scenario" the U.S. GDP is 0.7-1.0 percent higher than the baseline. The benefits under the optimistic scenario are primarily driven by an increase in agricultural and forestry productivity. However, any economic benefits simulated for the 21st century under the optimistic assumption are not sustainable, and economic damages are bound to occur later in the future (Jorgensen et al., 2004) This analysis did not include the adverse effects of larger economic damages outside the United States Furthermore, the study did not address a large number of non-market effects such as species distribution, reduction in biodiversity, ecosystem changes, and changes in human and natural habitats. J. Smith (2004) found that a global increase in temperature of 1-2 °C would have a net benefit on the economy of the United States, but that an increase of 3 °C or greater would have significant major consequences.

An analysis of global economic impacts from climate change was conducted by Stern (2006). It was concluded that if greenhouse gases continue to increase, the overall costs and risks of climate change would be equivalent to losing 5-20 percent of the GDP each year. The costs of taking measures to reduce greenhouse gas emissions to avoid the worst impacts would be about 1 percent of the global GDP each year.

(1) Gulf of Mexico Region

Climate models generally predict a rise in temperatures in the Gulf Coastal States this century. This would result in higher summertime heat index values and greater power demand for air conditioning (NAST, 2000). Model predictions of precipitation are less certain. In general, the models predict a slight decrease in precipitation in coastal areas, while model predictions vary widely in the upland areas, with one predicting an increase in precipitation and another a decrease. The models also predict more intense rainfall events and a higher frequency of droughts (Twilley et al., 2001).

Significant increases or decreases of river runoff would affect salinity and water circulation. Increased runoff would likely deliver increased amounts of nutrients such as nitrogen and phosphorous to estuaries, while also increasing the stratification between warmer fresher and colder saltier water (Boesch et al., 2000). This would increase the potential for algal blooms that deplete the water of oxygen and increase stresses on sea grasses, fish, shellfish and benthic communities. A significant increase in discharge from the Mississippi River could cause an expansion of the hypoxic zone in the Gulf of Mexico off Louisiana. Decreased runoff could diminish flushing, decrease the size of estuarine nursery zones, and allow an increase in predators and pathogens (Boesch et al., 2000). Permanent reductions of freshwater flows in rivers could substantially reduce biological productivity in Mobile Bay, Apalachicola Bay, Tampa Bay, and the lagoons of Texas (Twilley et al., 2001). More frequent or longer lasting droughts and reduced freshwater inflows could increase the salinity in coastal ecosystems, resulting in a decline in mangrove and seagrasses habitats.

Sea-level rise would affect the availability and distribution of high-quality freshwater because many Gulf Coast aquifers are susceptible to saltwater intrusion. Wetlands and mangroves are highly productive systems that are strongly linked to fisheries productivity. These habitats provide important nursery and habitat functions to many important fish and shellfish populations. Infilling, subsidence, altered hydrology, and a decrease in sediment supply have caused dramatic losses of wetlands in the region. With sea-level rise, wetland losses would likely be accelerated, particularly in coastal Louisiana, which would threaten the region's fisheries and agriculture. Loss of wetlands would have adverse effects on coastal navigation and infrastructure. While offshore oil and gas development may not be directly affected, indirect effects may occur due to stresses on coastal industrial infrastructure affected by sea-level rise. With rising sea-surface temperatures as a result of global warming, it is likely that there will be an increase in the intensity of hurricanes (IPCC, 2007). An increase in hurricane activity would adversely affect oil and gas production in the Gulf due to platform shutdowns associated with such events. Even without an increase in hurricane activity, damage to the coastline from storms could be aggravated due to the loss of wetlands and barrier islands which would otherwise act as buffers.

Many Gulf of Mexico commercial fish populations are already subject to stresses, and global climate change may aggravate the impacts of ongoing and future commercial fishing and human use of the coastal zone. Fish, including shellfish, respond directly to climate fluctuations, as well as to changes in their biological environment including predators, prey, species interactions, disease, and fishing pressure. Fish are not only influenced by temperature and salinity conditions but also by mixing and transport processes. Climate would only be one of several factors that regulate fish abundance and distribution. Projected changes in water temperatures, salinity, and currents can affect the growth, survival, reproduction, and spatial distribution of marine fish species and of the prey, competitors, and predators that influence the dynamics of these species (Watson et al., 1998). Changes in primary production levels in the ocean because of climate change may affect fish stock productivity. However, it is still unclear how climate-induced changes in primary productivity would affect the next trophic link, zooplankton. Changes in zooplankton biomass are known to affect fish productivity.

Recreational fishing is a highly valued activity that could have losses in some regions because of climate-induced changes in fisheries. The net economic effect of changes in recreational fishing opportunities because of climate-induced changes in fisheries is dependent on whether projected gains in cool- and warm-water fisheries offset losses in cold-water fisheries. Anadromous species, such as striped bass, rely on marine and freshwater aquatic systems at different points in their life cycles. Projected changes in marine and freshwater temperatures, ocean currents, and freshwater flows are more likely to impact growth, survival, reproduction, and spatial distribution of these species than of other species.

The survival, health, migration, and distribution of marine mammals and sea turtles may be impacted by projected changes in climate through impacts on their food supply and breeding habitats. The availability of necessary habitats and prey species that results from climate change will have the greatest impact on marine mammal and sea turtle populations that are already under endangered species status. Marine mammal calving and pupping grounds and sea turtle nesting beaches would be threatened by rising sea level (Watson et al., 1998).

(2) Alaska Region

A discussion of information about Arctic climate change and potential related impacts on species that could also be affected by oil and gas related activities in the Beaufort Sea OCS is provided in Appendices C and I of the Environmental Assessment (EA) for Beaufort Lease Sale 195 (MMS, 2004a). The reader is referred specifically to Appendix I and Section IV.C.4 of the Biological Evaluation in Appendix C of the EA. We hereby incorporate these sections of the EA by reference.

The average annual surface temperature in Alaska has been rising at the rate of about 1 ºC (1.5 ºF) per decade over the last three decades, with the largest warming occurring in the interior and arctic regions (Alaska Regional Assessment Group, 1999). The temperature increases are larger in winter. Precipitation has increased by about 30 percent overall, but there is more spatial variability. The two general circulation models used in the National Assessment predict an increase in the mean temperature in Alaska of 1.5-3.5 °C (3-6 °F) by the year 2030. Satellite data have shown that arctic sea-ice extent has decreased by about 2.9 percent per decade during the period of 1978 through 1996 (Cavalieri et al, 1997). Submarine sonar records have shown that sea ice thickness has decreased by more than 1.2 m (4 feet) between the 1970's and the 1990's (Rothrock et al., 1999). The IPCC has noted that there has been widespread retreat of glaciers worldwide, with the exception of western Norway and New Zealand (IPCC, 2001a). Annual snowfall has increased by about 11 percent over Alaska, but annual snow cover has decreased due to more rapid melting in spring and summer (Alaska Regional Assessment Group, 1999). Along a transect following the Trans-Alaska Pipeline route, permafrost temperatures at 15- to 20-m depths have increased between 0.6 and 1.5 °C over the past 20 years. Borehole measurements have shown an increase of the mean annual ground surface temperatures of 2.5 °C since the 1960's, while discontinuous permafrost has begun thawing downward at a rate of 0.1 m/yr at some locations (ACIA, 2005). Sea ice has already declined considerably over the past 50 years, and additional declines of 10-50 percent in annual average sea ice extent are projected by the year 2100, while summer sea ice is projected to decrease by 50 percent (ACIA, 2004). Retreat of sea ice would increase impacts to coastal areas from storms. Furthermore, coastlines where permafrost has thawed are more vulnerable to erosion from wave action. Aerial photo comparison has revealed total erosive losses up to 457 m (1,500 feet) over the past few decades along some stretches of the Alaskan coast (Alaska Regional Assessment Group, 1999). Several villages have been sufficiently threatened by increased erosion and inundation that they must be protected or relocated (Alaska Regional Assessment Group, 1999). At Barrow, Alaska, coastal erosion has been measured at the rate of 1-2.5 m/yr since 1948 (ACIA, 2005), and it has been causing severe impacts on the community.

Loss of sea ice could cause large-scale changes in marine ecosystems and could threaten populations of marine mammals, such as polar bears and ringed seals that depend on the ice. Ice edges are biologically productive systems where ice algae form the base of the food chain. The ice algae are crucial to arctic cod, which is a pivotal species in the arctic food web. As ice melts, there is concern that there would be loss of prey species of marine mammals, such as arctic cod and amphipods, that are associated with ice edges (MMS, 2004a). Changes in the extent, concentration, and thickness of the sea ice in the Arctic may alter the distribution, geographic ranges, migration patterns, nutritional status, reproductive success, and, ultimately, the abundance of ringed seals and other ice-dependent pinnipeds that rely on the ice platform for pupping, resting, and molting (MMS, 2004a). Reductions in sea ice coverage would adversely affect the availability of pinnipeds as prey for polar bears. More polar bears may stay onshore during the summer (MMS, 2004a). If the arctic climate continues to warm and early spring rains become more widespread, ringed seal lairs might collapse prematurely, exposing ringed seal pups to increased predation by polar bears and arctic foxes, negatively impacting the ringed seal population and, therefore, eventually the polar bear population (MMS, 2004a). Additionally, some birds have life history strategies adapted to sea ice. Impacts to marine mammal, fish, and bird populations may adversely impact Native subsistence harvests.

The loss of sea ice could have some potential effects on bowhead whales. These would include increased noise and disturbance related to increased shipping, increased interactions with commercial fisheries, including noise and disturbance, incidental intake, and gear entanglement; changes in prey species concentrations and distribution; and changes in subsistence-hunting practices.

There are some benefits associated with reduced sea ice. Reductions in sea ice would increase the possibilities for navigation during the open-water season, and there would be greater opportunity for the development of offshore oil and gas resources. With a longer ice-free season, exploratory drilling and construction activities would be less restricted by ice. Vessels would be able to reach facilities for longer periods during the year. Structures would not be subjected as frequently to severe stresses induced by sea ice. On the other hand, any gravel islands used for the placement of an oil production facility could be subject to greater erosion from an increase in wave action.

Changes in permafrost have caused failure of buildings and costly increases in road damage and road maintenance in Alaska (Alaska Regional Assessment Group, 1999). Present costs of thaw-related damage to structures and infrastructure in Alaska have been estimated at $35 million per year. A continued warming of the permafrost is likely to increase the severity of permafrost thaw-related problems. Thawing of any permafrost increases groundwater mobility, reduces soil bearing strength, and increases susceptibility to erosion and landslides. Thawing could disrupt petroleum exploration and production by shortening the availability of time for minimal-impact operations on ice roads and pads.

Ocean ecosystems and fisheries are highly vulnerable to changes in sea temperature and sea-ice conditions (Alaska Regional Assessment Group, 1999). The Bering Sea and Gulf of Alaska have shown marked fluctuations in their physical and ecological characteristics over time. Observed fluctuations have included large-scale shifts in the abundance and distribution of many important fish, invertebrates, and marine mammals. The warming brought about ecosystem shifts that favored herring stocks and enhanced productivity for Pacific cod, skates, flatfish, and non-crustacean invertebrates. The species composition of living things on the ocean floor changed from being crab-dominated to a more diverse mix of starfish, sponges, and other life forms. Many changes appear to show clear association with interdecadal climate variability (Alaska Regional Assessment Group, 1999). If the Arctic continues to warm at the present rate, large changes in the ocean ecosystems and fisheries can be expected, although the precise nature of the changes would be difficult to predict.

Climate change in the region would likely alter the habitat and the diversity, distribution, and abundance of fishes. Several species of Pacific salmon have been observed in the Arctic. Possible shifts in ocean circulation in the future would likely affect the migration routes of some fishes. Some species, such as Pacific salmon, would likely become more widespread and/or abundant, while other species, such as Arctic cod, may become less abundant or modify their distribution. Regional climate change would likely bring additional fishing activity to the Beaufort and Chukchi Seas where commercial operations have been minimal in the past (MMS, 2004a).

Native subsistence livelihoods could be threatened by changes in the ocean ecosystem and sea ice. Settlements may be threatened by sea-ice melt, permafrost loss, and sea-level rise. Traditional hunting locations would likely be altered, and subsistence travel and access may become more difficult. Game patterns may shift, and their seasonal availability may change (MMS, 2004a). The season for transportation by ice roads could be shortened significantly. For subsistence hunters, ice-based seal species have been more difficult to access and harvest (North Slope Borough [NSB], 2005). Continued reductions in sea ice would hinder future hunting activities. Retreat of sea ice would impact some species on which subsistence hunters depend, including bearded seals and walrus (Alaska Regional Assessment Group, 1999). Polar bears would be seriously impacted and may be threatened with extinction (Alaska Regional Assessment Group, 1999). Native residents have utilized ice cellars cut into the thermafrost for harvested fish and game. In several communities, the cellars are melting and becoming unusable. Residents unable to store large quantities of food must hunt more often. This results in more expense, time away from home and cash jobs, and more exposure to dangers of hunting in the harsh arctic environment (NSB, 2005).

Rapid and long-term impacts from climate change would likely disrupt long-standing, traditional hunting and gathering practices that promote health and cultural identity. Because of the limited capacities and choices for adaptation and the ongoing cultural challenges of globalization to indigenous communities, arctic communities would experience significant cultural stresses in addition to major impacts to population, employment, and local infrastructure (MMS, 2004a).

(3) Atlantic Region

The following discussion is based on a report by the National Oceanic and Atmospheric Administration (NOAA) produced as part of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change (Boesch et al., 2000). Global climate models predict a warming of air temperatures in the Atlantic Coast region. The models are less certain about changes in precipitation and freshwater runoff. One model used in the U.S. National Assessment predicts wetter conditions, while another predicts a drying trend. The primary potential effects of climate change in the mid-Atlantic region include sea-level rise, impacts on estuaries, changes in the hydrologic cycle, and changes in fishery resources.

Sea-level rise would result in increased erosion of shorelines and beaches, increased salinity of estuaries and freshwater aquifers, altered tidal ranges in rivers and bays, changes in sediment and nutrient transport, and increased coastal flooding during storms. Barrier islands would tend to be shifted shoreward or breached. Wetlands and their habitats would be shifted or suffer loss. Damage to homes and infrastructure from coastal flooding would have substantial economic impacts. Studies have shown that the economic costs of a 50-cm (18-inch) rise in sea level could be $20 billion to $200 billion nationwide by the year 2100.

Most estuaries in the mid-Atlantic region are already stressed as a result of water pollution and agricultural runoff. Warming of estuaries would affect species distribution. For example, species that are near their southern limits, such as the soft clam *Mya arenaria*, may no longer survive or be prolific in the Chesapeake Bay, while warm temperature species such as penaeid shrimp found in estuaries in the Carolinas may become more common. Due to the combined effects of global sea-level rise and regional land subsidence, the relative rate of rise in the Chesapeake Bay has been about 3.3 mm (0.13 inches) per year over the past 60 years. This would cause inundation of tidal wetlands, shoreline erosion, and loss of islands and other tidewater lands. The rise in water level could also result in intrusions of higher salinity in the estuaries and their tributaries. Possible consequences of this include changes in the ecosystem and increased potential for salinization of ground water.

With rising sea-surface temperatures as a result of global warming, it is likely that there will be an increase in the intensity of hurricanes (IPCC, 2007). There is some uncertainty about the effects of global warming on extratropical cyclones (such as the northeasters). An increase in the intensity of storms would exacerbate beach erosion and flooding along the Atlantic coast. An increase in regional precipitation, as is predicted by some models, would result in increased fresh flow into the estuaries, which would raise nutrient levels, making management of the estuaries more difficult. Increased winter-spring discharges may deliver more nutrients and increase the density stratification causing hypoxia. Warmer temperatures may also affect stratification and rates of plankton production and nutrient regeneration.

Poleward shifts in distribution of marine populations can be expected with increasing water temperatures. Species temperature preferences and overall habitat requirements would determine the extent of potential distribution shifts. For some species, the habitat requirements related to spawning and nursery areas can limit adaptation, which could result in loss of populations. Temperature changes may also affect the food web dynamics of the ecosystem. For example, substantial shifts in the distribution of small pelagic fishes such as herring and mackerel off the east coast of the United

States can be expected. This would affect the forage base for many piscivorous (fish eating) fishes, marine mammals, and sea birds.

b. Contribution of OCS Activities to Greenhouse Gas Emissions

Estimates were made of the total emissions of CO_2 and CH_4 for all projected activities associated with the proposed 5-year program. Emission estimates for the various activities were largely based on a comprehensive inventory of air emissions from OCS activities in the Gulf of Mexico for the year 2000 (Wilson et al., 2004). Air emissions resulting from the proposed 5-year program were estimated by considering the exploration and development scenarios presented in Tables IV-1 through IV-3. Emissions are given in terms of teragrams (Tg) of CO_2 equivalent, where one Tg is 10^{12} grams (10^6 metric tons). This measure takes into account a global warming potential (GWP) factor, which accounts for the relative effectiveness of a gas to contribute to global warming with respect to the same amount CO_2. In these calculations, CH_4 is given a GWP of 21.

Table IV-5 lists the total calculated emissions of CO_2 and CH_4 from activities associated with the proposed five-year program and compare them with current U.S. greenhouse gas emissions from all sources. The 5-year program emissions were averaged over a 40-year period. The projected CO_2 emissions from the proposed 5-year program are about 0.06-0.12 percent of all current CO_2 emissions in the United States. The 5-year program CH_4 emissions are about 0.43-0.82 percent of the current CH_4 emissions in the United States, which is a significantly higher percentage than that for CO_2. If one combines the CO_2 and CH_4 emissions, the 5-year program emissions are about 0.09-0.18 percent of the current nationwide figures. The estimated global CO_2 emission rate from combustion of fossil fuels for the year 2000 is approximately 24,240 Tg (USEPA, 2005). The U.S. contribution to this total is about 23 percent (USEPA, 2005). The estimated 5-year program CO_2 emissions are about 0.08-0.016 percent of the global CO_2 emissions from fossil fuel combustion.

A number of mitigation strategies could be adopted by operators with the goal to reduce greenhouse gas emissions from OCS oil and gas development activities. Use of more energy-efficient engines, turbines, and boilers would reduce CO_2 emissions. Use of gas instead of diesel fuel to provide power on platforms would significantly reduce emissions. However, many operators already primarily rely on produced gas once production starts. More efficient scheduling of transport of material and personnel could lower service vessel CO_2 emissions by reducing the number of vessel and helicopter trips. Application of optimum power settings on vessels would reduce fuel use and, hence, greenhouse gas emissions.

As noted above, the percentage contribution of CH_4 to the nationwide emissions is significantly greater than that for CO_2. Reductions in CH_4 emissions appear to have the greatest potential in achieving reductions of greenhouse gas emissions from OCS sources. Venting natural gas currently contributes about 59 percent to the total CH_4 emissions in the Gulf of Mexico. Fugitive emissions sources contribute another 19 percent. Flaring excess gas rather than venting it would significantly lower overall greenhouse gas emissions from OCS platforms (Herkhof, 2005), though flaring gas would increase CO_2 emissions. More intensive programs to check for fugitive leaks on platforms would also lower CH_4 emissions. Other possible measures to reduce CH_4 emissions would include use of a lighter color of paint on storage tanks to reduce vapor losses and, in cases where crude oil is transported by tanker, use of vapor balance lines during oil transfer operations.