

## CHAPTER 5. NATURAL SYSTEMS

The Natural Systems sector addresses the observed and projected impacts of climate change on Alaska's ecosystems and the services they provide, and recommends priority adaptation actions that the State of Alaska should take to address the impacts and vulnerabilities associated with these impacts. Box 5-1 summarizes the mission statement for the sector.

### Box 5-1. Natural Systems Sector Mission Statement

Sustain natural ecosystem services in Alaska that meet society's essential needs, through adaptation to changing environmental conditions.

Overview of Natural Systems Options		
	Option Name	Level of Support
NS-1	Fisheries Management	Unanimous
NS-2	Wildland Fire Management	Unanimous
NS-3	Freshwater Management	Unanimous
NS-4	Invasive and Eruptive Species Prevention & Response	Unanimous
NS-5	Adaptive Fish & Wildlife Management	Unanimous
NS-6	Support Local Sustainable Agriculture	Unanimous

### Impacts and Vulnerabilities

Alaskans (as well as humans across the globe) benefit from a multitude of resources and processes supplied by natural ecosystems. Collectively, these benefits are known as **ecosystem services** and they include products upon which humans depend, such as clean drinking water, timber, habitat for fisheries and wildlife, and pollination of native and agricultural plants. Natural ecosystem services can be *provisioning* such as the production of food, clean water, fiber and energy; *regulating*, such as the control of climate and disease; *supporting*, such as nutrient cycling, water purification and plant pollination; *cultural*, such as spiritual and recreational benefits; and *preserving*, such as maintaining ecological diversity and the resilience and stability it brings.

In the past three decades, Alaska has warmed at a rate approximately twice the global average, and additional warming of 5-13°F is projected over the next 100 years. Rapid warming has substantially affected Alaska's marine, terrestrial, and freshwater ecosystems (ACIA, 2004). The resilience and ecological integrity of these ecosystems varies, depending on the sensitivity of the physical environment to warming and the capacity of the current dependent-species to adapt or move in response to environmental changes. Warming also brings the arrival of new species (including invasives) that can modify natural ecosystems in ways that challenge their resilience to environmental change.

Key impacts and vulnerabilities for the natural systems sector include:<sup>1</sup>

**Marine Ecosystems:** The seas around Alaska are responding to warming in ways that substantially influence circulation patterns, sea ice, food webs, and productivity regimes. In addition, independent of the effects of warming, carbon dioxide from human emissions is causing about a 30% increase in the acidity of the oceans worldwide, an effect projected to increase substantially by the end of this century. Impacts will be significant in the Arctic Ocean, Bering Sea and the Gulf of Alaska, including changes in fish and wildlife species' diversity, ranges, distribution and abundance; elimination of some species from Alaskan seas; introduction of new species (including invasive species and pathogens); and loss of habitat for sea-ice-dependent species. Alaskans will face impacts to commercial, subsistence, and sport fisheries; changes in traditional modes of travel, fishing, and hunting in areas historically covered by sea ice; and other effects. Communities and industries reliant on marine-based fisheries will be particularly affected, as will individuals and communities dependent on subsistence harvest of marine fish and wildlife as essential elements of their food supply and cultural well-being (ACIA, 2004; Anderson et al., 1999; Brodeur et al., 1992; Grebmeier et al., 2006; Hunt et al., 2002; Sarmiento et al., 2004).

**Terrestrial Ecosystems:** Although effects will vary in different regions of the state, Alaska's terrestrial ecosystems are generally expected to experience warmer and drier conditions with climate change. Thawing permafrost and increases in the active soil layer will alter the hydrologic regime. In southeast Alaska, changing seasonality is expected to shift temperatures across the freezing threshold, significantly impacting the amount of precipitation that falls as rain vs. snow and impacting ecosystem water availability. Vegetation zones in Alaska are likely to shift, with tree line moving northward and to higher elevations, and forests replacing a significant fraction of existing tundra. Animal species' diversity, ranges, distribution, and abundance will change, with new species arriving (including invasives) and some current species no longer able to thrive. Impacts of warmer and drier conditions may include increased area and frequency of wildland fire, increased insect outbreaks, retreat of inland glaciers, decrease in the area of continuous and discontinuous permafrost and lakes, and an expanded growing season. These potential changes—some negative, some beneficial—will substantially affect a wide range of human uses of terrestrial resources, including forestry and subsistence harvest of fish and wildlife (ACIA, 2004; Werner et al., 2006; USDA Forest Service, 2008; Juday, 2008).

**Freshwater Ecosystems:** While effects will vary regionally, impacts to Alaska's freshwater ecosystems are generally expected to include reduced summer and fall stream flows, increased winter flooding, warmer summer stream temperatures, loss of perched lakes and other surface water sources underlain by permafrost, and potential water quality changes. Changes to freshwater species will occur, as species that have adapted to colder conditions find it more difficult to thrive and species that have adapted to warmer water temperatures benefit (including invasives). These impacts will have major effects on people who access and harvest the fish and wildlife that depend on freshwater habitat, as well as entities seeking freshwater appropriations for community, industrial, or other purposes (ACIA, 2004; White et al., 2007; Wrona et al., 2006).

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<sup>1</sup> Climate change is expected to drive significant ecosystem changes in Alaska in the coming decades. The Natural Systems Technical Work Group (NS TWG, 2008) summarized changes to Alaska's ecosystems and expected future trends in [www.climatechange.alaska.gov/aag/docs/AAG4a\\_NSTWG\\_DftOptnsCtlg\\_17dec08.pdf](http://www.climatechange.alaska.gov/aag/docs/AAG4a_NSTWG_DftOptnsCtlg_17dec08.pdf).

## Natural Systems Adaptation Strategy

Climate change is already altering the natural ecosystem services that provide life requisites and cultural well-being in Alaska. **The Natural Resources Adaptation Strategy recommends actions that the State of Alaska should take to sustain the natural ecosystem services that meet society’s essential needs, through adaptation to changing environmental conditions.** To sustain ecosystems services, the State must adaptively manage its biotic natural resources by managing negative impacts and capitalizing on new opportunities, in coordination with others who manage or benefit from these resources.

**The State of Alaska has an essential leadership role in adapting to natural systems change.** State government is a primary manager of Alaska’s natural biotic resources—with management authority and responsibility for fish and wildlife conservation and harvest, forest and wildland fire management, freshwater appropriations, Alaskan agriculture, infrastructure development, and use of State lands and other resources. The State must be fully prepared to adapt its management policies, strategies, and actions to respond flexibly to the effects of climate change on natural ecosystem services and the human use of those services. The State’s planning and response actions must also be fully coordinated with the federal government, local communities, tribes, industry, non-governmental organizations (NGOs), universities, and the public.

The six adaptation options recommended for the NS sector are **targeted to sustaining the natural ecosystem services that meet Alaskan’s essential needs for food, water, renewable resource economies, community stability and safety, and cultural well-being.** Box 5-2 summarizes the NS recommendations.

### Box 5-2. Overview of Natural Systems Recommendations

#### *NS-1 Fisheries Management*

Incorporate climate change into fisheries assessment and management and assist fishing communities and users in adaptation.

#### *NS-2 Wildland Fire*

Review and modify Alaska’s wildland fire policy and programs in the context of increased wildfire risk.

#### *NS-3 Freshwater Management*

Address the effects of climate change on Alaska’s freshwater resources through adaptive management, supported by improved hydrologic data.

#### *NS-4 Invasive and Eruptive Species*

Reduce introduction and spread of invasive species and eruptive species in the context of climate change.

#### *NS-5 Fish and Wildlife*

Improve capability to adapt harvest regulations and monitoring of fish and wildlife to respond to climate change.

#### *NS-6 Sustainable Agriculture*

Develop a program to support sustainable agriculture that will improve, secure, and sustain the supply of quality, affordable food

These recommendations build on existing state authorities and programs, and will move Alaska forward substantially in its ability to adapt to climate change impacts. Implementation of these options will require leadership and policy direction, as well as a moderate investment in staffing and funding to complete priority tasks. However, through this work, the State will take a major step forward in integrating adaptive management to climate change over the long-term into the State's resource management programs and practices, so that it becomes a way of doing business—not a suite of separate initiatives.

The NS sector encompasses a wide range of ecosystems, biotic resources, and ecosystem services; yet there are common approaches that will improve the State's capacity for adaptive management across this broad spectrum. Recommended approaches include:

- Organize, coordinate, and facilitate access to research and monitoring data, and identify important data gaps (e.g., data essential to adaptive management of fish and wildlife conservation and harvest; hydrologic data essential to freshwater resource management).
- Review and modify (as needed) resource management policies, practices, and plans to facilitate adaptive management to address climate change impacts (e.g., fishery management plans; wildland fire response practices; water management policies).
- Provide strategic plans and tools to accomplish specific, effective adaptive actions (e.g., regulation change for adaptive management of wildlife harvest; strategic plans for invasive and eruptive species control; plans for community wildfire protection and management of high-risk fire areas).
- Establish and/or fully utilize effective forums for coordination and communication to combine and leverage resources and increase effectiveness (e.g., Invasive Species Council, Alaska Water Resources Board).
- Increase the adaptive capacity of local communities, the public, and others who benefit from ecosystems services (e.g., provide information/technical assistance to fishing-reliant communities; prepare community wildfire protection plans).

These recommendations represent a concise set of feasible actions that the State of Alaska can lead and accomplish, generally in the short- to mid-term, with modest additional funding. The recommendations represent high priority actions, based on criteria that include significance of impacts addressed; anticipated benefits, effectiveness, cost, and feasibility of the adaptation action; timing considerations; and the adaptive capacity of the natural ecosystem and human uses of the ecosystem. Research will be a critical part of these recommendations, as described in Boxes 5-3 and 5-4. The recommendations are also intended to build on existing public and private sector programs and activities as described in Box 5-5. These three boxes appear at the end of this chapter.

In addition to the recommendations presented in this chapter, there is a substantial need for coordination and sharing of data regarding climate change and its effects in Alaska, and assurance that entities that need this data to build their adaptive capacity (e.g., local communities, tribes) can access, understand, and successfully apply these data and findings. This recommendation is presented in Chapter 8, "Common Themes," as Common Themes Option #1, establishment of an *Alaska Climate Change Knowledge Network*. There is also a need to increase climate change education in the Alaska school system, an option that is also presented in Common Themes.

Option name		Type of option										Implementation				
		Coordination				Data collection (research, monitoring, observation, etc.)	Regulatory / programmatic change or addition	Assessment, evaluation, or planning	Capacity building, education, outreach	Direct or indirect financial assistance (e.g., tax incentives)	Capital improvements	Requires new institutions / government agency	Requires new staffing	Requires funding	Requires new legislative authority	Lead role for state government
NS-1	Fisheries Management	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	possibly	✓
NS-2	Wildland Fire Management	✓	✓			✓		✓	✓				✓	✓		✓
NS-3	Freshwater Management	✓			✓	✓	✓	✓					✓	✓		✓
NS-4	Invasive and Eruptive Species Prevention & Response	✓				✓		✓					✓	✓	✓	✓
NS-5	Adaptive Fish & Wildlife Management	✓	✓	✓	✓	✓	✓						✓	✓		✓
NS-6	Sustainable Agriculture	✓	✓	✓		✓		✓	✓				✓	✓		✓

## Description of Natural Systems Recommendations

This section describes the options recommended for the Natural Systems sector.

### NS-1 Incorporate Climate Change into Fisheries Management and Assist Fishing Communities and Users in Adaptation

The State of Alaska will take into account climate change impacts when developing fisheries policy and management options for the state’s commercial, recreational, subsistence and personal use fisheries. In addition, because of commercial fishing’s contribution to Alaska’s economy and jobs, the State will develop a program to assist the commercial fishing industry—and the communities and user groups reliant on the industry—in adapting to the impacts from climate change. These actions will improve the adaptive capacity of state managers, the fishing industry, and fishing-reliant communities to changes in fish species ranges, distribution, and abundance while addressing the sustainability and conservation of fisheries. Key elements of NS-1 include:

- 1 Review of the State's fishing-related statutes, policies, management actions, and programs to determine if and how climate change considerations might be included in these. This review could be conducted by state agencies, or through a combined effort of agencies and a stakeholder group.
- 2 Comprehensive assessment of existing habitat, fish species, and stock monitoring programs for commercially-fished species to determine program effectiveness and how better information could facilitate meaningful responses to climate change. A panel of agency scientists and independent scientific experts would best accomplish this assessment. This assessment must go hand-in-hand with development of a comprehensive long-term monitoring program that builds upon existing federal and state programs and that also addresses physical and biological components, fisheries abundance and distribution, habitat monitoring, human activity and effects, and socioeconomic data trends.
- 3 Development of a centralized source of information regarding effects of climate change on marine and freshwater ecosystems and fisheries (see the *Alaska Climate Change Knowledge Network*, proposed as Common Themes Option #1).
- 4 Development of a long-term strategy to work with fishing-reliant communities and businesses to identify the needs for modified or new fisheries-related infrastructure to meet the changing needs of the industry and fishermen, including possible construction, loans, etc.

Alaska's fisheries are an essential part of the state's economy, food supply, heritage, and culture. The potential negative impacts of *not* being prepared to adapt to changes in the state's fisheries cannot be overstated.

The State of Alaska could realistically implement these actions in the short- to mid-term with the leadership of the Alaska Department of Fish and Game (ADF&G), in cooperation with federal fisheries managers, University of Alaska, fishing-reliant communities, the fishing industry, and other stakeholders. Legislative action would be required only if changes to statutes were identified as required for adaptive management. Completing the assessments and strategic planning described above would not be high cost. However, substantial funding would be needed to implement a more robust marine ecosystem monitoring program (#2 above) or to fund changes to fisheries-related infrastructure (#4). New federal funding sources would likely be required to implement these initiatives (e.g., Ocean Trust Fund).

This recommendation is linked to several high priority research needs, including reviewing effective adaptive management programs from other fishing-reliant countries and states, and developing a comprehensive long-term monitoring program for marine ecosystem changes. As noted above, NS-1 is also linked to Common Themes Option #1.

## NS-2 Review and Modify Alaska's Wildland Fire Policies and Programs

The State of Alaska will thoroughly review and modify as appropriate, Alaska's wildland fire policy and programs to address potential climate-induced increases in wildland fire frequency, size, and geographic location. Key elements of NS-2 include:

- 1 Increase the capacity of communities to initiate, complete, and implement Community Wildfire Protection Plans (CWPP) – providing additional emphasis and funding to a well-established state program.

- 2 Review selected wildland fire management practices for lands in Alaska, including special consideration of tundra wildfires, which have increased in the last two decades due to warming.
- 3 Develop a comprehensive fuels management program to treat high-risk areas through fire and mechanical fuel treatment with the goal of minimizing the negative impacts of wildland fire on humans while increasing the beneficial aspects of fire, especially to wildlife habitat.

Taking these actions will benefit public health and safety (life and property), help maintain healthy forest ecosystems, improve homeowner and community preparedness and capacity, provide jobs, supply woody biomass for carbon neutral energy projects, and potentially reduce greenhouse gas (GHG) emissions from wildland fires.

These recommendations build upon programs and coordinating bodies (state, federal, community, NGOs) that are already in place, with coordination by the Alaska Department of Natural Resources (ADNR), Division of Forestry. The actions are highly feasible, could be completed in the short- to mid-term, and are not high in cost. Addition of a CWPP coordinator position and planning funds would be needed to achieve the desired target of completing five new CWPPs each year for the next ten years and keeping all plans updated. Additional funding may also be necessary if a decision were made to implement a higher fire protection status in regions of the state. Federal funding is generally available to support fuels management projects in high-risk areas.

### **NS-3 Address Effects of Climate Change on Alaska's Freshwater Resources through Adaptive Management, Supported by Improved Hydrologic Data**

The State of Alaska will improve the capacity of its freshwater management program to adapt to the impact of climate change to meet the diverse needs for freshwater in Alaska. Key elements of NS-3 include:

- 1 Advocate for and coordinate with the federal government and others to fill the substantial need for additional, essential data on stream flow and groundwater hydrology.
- 2 Reestablish the Alaska Water Resources Board to improve coordination among water resource agencies and with the public.
- 3 Protect water for fish and wildlife habitat through reservation of instream flows, in rivers and lakes for which there is sufficient hydrologic data.
- 4 Review and adjust water management laws, policies, and practices as necessary to improve adaptive capacity.

Natural ecosystems, communities, residents, industries, and transportation/utility systems all benefit from use of Alaska's freshwater resources. By closing existing substantial data gaps and strengthening its water management structure, the State will be better prepared to develop a strategic approach to water management in the face of climate change, assess risk of water shortage and the need for replacement sources within and between regions, avoid over-appropriation, and protect beneficial uses. These actions would be taken under the leadership of the ADNR Division of Mining, Lands and Water and Department of Environmental Conservation (ADEC).

Alaska's primary water management challenge is the lack of sufficient surface and groundwater hydrologic data. This option recommends a concerted effort to identify sources of data regarding the quantity and quality of Alaska's freshwater sources, crucial data gaps, and a strategic plan for filling gaps. Very substantial funding

would be needed to provide sufficient data for hydrologic modeling and well-informed decisions on water appropriation. Substantial federal funding sources would be needed and data collection would need to be strategically prioritized to use funds to their greatest advantage.

Reestablishment and funding of the public/private Alaska Water Resources Board (the board is authorized, but has not been seated since 1994) would provide needed Cabinet-level emphasis to water resource management issues and programs, including coordination with ADNR regarding improving data and the potential need to adapt Alaska's water management laws, policies and practices, and the water rights adjudication process. Additional state agency funding would be needed to achieve a desired target of completing adjudication of water rights within five years for the fish-bearing streams in South, Central, and Interior Alaska that have adequate hydrologic information.

#### NS-4 Reduce Introduction and Spread of Invasive and Eruptive Species

The State of Alaska will expand its efforts to be an active partner with all levels of government and other entities in addressing the problem of invasive and eruptive species in Alaska. NS-4 recommends state support for the Legislature's establishment of the Alaska Invasive Species Council (House Bill 12), and state commitment to partnering with others to prevent and control invasive and eruptive species in Alaska.

The combination of changing climate (lengthening growing seasons and warming temperatures) and increasing globalization has dramatically increased the rate of introduction and the spread of non-native, invasive species in Alaska. Invasive plants, eruptive insects and diseases, and invasive marine species have the potential to damage important economic sectors such as fisheries and forestry, as well as to alter fire cycles and subsistence opportunities and to spread disease.

NS-4 recommends that the State of Alaska immediately join in the work underway to address invasive species in Alaska.<sup>2</sup> ADF&G, ADNR, ADEC and Department of Transportation and Public Facilities (ADOT&PF) need to be fully involved. Establishment of the Alaska Invasive Species Council would cement the partnership between the state and other levels of government, and would provide leadership, policy decisions, and leverage and coordination of resources and authorities to implement effective prevention and response actions.

Many actions to prevent introduction of invasives and those to control invasives already in Alaska could be implemented within the short- to mid-term (two to five years). Funding for two state positions (ADOT&PF vegetation management and ADNR plant/wood products inspector) is recommended to address two significant points where invasives can be effectively controlled. It is *much more cost-effective to invest in prevention and early control of invasive and eruptive species* than to combat their spread and their substantial impacts to Alaska's ecosystems and economy in the future.

#### NS-5 Provide for Adaptive Management of Fish and Wildlife

The State of Alaska will improve its capability to manage fish and wildlife species adaptively in Alaska to assure sustainable management of these important resources under conditions of rapid and substantial climatic change. NS-5 proposes two specific actions under the leadership of ADF&G:

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<sup>2</sup> This recommendation would contribute to and build on work underway by the ad hoc statewide Alaska Committee on Noxious and Invasive Plant Management (CNIPM) and the Alaska Invasive Species Working Group (AISWG).

- 1 Develop and adopt a more timely regulatory process for the harvest of wildlife to adapt and respond to short- and long-term changes in climate that can decrease harvest success under a static harvest season.
- 2 Develop a coordinated framework that documents existing fish and wildlife monitoring efforts (for both harvested and non-harvested species), identifies priorities for monitoring in the context of climate change, and identifies gaps and potential for collaboration. This option would also include development and use of a common structure for cataloguing and disseminating monitoring information, such as the *Alaska Climate Change Knowledge Network*, proposed as Common Themes Option #1.

Under sub-option #1 above, the Alaska Board of Game would need to delegate regulatory authority to state wildlife managers to adjust wildlife harvest regulations in-season when situations presented by climate change hinder harvest or meat care (e.g., warm, dry conditions reduce access by boat and/or change migration routes). This action could be implemented in the short-term at low cost as a collaborative pilot study with a community or small region. A working group could develop a proposal to the Board of Game for an in-season management option, to determine if there is a management tool that will help respond to climate change impacts on hunting success, and to meet subsistence needs for wildlife. (This recommendation focuses on management of wildlife harvest; note that state fisheries management regulations and practices already provide for adaptive in-season management by state fishery managers).

Under sub-option #2 above, collaboration amongst agencies, scientists, and stakeholders to develop a monitoring framework for fish and wildlife species in Alaska could be accomplished in the short- to mid-term; the cost of this initial product (framework, data coverage, data gaps) is not expected to be high. However, implementation of additional monitoring to fill data gaps would require substantial funding. This recommendation is linked to NS-1, which recommends a similar assessment for monitoring focused on commercially fished species and the habitats that support those species. As noted above, it is also linked to Common Themes Option #1, which addresses coordinated access to data and information regarding climate change.

## NS-6 Support Local Sustainable Agriculture in Alaska

Increasing locally grown foods can contribute significantly to Alaskans' efforts to adapt to some consequences of a warming climate. In particular, agriculture can play a critical role in maintaining continuity of food supplies for rural Alaskans who are facing changes in the timing and availability of subsistence foods. It could also reduce the risk of disruptions to transportation systems, which may have consequences for Alaskans in both urban centers and remote communities. In addition, agriculture can take advantage of climate effects that will create a more hospitable environment for some crops, and possibly livestock. Together, actions taken to provide continuity of food supplies (by increasing reliance on locally produced foods) and to take opportunity of potential benefits of climate change can work to create a more sustainable agricultural system while dovetailing with recommendations to reduce emissions contained in the companion report from the advisory group focused on mitigation.

Under this option, the State of Alaska will develop a program to support sustainable agriculture in Alaska that will improve, secure, and sustain the supply of quality, affordable food for all Alaskans by responding to new challenges and opportunities presented by a changing climate and other future changes (e.g., increasing food

transportation costs to and within Alaska). NS-6 recommends four key actions to increase food security, to be led by the ADNR Division of Agriculture:

- 1 Encourage community-based agriculture and practices that optimize the use of the land and resources available.
- 2 Research the magnitude and composition of food consumption in the state.
- 3 Research the sources of food supply and the risk associated with high reliance on imported foods.
- 4 Develop, in cooperation with stakeholders, a strategic Alaska food policy to increase reliance on locally produced food sources through agriculture, seafood harvesting, and subsistence activities, including enhanced intrastate marketing of Alaska-grown products.

Enhancing food security through locally sustainable food sources can address potential interruptions in current sources, increase availability of quality, affordable food for Alaskans, increase business opportunities, improve nutrition and health, and provide socio-cultural benefits.

These actions fit within the framework of the Division of Agriculture's 2008 Strategic Plan—which calls for addressing climate change effects on Alaska's agriculture sector and increasing local sustainable agriculture—and could be implemented in the short- to mid-term. Funding for two positions in the Division of Agriculture is recommended to lead and accomplish these tasks; as well as moderate funding for research on Alaska's food supply and to support meetings of the Alaska food coalition.

**Box 5-3. Natural Systems Recommended Research Needs: *Overarching Research Needs***

The Research Needs Work Group identified several overarching needs to help the State of Alaska better understand the impacts of climate change on its natural systems:

- NS/RN-1.1      Develop improved hydrology data and models statewide.
- NS/RN-1.2      Identify permafrost thaw hazards and incorporate into engineering guidelines.
- NS/RN- 3        Identify laws, policies, and regulations that could be modified to better support adaptation.
- NS/RN- 4        Implement local climate change scenario planning workshops in communities across Alaska (Coastal, Arctic, Interior, etc.).
- NS/RN-5        Identify and assess health and safety hazards resulting from climate change
- NS/RN-6        Coordinate data integration.
- NS/RN-7        Fill gaps in geospatial data coverage, aerial photography, digital elevation models (DEM), and remote sensing data that are needed to assess and forecast climate change impacts.
- NS/RN-8        Conduct coastal mapping and shoreline characterization.
- NS/RN-9        Assess, model, and monitor coastal impacts of changes to sea level and ice.
- NS/RN- 10      Develop and refine down-scaled climate models.
- NS/RN-11      Coordinate climate and ecosystem monitoring programs among agencies, organizations, and institutions.
- NS/RN-12      Work with communities to determine appropriate indicators of climate change and community impacts. Improve monitoring of key climate change indicators & effects, with emphasis on effects having large societal impacts. Monitor climate change indicators and their societal impacts.
- NS/RN-13      Conduct research on protecting community water supplies and instream flows.
- NS/RN-14      Expand research and monitoring of contaminants deposition and bioavailability under changing climate.
- NS/RN-15      Acquire or produce vegetation maps that are usually compiled from satellite imagery. Ortho rectified imagery would show human improvements and vegetation. A base map is needed for the state.
- NS/RN-16      Assess and improve communications strategies for climate change information.

*For additional information on each recommendation, and for a broader set of identified needs, see Research Needs Work Group (2009). The numbering system above refers to the last two subsection numbers in the appropriate chapter in the report.*

#### Box 5-4. Natural Systems Recommended Research Needs: *Specific Research Needs*

The Research Needs Work Group identified research necessary to assist in implementing specific natural systems recommendations.

##### FISHERIES

NS/RN-2.1 Synthesize current information about climate change impacts on fisheries and assess its reliability and degree of uncertainty.

NS/RN-2.2 Conduct Arctic Ocean fisheries assessments to prepare for potential changes due to changes in both climate and commercial fishing patterns.

NS/RN-2.3 Increase real-time monitoring and forecasts of physical ocean conditions (winds, waves, sea ice, currents, temperature, salinity, pH, etc.).

NS/RN-2.4 Assess the applicability of alternative government approaches to integrating climate change considerations into fisheries policy.

NS/RN-2.5 Conduct physical, biological, and socioeconomic monitoring to understand environmental change, distribution and abundance of freshwater, marine and, anadromous species as well as societal impacts.

NS/RN- 2.6 Consider need for protected fish conservation areas in response to impacts on fisheries.

##### WILDLAND FIRE

NS/RN-3.1 Expand modeling of wildland fire, fuel, and smoke.

NS/RN-3.2 Review and coordinate wildland fire policies with Canadian counterparts.

NS/RN-3.3/6.1 Research and monitor Tundra and forest response after fire disturbance and develop measures to reduce impacts.

##### INVASIVE SPECIES

NS/RN-4.1 Identify and develop methods to assess and control invasive and eruptive plant, animal, and diseases that are likely to become established, expand their range, or be intentionally introduced in Alaska due to climate change.

NS/RN-4.2 Provide effective monitoring, forecasting, and response to marine invasive species.

##### FISH AND WILDLIFE

NS/RN-5.1 Improve data and access regarding wildlife and fisheries populations and harvest rates.

NS/RN-5.2 Project likely changes to wildlife habitat due to climate-driven impacts on landscape, vegetation cover, wildfire frequency and intensity, permafrost thaw, and fragmented migratory corridors.

NS/RN-5.3 Improve methods for enumerating caribou and moose populations, to assist subsistence communities.

NS/RN-5.4 Assess disjoint between calendar dates for legal harvest and timing of biological behavior.

NS/RN-5.5 Identify how "sentinel" ecosystems are changing to provide long-term trend information.

##### SUSTAINABLE AGRICULTURE

NS/RN-7.1 Research agricultural products and practices suitable for changing conditions

##### NATURAL HAZARDS

NS/RN-8.1 Assess effects of climate on safe access for hunting, fishing and other subsistence activities.

NS/RN-8.2 Update the Environmental Atlas of Alaska and Alaska Engineering Design Information System (AEDIS).

*For additional information on each recommendation, and for a broader set of identified needs, see Research Needs Work Group (2009). The numbering system above refers to the last two subsection numbers in the appropriate chapter in the report.*

**Box 5-5. A Sampling of Relevant Current Activities**

*The examples presented below are not intended to be exhaustive, but rather to illustrate ongoing and proposed initiatives and activities.*

Many ongoing research and management programs are relevant to the effects of climate change on Alaska's natural systems and ecosystem services. The most effective adaptation actions by the State of Alaska will be those that partner with, contribute to, leverage, and build upon these types of existing efforts.

***NS-1 Fisheries and NS-5 Adaptive Management of Fish and Wildlife***

There are many government agencies, universities, and NGOs involved in monitoring the status of Alaska's fish and wildlife, their habitats, and the effects of climate change on these important resources.

***NS-2 Wildland Fire***

The existing Alaska Wildland Fire Coordinating Group is a highly-effective interagency mechanism for adaptive management of fire response and management. The Community Wildfire Protection Plan program is an existing, but not well-funded program. State, federal and university mapping projects provide essential baseline information (e.g., vegetative land cover).

***NS-3 Freshwater Management***

Relevant programs include the State's existing management authorities for water quantity and quality; hydrologic data collection by federal agencies, and other programs through the University of Alaska, private sector, and others. There is occasionally ad hoc coordination regarding water management and hydrologic issues at the agency staff level (e.g., Interagency Hydrology Committee for Alaska).

***NS-4 Invasive and Eruptive Species***

Several federal agencies have recently developed effective invasive species programs in Alaska. Ad hoc agency groups have been operating (Alaska Committee for Noxious and Invasive Plant Management, Alaska Invasive Species Working Group), but are hampered by lack of consistent State participation.