

Appendix B

State Aquatic Invasive Species Management Plan Summaries

Methods

We reviewed state AIS management plans, where available, and assessed how the state considers climate change specifically, as well as how they generally provide for adaptation of strategies and actions under changing conditions. There are a total of 25 state plans, including 23 AIS-specific plans and 2 general invasive species management plans with a significant AIS focus. As noted in Appendix A, as of 2007, several other states currently are in the process of developing AIS management plans. State plans generally refer to AIS as aquatic nuisance species or ANS. To maintain consistency with state plan language, this appendix generally uses ANS as a synonym for AIS. State plans examined include:

- Alaska Aquatic Nuisance Species Management Plan
- Arizona Aquatic Nuisance Species Management Plan
- Connecticut Aquatic Nuisance Species Management Plan
- Hawai‘i Aquatic Invasive Species Management Plan
- Idaho Action Plan for Invasive Species
- Illinois State Comprehensive Management Plan
- Indiana Aquatic Nuisance Species Management Plan
- Iowa Plan for the Management of Aquatic Nuisance Species in Iowa
- Kansas Aquatic Nuisance Species Management Plan
- Louisiana State Management Plan for Aquatic Invasive Species in Louisiana
- Maine Action Plan for Managing Invasive Aquatic Species
- Massachusetts Aquatic Invasive Species Management Plan
- Michigan Aquatic Nuisance Species State Management Plan: Update
- Missouri Aquatic Nuisance Species Management Plan
- Montana Aquatic Nuisance Species Management Plan
- New York Nonindigenous Aquatic Species Comprehensive Management Plan
- North Dakota Aquatic Nuisance Species Management Plan
- Ohio Comprehensive Management Plan for Aquatic Nuisance Species
- Oregon Aquatic Nuisance Species Management Plan
- Pennsylvania Aquatic Invasive Species Management Plan
- South Carolina Aquatic Plant Management Plan Part I and II
- Texas State Comprehensive Management Plan for Aquatic Nuisance Species
- Virginia Invasive Species Management Plan
- Washington State Aquatic Nuisance Species Management Plan
- Wisconsin Comprehensive Management Plan to Prevent Further Introductions and Control Existing Populations of Aquatic Invasive Species

The following summaries also provide recommendations for revising plans to incorporate climate considerations and management strategies to adapt to climate change. Recommendations are listed for individual plan goals and strategies.

Alaska Aquatic Nuisance Species Management Plan

Available at: http://www.adfg.state.ak.us/special/invasive/ak_ansmp.pdf

General Description of Alaska's Plan

Alaska's *Aquatic Nuisance Species Management Plan* was written by the Alaska Department of Fish and Game (ADF&G) and released in October 2002. The management plan focuses on the prevention of new introductions and the identification of and response to the highest invasive species threats. The plan outlines current aquatic nuisance species (ANS) problems and concerns in Alaska and outlines the deficiencies in state law with respect to ANS prevention and control. The primary goals of the plan are to increase coordination between the public and federal, state, local, and tribal governments on the prevention and monitoring of invasive species and the development of a public information program. To obtain these goals, ADF&G established an invasive species policy and several Strategic Actions. Recommended Strategic Actions relate to six specific management goals:

1. Coordinate all ANS Management Programs in Alaska and collaborate with regional, national, and international programs;
2. Prevent the introduction of new ANS into Alaska waters;
3. Detect, monitor, contain, reduce, or eradicate populations of ANS as quickly as possible with minimum environmental impact;
4. Educate the public and appropriate resource user groups about the importance of preventing ANS introductions and how the harmful impacts of ANS can be reduced;
5. Identify, develop, conduct, and disseminate research on ANS of concern in Alaska; and
6. Take appropriate steps to ensure that federal and state regulations promote the prevention and control of ANS.

The plan includes a timetable for the completion of the Strategic Actions associated with each goal.

Climate Change and Invasive Species in Alaska

Climate models project that temperature in the Arctic will increase 1.5 to 5°F (1 to 3°C) by 2030, and 5 to 18°F by 2100, with higher magnitudes of warming in the north and in the winter. Models also project precipitation increases in most of the state with as much as a 20 to 25 percent increase in the north and northwest; however, a 10 percent decrease in precipitation is projected along the south coast. Increased evaporation in response to warmer temperatures, however, will make soils drier throughout most of the state (Parson, 2000a).

In addition, permafrost thawing is projected to accelerate, with as much as the top 30 to 35 feet of discontinuous permafrost thawing by 2100. All climate models for Alaska project significant continued loss of sea ice, with year-round ice disappearing completely in one model by 2100. Loss of sea ice allows for larger storm surges to develop, increasing erosion and coastal inundation and threatening populations of polar bears and marine mammals that depend on ice. (Parson, 2000a)

Changing water and air temperatures and precipitation levels may modify ecosystems, making them more vulnerable to species once limited by Alaska’s cold climate. For example, Alaska’s plan identifies the green crab (*Carcinus maenas*) as one of the state’s highest potential invasive threats, currently thought to be limited from establishment in part due to cold water temperatures. However, the future effects of climate change may allow this species’ range to expand to Alaska.

In addition, melting permafrost may increase nutrient supply into aquatic systems, making them more susceptible to invasion by species previously limited by lack of nutrient availability. Alaska’s plan also includes Whirling disease (*Myxobolus cerebralis*) as one of its highest invasive threats. Vectors associated with the fish pathogen require a more nutrient-rich environment than the state’s freshwater streams currently provide. Melting permafrost may deliver the nutrients needed to facilitate the movement of Whirling disease into Alaska’s environment.

The Alaska Plan’s Consideration of Climate

The table below summarizes how the *Alaska Aquatic Nuisance Species Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	2
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	2
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	1
...prevention goals and strategies	1
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	1
...information management goals and strategies	0
...education and public awareness goals and strategies	1
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	2
Plan includes strategy for managing/updating monitoring data	3
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	2
<i>Funding:</i>	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required	

funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	1
Total score:	16

Although Alaska’s plan does not at any point specifically consider climate change, recognition that climate zones and changing conditions affect ANS ranges is embedded throughout the plan, including many of the management tasks outlined.

Building in Climate Change Information

In light of the significant effects of climate change predicted for Alaska, the state may consider specifying climate change-related actions and strategies within the ANS Management Plan. Climate change-related data, criteria, and models could be incorporated into the existing tasks outlined in the plan. For example, the following Strategic Actions outlined in the plan could incorporate climate change considerations:

- *Leadership and Coordination.* Strategic Action 2A1 calls for coordination among states, tribes, NGOs, and countries, including the development of action plans for individual species, multiple species, or pathways for invasive species threats currently thought to be the highest priority. The action item also calls for coordination on preparing risk assessments to determine additional ANS priority threats. Because species’ abilities to spread are affected in part by climate, action plans could consider predicted changes in water and air temperatures as a preliminary assessment of invasion threats. Furthermore, plans could consider the invasion pathways linked to human activities that may be sensitive to climate change. For example, recreational boating may increase as the climate warms, which will provide additional invasive species transport opportunities. Future risk assessments should consider the anticipated effects of climate change on species’ life cycles and pathways in order to identify species that may pose a threat with continued climate change.

- *Prevention.* Strategic Action 2A3 recommends that the state prohibit, control, or permit the importation of nonnative aquatic species based on their invasive potential. Two of the tasks associated with this action include the development of an invasive species list of prohibited species and the development of an annual process to identify new and existing threats and assess the environmental risks of these threats. Criteria used to identify potentially invasive species could account for predicted changes in temperature, nutrient availability, hydrology, and other climate change-related ecological impacts that could modify potential habitat for invasive species previously limited by these factors.

- *Early Detection/Rapid Response, Control and Management.* Strategic Action 3A1, designed to help detect, monitor, contain, reduce, or eradicate populations of ANS as quickly as possible, calls for the monitoring of waters vulnerable to new ANS introductions and the tracking of existing populations’ distributions. Considering climate change in these assessments may help managers determine which waters are vulnerable to species invasions. Collecting available monitoring data from neighboring states may also allow managers to track invasive species that are spreading in response to climate change.

- *Research.* Strategic Action 5A1, designed around the goal of identifying, developing, conducting, and disseminating research on ANS, recommends an assessment of the risks posed to human health, ecosystems, and the economy by ANS introductions. The plan recommends characterizing resources and habitats containing ecological communities that are highly sensitive to invasion. Because climate changes may make some communities more susceptible to invasions, the assessment could benefit from considering the predicted effects of climate change.

Arizona Aquatic Nuisance Species Management Plan

Available at: <http://ag.arizona.edu/azaqua/extension/ANS/ArizonaPlan.htm>

General Description of Arizona's Plan

Arizona's *Aquatic Nuisance Species Management Plan* was written by the University of Arizona's Agriculture Department and released in May 2002; however, as of December 2006, it has not been finalized or approved by the state government. The Arizona Invasive Species Council (chartered by Governor Napolitano and co-chaired by the Arizona Game and Fish Department and the Arizona Department of Agriculture) has recommended development of an Invasive Species Management Plan. This plan will include a chapter on aquatic nuisance species (ANS) and will be based on the draft ANS plan described here.

The draft ANS plan describes state, national, and international laws that impact aquatic nuisance species management in Arizona. The plan aims to improve coordination between the various ANS management programs and activities being implemented in Arizona. The plan also identifies seven priority aquatic nuisance species (zebra mussel, hydrilla, Brazilian elodea, parrotfeather, purple loosestrife, giant salvinia, and water hyacinth) and proposes strategies and management actions specific to these species. The ANS plan's premise is to focus on priority species, which will result in the prevention of other lower priority species as well.

Recommended strategies and actions relate to three specific goals are:

1. Prevent new and unintended introductions of nonindigenous ANS into the Colorado River and inland waters of Arizona;
2. Limit the spread of established populations of nonindigenous ANS into uninfested waters of the state; and
3. Abate harmful ecological, economic, social and public health impacts resulting from infestations on nonindigenous ANS.

Climate Change and Invasive Species in Arizona

Temperatures are expected to rise as much as 5° F in Southwestern United States (U.S.) over the next 30 years, and precipitation is projected to decrease significantly through the end of the century (Seager et al., 2007).

Water resources are projected to become scarcer as the climate changes and demand on water supplies increases as the population grows (Seager et al., 2007). This decrease in water availability could favor more drought-tolerant invasive species such as tamarisk. A change in temperature and precipitation may also change the structure and composition of Arizona's sensitive ecosystems and native species (SAG, 2002). This change could potentially benefit fast-growing, more tropical species such as water hyacinth.

The Arizona Plan's Consideration of Climate

The table below summarizes how the *Arizona Aquatic Nuisance Species Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
Understanding and incorporating potential impacts resulting from climate change:	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	1
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
Capacity to adapt to changing conditions:	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	1
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	1
...information management goals and strategies	0
...education and public awareness goals and strategies	0
Monitoring strategies:	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	3
Plan includes strategy for managing/updating monitoring data	0
Revision:	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	0*
Funding:	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	0*
Total score:	6
* Arizona's plan has not been formally approved and will be incorporated into the state's larger ANS plan, which is under development as of December 2006.	

Arizona's management plan does not specifically consider the effects of climate change, but a few elements in the plan allow for changing conditions to be considered in the implementation of the plan.

Building in Climate Change Information

Given the anticipated effects of climate change on Arizona's aquatic ecosystems, the state may consider incorporating predicted impacts into subsequent revisions to the ANS Management Plan. The plan would be more robust in a changing climate if it were to account for predicted effects of climate change, such as increased water temperatures and decreased water levels in the summer, on both native species' ability to survive and invasive species' ability to become established or expand. The following strategies outlined in the plan could incorporate climate change considerations:

- *Leadership and Coordination.* Strategic Action IA calls for coordination on developing state-specific and regional lists of ANS that have the potential to spread to Arizona's waters. The plan also calls for coordination on identifying existing and potential transport pathways. Task IE1 recommends assessing these transport mechanisms and developing preventative action plans to interrupt pathways. Because species' abilities to spread and become established also are affected by climate, species lists should include AIS that could be influenced by projected climate changes. Transport pathways that are linked to human activities that could be sensitive to climate change also should be considered and assessed. For example, recreational boating may increase as the climate warms (unless precipitation also decreases), which will provide increased transport opportunities for primary species of concern such as zebra mussels.
- *Prevention, Early Detection/Rapid Response.* Strategic Action ID recommends developing and maintaining a monitoring program to provide for early detection and prevention of AIS in watersheds that presently have no invasive species. Accounting for predicted effects of climate change, such as increased water temperatures and decreased water levels in the summer, on both native species' ability to survive and invasive species' ability to become established, could help managers more effectively determine which watersheds may be more vulnerable to invasion under a changing climate. Additionally, collecting information from adjacent states may increase managers' awareness of climate-related invasive species threats.
- *Research.* Strategic Action IIF calls for collaboration among state and federal agencies and academic institutions to study and evaluate potential management actions to limit spread of AIS. This assessment and evaluation could also examine how management actions could be adapted in the context of a changing climate and the predicted impacts for the state.

Connecticut Aquatic Nuisance Species Management Plan

Available at:

<http://www.ctiwr.uconn.edu/ProjANS/SubmittedMaterial2005/Material200601/ANS%20Plan%20Final%20Draft121905.pdf>

General Description of Connecticut’s Plan

Connecticut’s *Aquatic Nuisance Species (ANS) Management Plan* was written by the Connecticut ANS Working Group with public input. The ANS Working Group is composed of staff from the Connecticut Department of Environmental Protection, Sea Grant College Program, and the Connecticut Institute of Water Resources, as well as other state and regional partners. The plan’s primary goal is to establish a comprehensive strategy to minimize the negative impacts of ANS to the state’s ecology, economy, and public health. Other goals relate to preventive strategies based on monitoring and early-detection efforts. The plan catalogues and characterizes existing ANS, including their impacts and costs, and discusses the benefits of planned introductions. Research, resource needs, management programs, and funding sources are also described.

Climate Change and Invasive Species in Connecticut

Projected increases in annual surface temperatures in the northeastern region of the U.S. are projected to average 5.3°C by 2070. Nearly all model simulations of future precipitation show consistent increases in winter precipitation and no change to a decrease in summer rainfall. By 2100, precipitation is projected to increase an average of 11 to 14 percent in the winter. Regional sea surface temperatures are projected to increase in accordance with regional air temperatures; these increasing temperatures have the potential to expand the range of warm water species northward and permit invasive species to spread into these waters that previously were too cold to allow for their survival (Hayhoe, 2007).

The Connecticut Plan’s Consideration of Climate

The table below summarizes how the *Connecticut Aquatic Nuisance Species Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	1
Plan acknowledges climatic boundaries of species	1
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	1
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	1
...prevention goals and strategies	1
...early detection/rapid response goals and strategies	0

...control and management goals and strategies	1
...restoration goals and strategies	0
...research goals and strategies	1
...information management goals and strategies	0
...education and public awareness goals and strategies	0
Monitoring strategies: 0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	1
Plan includes strategy for managing/updating monitoring data	1
Revision: 0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	1
Funding: 0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	2
Total score:	12

While Connecticut’s plan does not include a strong focus on climate change, changing temperatures, shifting winds and currents, and the climatic sensitivities of the region are briefly mentioned in relation to specific species or habitats. Many of the research and management tasks stress the importance of carefully monitoring changing conditions.

Building in Climate Change Information

In light of the predicted effects of climate change for the state, Connecticut should incorporate climate change data in implementing the actions and strategies described in its ANS Management Plan. While changing conditions are acknowledged, the full scope of effects resulting from climate change is not explicitly addressed in the plan’s management strategies. For example, the following Strategic Actions outlined in the plan could incorporate climate change considerations.

- *Leadership and Coordination.* The plan’s “Coordinate Beyond Connecticut” (5.1.C) section recognizes that formal jurisdictional boundaries do not necessarily apply in managing ANS. Strategies related to regional coordination provide an excellent opportunity for information sharing about habitat transformation and other changing conditions that could allow species to move from one habitat to the next.
- *Prevention.* Objective 3 in Chapter 5 of the plan outlines prevention actions. The plan recognizes that the most likely AIS introductions have already occurred in other Northeast states. When looking at new species that are likely to establish, information on climate change should also be considered.
- *Early Detection/Rapid Response.* The keystone of the Connecticut plan relies on an expanded monitoring strategy that will allow for the early detection of new infestations, as well as monitoring of existing ANS populations. Monitoring strategies should

incorporate climate change information in order to accurately detect species that may arrive in the state's habitats as a result of changing conditions. Considering climate change may increase the effectiveness of early detection/rapid response protocols. Furthermore, regional efforts may become more effective as Connecticut and other states document AIS populations, allowing species-specific rapid response protocols to be developed.

- *Control and Management.* ANS management strategies may need to be adapted as conditions in the state change. Control of existing ANS may be more effective if managers consider projected changes in water temperature and precipitation patterns.
- *Research, Information Management.* Objective 7 in Chapter 5 of the plan describes a research strategy that may be modified according to changes in ANS populations. The effects of climate change on Long Island Sound and the state's inland waterways and aquatic habitats should be included as a research priority. Ecological communities will become more or less susceptible to invasion as a result of changing conditions. Assessment of these risks can be applied to state management strategies. The plan requires the on-going designation of priority species using "improved knowledge of ANS distribution and impacts." Given that species distributions may be affected by climate change, the method used to designate priorities should consider these effects.

Hawai‘i Aquatic Invasive Species Management Plan

Available at: http://www.state.hi.us/dlnr/dar/pubs/ais_mgmt_plan_final.pdf

General Description of Hawaii’s Plan

Hawaii’s *Aquatic Invasive Species Management Plan* was developed by the Hawai‘i Invasive Species Council (HISC) and the Department of Land and Natural Resources (DLNR) - Division of Aquatic Resources (DAR) and released in 2003. The plan serves as a tool to increase coordination on management efforts, identify problems and gaps, and make recommendations to resolve aquatic invasive species (AIS) issues. The overall goal of the plan is “[t]o minimize the harmful ecological, economic, and human health impacts of AIS through the prevention and management of their introduction, expansion, and dispersal into, within, and from Hawai‘i.” The plan identifies seven objectives to achieve this goal:

1. Improve the coordination and collaboration of people, resources, and efforts involved with AIS;
2. Minimize the introduction and spread of AIS into and throughout the waters of Hawai‘i;
3. Ensure effective programs that allow for the early detection of new AIS and the monitoring of existing AIS;
4. Establish effective systems for rapid response, eradication, control, and restoration;
5. Increase education and outreach efforts to ensure awareness throughout the state on AIS threats and solutions;
6. Increase research efforts on key AIS species, associated issues, and economic impacts to allow for more effective management; and
7. Ensure state laws and regulations effectively promote the prevention and control of AIS.

The management plan also prioritizes tasks to ensure objectives and strategies are accomplished. A monitoring and evaluation program has been established, and the plan includes an implementation table that outlines responsible agencies and funding.

Climate Change and Invasive Species in Hawai‘i

The effects of climate change in the tropical Pacific Basin are expected to cause a gradual warming of the sea surface and air temperatures. Climate models project approximately an increase of 1.8° C between 2080 and 2099 with a possible range of 1.4 to 3.1° C (Christensen et al., 2007). Averaged model predictions project a three percent increase in precipitation in the southern Pacific. Sea-levels are also expected to rise in the Pacific, although scientists are uncertain as to what degree (Christensen et al., 2007). Climate models also predict a gradual increase in the frequency of tropical cyclones for islands in the Central and East-Central Pacific, both north and south of the equator (PIRAG, 2001).

Atolls are particularly vulnerable to sea-level rise. Sea-level rise can result in the loss of low-lying coastal areas due to erosion and inundation; accelerate reduction in the volume of the fresh-water lenses, stressing freshwater resources that may already be affected by reduced rainfall; and exacerbate the effects of tropical cyclones and storm surge. The model-based scenarios used in the National Assessment project a sea-level rise of between 10 and 12 centimeters (3.9 to 4.7

inches) for much of the tropical Pacific in the short-term and a rise of 30 to 38 centimeters (11.8 to 15.0 inches) over the long-term (PIRAG, 2001).

Hawai'i holds 40 percent of the United States' endangered species. Invasive species are one of the major threats. For example, warming temperatures may allow mosquitoes to survive at higher altitudes, pushing already threatened native forest birds to higher elevations and into smaller ranges. Coral species and coral reef-dependent species also may be impacted by climate change and invasive species (Harvell, 1999). Warming water temperatures are predicted to cause coral bleaching and increase occurrence, severity, and spread of marine diseases (Harvell, 2002; Jones, 2004). Diseases could further exacerbate these problems by weakening ecosystems (Jones et al., 2004).

The Hawai'i Plan's Consideration of Climate

The table below summarizes how the *Hawai'i Aquatic Invasive Species Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	2
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	2
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	1
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	1
...information management goals and strategies	0
...education and public awareness goals and strategies	1
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	3
Plan includes strategy for managing/updating monitoring data	3
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	1
<i>Funding:</i>	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	0

Although Hawaii’s plan does not explicitly mention climate change, it does call for regular updates to address and adapt to changing circumstances. This provides the opportunity to incorporate climate change concerns into future drafts.

Building in Climate Change Information

Climate change is projected to have significant ecological effects in Hawai‘i, and considering climate change effects may increase the effectiveness of actions and strategies outlined in the AIS Management Plan. Climate change data and models could also be included in risk analyses. The following specific Strategies of the plan could include climate change considerations:

- *Prevention.* Strategy 2B8 calls for identifying “ecologically sensitive” marine and inland water areas that currently have few or no AIS and to determine and implement precautionary actions. Many areas not previously considered may be more vulnerable to AIS as a result of climate change impacts such as warmer waters, droughts or flooding, and sea-level rise, or increased carbon dioxide levels. In conjunction with AIS, these impacts could cause greater harm to ecologically sensitive areas. For example, salt water intrusion from sea level rise may not only harm freshwater ecosystems close to the coast, but also allow salt tolerant aquatic invasives to thrive and out-compete native species. Thus, climate change considerations must be taken into account when identifying “ecologically sensitive” areas. Incorporating these considerations will ensure that limited resources are efficiently and effectively allocated.
- *Early Detection/Rapid Response.* Strategies 3A and 3B call for continuing current monitoring efforts to improve understanding of spatial and temporal distributions of existing species and to detect incipient species. Monitoring efforts should be modified to address how climate change may impact AIS rates of spread in order to more accurately predict their movement and prevent their establishment. Proactive monitoring will increase the efficacy and success of early detection and rapid response.
- *Control and Management.* Strategy 4C recommends integrating knowledge on control and management efforts from Hawai‘i with national and international information on specific species. The plan proposes that this information be used to develop long-term plans for containment and eradication where possible. State staff must consider how the anticipated effects of climate change, such as increased runoff, changes in water temperature, or drought, may impact the success of recommended control and eradication methods, and must adapt strategies accordingly.
- *Research.* Objective six recommends research on the economic impacts of AIS. Climate change must be considered in this research as its impacts may make some economic sectors more susceptible to impacts from invasive species. For example, if coral or fish diseases become more prevalent due to warmer waters and destroy increasing amounts of coral reefs, Hawaii’s tourism industry could suffer. Coral bleaching due to climate change could exacerbate this impact.

**Idaho
Action Plan for Invasive Species**

Available at:

<http://www.agri.state.id.us/Categories/Environment/InvasiveSpeciesCouncil/documents/Idaho%27s%20Invasive%20Species%20Plan.pdf>

General Description of Idaho’s Plan

As of December 2006, Idaho’s *Aquatic Nuisance Species (ANS) Management Plan* was under development; however, the state’s *Action Plan for Invasive Species* includes extensive information on ANS and is summarized here. The plan, written by the Idaho Invasive Species Council for Governor Kempthorne in 2005, identifies gaps in current state management efforts for invasive species, as well as how gaps may be addressed. The plan contains 22 actions to address seven main management approaches, each with a long-term goal: (1) early intervention; (2) containment, control, and restoration; (3) education and training; (4) research and technology transfer; (5) assurance of adequate funding; (6) creation of an adequate, effective legal structure; and (7) coordination. All proposed actions have associated short-term goals, a measurable objective, and an implementation timeline.

Climate Change and Invasive Species in Idaho

Average warming in the pacific northwestern region of the U.S. is projected to reach 3°F (1.7°C) by the 2020s and 5°F (2.8°C) by the 2050s. Annual precipitation projections are less certain; projected precipitation levels range from a small decrease (7 percent or 2 inches) to a slightly larger increase (13 percent or 4 inches). Heavier winter rainfall would increase soil saturation, landslides, and winter flooding. The projected precipitation increases are expected to be concentrated in winter, with decreases or smaller increases during summer; for this reason, even the projections that show increases in annual precipitation show decreases in water availability (Parson, 2000b).

As temperatures increase and water supplies decrease, AIS such as salt cedar may gain an advantage over native, less tolerant species. Idaho may experience an increase in AIS transported by humans as air and water temperatures warm and water-based recreation increases or is extended for longer periods throughout the year.

The Idaho Plan’s Consideration of Climate

The table below summarizes how the *Idaho Action Plan for Invasive Species* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	1
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	

0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
Monitoring strategies: 0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	0
Plan includes strategy for managing/updating monitoring data	0
Revision: 0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	0
Funding: 0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	0
Total score:	1

Idaho’s *Action Plan for Invasive Species* does not consider climate change impacts on its management actions.

Building in Climate Change Information

Considering the climate change impacts predicted for the State of Idaho, it will be important for the state to incorporate climate change into future revisions of this Action Plan, as well as into the AIS Management Plan currently under development. For example, climate change considerations could be incorporated into the following aspects of the *Idaho Action Plan for Invasive Species*:

- *Early Detection/Rapid Response.* Task 1 in the Early Interventions-Prevention, Early Detection and Rapid Response Section calls for the creation of lists of high-risk invasive species, or those species that have a high probability of being introduced. Task 1 also calls for the creation of a “red list” comprising species that pose the highest threat. Warming waters and/or decreased water levels not only may influence ecosystem vulnerability, allowing certain species invade and to become established, but also may allow for previously limited invasive species’ ranges to expand. These possibilities must be considered in developing a list of high risk species. Additionally, collecting available monitoring data from neighboring states may allow managers to track invasive species that are spreading as a result of climate change. This information will also be useful in developing a statewide system for early detection and rapid response, as described in

Task 2. The system will utilize scientific protocols to determine the risks posed by invasive species.

- *Research.* Task 1 under the Broadening Knowledge through Research and Technology Transfer Section calls for identifying and setting priorities for invasive species research. The plan highlights species risk assessments for invasability and potential damage. Because some ecosystems may be more susceptible to invasions as a result of climate change, risk assessments would be more accurate if they consider the predicted effects of climate change.

**Illinois
State Comprehensive Management Plan**

Available at: <http://www.anstaskforce.gov/State%20Plans/ilansplan.pdf>

General Description of Illinois' Plan

The Illinois *State Comprehensive Management Plan* has three primary goals:

1. Preventing new aquatic nuisance species (ANS) introductions into both the Great Lakes and the Mississippi River Basin;
2. Limiting the spread of established populations of AIS within waters of the state; and
3. Abating harm, both ecological and socioeconomic, by currently established AIS.

The plan includes a list of AIS management tasks for state waters. In addition, arguing that the costs of AIS to industry and resource production far outweigh the cost of conducting AIS management, the plan calls for the proper commitment of staff and necessary resources to appropriately address AIS and implement prescribed management tasks. However, the plan leaves specific budgeting to be addressed in a future work plan, as the state hopes to secure federal funding and rally further interest by building project proposals with the interest generated from the plan.

Climate Change and Invasive Species in Illinois

Temperatures are projected to increase by 5 to 10°F in the Midwest region throughout the 21st century. Precipitation is expected to increase by approximately 10 to 30 percent across the region. Increasing temperatures are expected to substantially increase evaporation, triggering a soil moisture deficit, reduction in lake and river levels, and more drought-like conditions in much of the region. For smaller lakes and rivers, reduced flows are likely to intensify water quality issues. In particular, eutrophication of lakes will likely increase due to increases in excess nutrient runoff from heavy precipitation events and warmer lake temperatures that stimulate algae growth (Easterling and Karl, 2000).

As water temperatures in lakes increase, significant changes in freshwater ecosystems will occur. For example, a shift from cold water fish species such as trout, to warmer water species, like bass and catfish could take place. Warmer waters also may create an environment that is more susceptible to invasions by non-native species (Easterling and Karl, 2000)

The Illinois Plan's Consideration of Climate

The table below summarizes how the *State Comprehensive Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	1
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	1
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0

Capacity to adapt to changing conditions:	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	2
...information management goals and strategies	0
...education and public awareness goals and strategies	0
Monitoring strategies:	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	1
Plan includes strategy for managing/updating monitoring data	1
Revision:	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	0
Funding:	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	0
Total score:	6

Illinois' plan notes that habitat changes are imminent and related to AIS infestations, but it does not discuss climate change as the specific cause of these changes. The plan is designed to be adaptable in a changing environment and allows for continuous reassessment of strategy.

Building in Climate Change Information

Illinois would strengthen its AIS strategy by incorporating climate change considerations into regional planning goals and the development of a statewide database to record information on habitat. Specific examples of how the state could account for climate change in its plan include:

- ***Leadership and Coordination.*** The Non-Indigenous Aquatic Nuisance Species Prevention and Control Act calls for a Great Lakes panel to convene and organize on AIS. The coordinated regional effort addresses regional priorities, recommendations to the federal ANS Task Force, and additional federal communications and recommendations. However, the state plan does not outline specific responsibilities for Illinois in this effort. Illinois and the Great Lakes panel could bolster their efforts by communicating on the anticipated effects of climate change, vectors and species potentially invasive as a result of changing conditions, as well as management strategies adapted to account for changing conditions.
- ***Prevention.*** The Illinois plan's prevention strategies, outlined in Strategic Action 2-2, focus on vectors and barriers to physical dispersal. Prevention strategies may need to be

adapted in light of fluctuating lake levels, water temperatures, increased vectors, and other changes influenced by climate. These considerations will ensure the robustness of AIS prevention management decisions and efficient use of scarce resources.

- *Early Detection/Rapid Response (ED/RR)*. Illinois has not yet developed an ED/RR protocol, but has listed it as a requirement in the state AIS plan. Changing conditions must be considered as the ED/RR system is developed in order to increase the effectiveness of monitoring strategies for high priority species. Furthermore, climate change may influence which species are determined to be of high risk—thus, climate change information should be considered in developing AIS priority lists.
- *Research*. The Illinois plan sets more effective control strategies and better dispersal barriers as research priorities. This research should include adapting management strategies to address the anticipated effects of climate change.

Indiana Aquatic Nuisance Species Management Plan

Available at: <http://www.in.gov/dnr/invasivespecies/inansmanagementplan.html>

General Description of Indiana's Plan

The Indiana *Aquatic Nuisance Species (ANS) Management Plan* outlines strategies for state and local government agencies and concerned community and research organizations to control AIS infestations in a safe and effective manner. The five-year plan is designed address the different stages of AIS invasions. Goals include:

1. Preventing the introduction of new nonindigenous species transported from water bodies in other parts of the continent or world;
2. Limiting the spread of established, reproducing AIS populations to other water bodies in Indiana and other states; and
3. Mitigating the harmful ecological, economic, social, and public health impacts of established AIS populations.

No comprehensive survey of the AIS populations in Indiana has been conducted to date, and so the plan emphasizes building a foundation of information as a priority. Guiding principles for the plan include strong leadership, provision of resources and staff, illustration of the economic and environmental damages wrought by invasive species, and implementation at all levels of government.

Climate Change and Invasive Species in Indiana

Temperatures are projected to increase by 5 to 10°F in the Midwest region throughout the 21st century. Precipitation is expected to increase by approximately 10 to 30 percent across the region. Increasing temperatures are expected to substantially increase evaporation, triggering a soil moisture deficit, reduction in lake and river levels, and more drought-like conditions in much of the region. For smaller lakes and rivers, reduced flows are likely to intensify water quality issues. In particular, eutrophication of lakes will likely increase due to increases in excess nutrient runoff from heavy precipitation events and warmer lake temperatures that stimulate algae growth (Easterling and Karl, 2000).

As water temperatures in lakes increase, significant changes in freshwater ecosystems will occur. For example, a shift from cold water fish species, such as trout, to warmer water species, like bass and catfish could take place. Warmer waters also may create an environment that is more susceptible to invasions by non-native species (Easterling and Karl, 2000)

Changes in temperature and stream flow could affect the ability of these systems to resist the invasion of AIS that may be able to overwinter as a result of climate change.

The Indiana Plan's Consideration of Climate

The table below summarizes how the *Indiana Aquatic Nuisance Species Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
--	-------

Understanding and incorporating potential impacts resulting from climate change:	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	3
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
Capacity to adapt to changing conditions:	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	1
...early detection/rapid response goals and strategies	1
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
Monitoring strategies:	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	3
Plan includes strategy for managing/updating monitoring data	0
Revision:	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	3
Funding:	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	1
Total score:	12

The Indiana plan includes a broad array of preventative and mitigative actions, but it does not specifically consider how climate change may affect AIS or associated management strategies.

Building in Climate Change Information

Indiana could ensure the effectiveness and robustness of its plan by considering anticipated changing conditions that may result from climate change in its AIS management strategies. For example:

- ***Leadership and Coordination.*** The plan calls for the establishment of consistent methods and priority lists among states that trade regularly or that have overlapping watersheds. Climate change should be a consideration in communication on encroaching species and potential vectors and on adapting management practices to accommodate for changing conditions.

- *Prevention.* Objective II.A. of the plan discusses priority vectors for AIS. Climate change should be a consideration in determining vectors and risk of AIS invasion. Not only will species ranges expand as a result of changing conditions, but also vectors may increase AIS dispersal indirectly. For example, recreational boating may increase as the climate warms and waterways remain open for longer periods, which will provide additional invasive species transport opportunities. AIS risk assessments should also consider the anticipated effects of climate change on species' life cycles and pathways in order to identify species that may pose a threat with continued climate change. Because species' abilities to spread are affected in part by climate, action plans could consider predicted changes in water and air temperatures as a way to assess invasion threats. Finally, Indiana's plan emphasizes the importance of monitoring not only high-priority species, but also geographic areas at risk. Climate change data should be considered in determining both species and locations at high risk of invasion.
- *Early Detection/Rapid Response.* Objective III.A. of the plan outlines the use of monitoring programs to ensure that invasive species are properly detected, verified, and reported. Because changing water levels and temperatures and precipitation patterns affect AIS' habitat ranges climate change information should be considered in developing monitoring strategies.

Iowa
Plan for the Management of Aquatic Nuisance Species in Iowa

Available at: <http://www.anstaskforce.gov/Iowa-ANS-Mangement-Plan.pdf>

General Description of Iowa's Plan

Iowa's Department of Natural Resources (DNR) Eurasian Watermilfoil Program and the Iowa Aquatic Nuisance Species (ANS) Special Task Force led the development of the *Plan for the Management of ANS in Iowa*. The plan was written to guide development of management actions for invasive species, as well as funding mechanisms for prevention, control, and abatement activities for state agencies, local governments, and resource users. The plan outlines three management goals:

1. Minimize the risk of further introductions of AIS into the state of Iowa;
2. Limit the spread of established populations of AIS into uninfested waters in Iowa; and
3. Eradicate or control to a minimal level of impact the harmful ecological, economic, social, and public health impacts resulting from infestation of AIS in Iowa.

Eights objectives are designed to accomplish the three goals of the plan:

1. Coordinate all AIS management programs within Iowa and collaborate with regional and national AIS programs;
2. Prevent the introduction of new AIS into Iowa waters;
3. Eradicate or contain new AIS introductions or establish populations as quickly as possible; prevent or slow their spread into uninfested areas; and reduce the size of established AIS populations;
4. Educate appropriate resource user groups about the importance of preventing the introduction and spread of AIS, and how their harmful impacts can be reduced;
5. Monitor state waters to determine the occurrence and distribution of AIS;
6. Support research on AIS priority species in Iowa, and develop efficient systems to disseminate AIS research information to the research and management communities;
7. Gain passage of AIS legislation in Iowa to ensure that state AIS rules and regulations efficiently promote the prevention and control of AIS in coordination with federal regulations; and
8. Establish a permanent funding mechanism for an Iowa AIS management program.

Each objective has associated strategic actions and tasks. The plan also focuses on three priority AIS, but notes that, as the state AIS program evolves, it will incorporate more species. Additionally, the plan states that focusing on prevention and pathways may prevent other lower priority AIS. The plan also includes a management plan implementation table and a program monitoring and evaluation planning table.

Climate Change and Invasive Species in Iowa

Temperatures are predicted to increase by 5 to 14°F in the winter and 9 to 22°F in the summer. These warmer temperatures will lead to earlier spring snowmelt, which, in combination with increased evaporation in the summer months, could lead to a decrease in surface and ground water availability. Although winter and spring precipitation is expected to increase by 30

percent, summer precipitation is expected to decrease by 10 to 35 percent—further impacting water supply. Less water could lead to drier soils and droughts in the summer months. Flood control capacity of wetlands and floodplains may also be degraded, which could result in increased flooding in winter and spring months. Additional flooding in these seasons could cause increased sedimentation and pollution into Iowa’s waters (Moser et al., 2004).

As water temperatures warm, species such as mosquito fish that currently are limited by Iowa’s winter temperatures, may begin to invade the state. Other species found even further south, such as the spotted gar, may begin to move northward in the Mississippi River (Moser et al., 2004). Eurasian watermilfoil, already a major problem in the state, could worsen under climate change conditions as this species is tolerant of a wide range of conditions (Moser et al., 2004).

The Iowa Plan’s Consideration of Climate

The table below summarizes how the *Plan for the Management of ANS in Iowa* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	1
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	3
Plan includes strategy for managing/updating monitoring data	0
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	2
<i>Funding:</i>	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	2

Although the *Plan for Management of AIS in Iowa* includes no climate change considerations, the plan does include extensive monitoring and prevention strategies and actions.

Building in Climate Change Information

Predicted effects of climate changes in Iowa include warmer temperatures and lower ground and surface water levels. These and other concerns need to be incorporated into the state plan’s strategies and actions, monitoring and prevention strategies in particular. Including these considerations will ensure that the plan and its associated AIS management actions are effective and efficient in the long-term. The following Strategic Actions outlined in the plan could consider climate change:

- *Leadership and Coordination.* Strategic Action 1A3 calls for developing partnerships with states in the region to evaluate the regional threat of AIS and to coordinate management efforts. Iowa should use this opportunity to work with other states to determine what AIS are moving north as a result of climate change and what more southern states are doing to prevent, control, and manage these AIS. Strategic Action 5A1 also calls for working with partners in regional states to share AIS distribution information based on each state’s monitoring efforts. Using this data will help not only identifying what AIS threats, but it will also help the state coordinate and design rapid response and eradication efforts.

- *Prevention.* Strategic Action 2A2 calls for risk assessments to identify water bodies at high-risk of AIS invasion. An associated task recommends incorporating data on species’ life histories and habitat preferences. Water bodies may become more sensitive to specific AIS if their temperatures rise or water levels decrease; thus, it will be important for staff conducting risk assessments to incorporate these considerations into the analysis. Similarly, Strategic Action 5A2 and associated Task 5A2b call for designing a monitoring program to help limit the spread of AIS. Understanding invasive threats in the context of climate change will ensure that monitoring efforts target appropriate AIS and habitats.

- *Control and Management.* Strategic Action 6A3 calls for supporting research that identifies effective management actions for successful AIS control and eradication methods in Iowa. Research must examine how management actions should be adapted in the context of a changing climate and the predicted impacts for the state. Task 6A3a also recommends identifying important data needed to control and/or eradicate AIS in Iowa. Climate change data should be considered as a part of this research because climate change can impact the success of control and eradication methods.

Kansas Aquatic Nuisance Species Management Plan

Available at:

http://www.kdwp.state.ks.us/news/fishing/aquatic_nuisance_species/ks_nuisance_species_plan

General Description of Kansas' Plan

Kansas's *Aquatic Nuisance Species Management Plan* was developed by the state's Aquatic Nuisance Species (ANS) committee. The lead state agency that coordinated the drafting of the plan was the Kansas Department of Wildlife and Parks. The purpose of the plan is to guide state agencies, local governments, public and private organizations, and aquatic resource user groups in developing management strategies, designing public awareness and educational materials, and prioritizing AIS activities. The goals of the plan are: to prevent new introductions of AIS; to prevent the dispersal of established AIS; to minimize the ecological, economic, social, and public health effects of AIS; to educate aquatic users about AIS risks; and to support research on AIS in Kansas and develop systems to disseminate information. The Plan outlines several management objectives to achieve these goals:

1. Coordinate and implement a comprehensive management plan;
2. Prevent the introduction of new AIS into Kansas waters;
3. Detect, monitor, and eradicate AIS;
4. Control and eradicate established AIS that have significant impacts;
5. Educate resource user groups about the risks and impacts of AIS and how to reduce these harmful impacts; and
6. Support research on AIS in Kansas and develop systems to disseminate information to research and management communities.

In addition to these objectives and their associated tasks, the plan includes: a discussion of existing problems with AIS; a summary of federal, regional, and state policies on AIS; a list of nonindigenous species in Kansas; identification of existing priority AIS; and a discussion of the regional AIS that threaten Kansas waters.

Climate Change and Invasive Species in Kansas

Climate models predict that Kansas will experience increasing average temperatures in the future – perhaps as much 3°F in the summer and 4°F in the winter by 2030 (Covich, 1997). The overall increase in summer temperatures and increased evaporation would likely lead to lower stream flows and lake levels. Decreased water levels could affect biodiversity in springs, playas, and ox-bow lakes in the Great Plains region (Covich, 1997). Lower flows and higher temperatures in the summer also could concentrate pollutant levels in water and compromise aquatic habitats.

Under these predicted climate change conditions, exotic species invasions could increase in state waters. The rapid rate of climate change may negatively impact native species and allow invasive species' ranges to expand across the Great Plains region (Joyce et al., 2000). For example, purple loosestrife, identified as a priority species in Kansas' AIS plan, can withstand shallow flooding, which may provide a competitive advantage over some native aquatic plant species as flooding increases with climate change (USGS, 2006). In addition, zebra mussels,

another priority species, may also benefit from warmer temperatures. Zebra mussels begin spawning when water temperatures warm to about 54°F and continue spawning until the water temperature drops below 54°F (KDHE). Increasing temperatures may provide a longer spawning season for this species.

The Kansas Plan’s Consideration of Climate

The table below summarizes how the *Kansas Aquatic Nuisance Species Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	0
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	3
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	3
Plan includes strategy for managing/updating monitoring data	3
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	3
<i>Funding:</i>	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	2
Total score:	14

Although Kansas’s plan does not consider climate change, it does recognize the importance of researching the relationship between changing conditions (i.e. anthropogenic disturbances of aquatic habitats) and AIS invasion, establishment, and impacts.

Building in Climate Change Information

Given the predicted impacts of climate change in the state, Kansas should consider climate change in its AIS management strategies. The plan could anticipate the impacts of changing temperatures, water levels, and water quality on both exotic species' abilities to become established and flourish and native species' abilities to survive. For example, staff could consider the effects of changing climate in the following parts of the plan:

- *Prevention.* Strategic Action 2A1 calls for the identification of AIS that have the greatest potential to infest Kansas' aquatic resources and the identification of existing and potential pathways that facilitate new AIS introductions. Kansas could more accurately predict the invasive potential of AIS if climate change data (such as changing temperatures, flooding frequency, water quality, and stream flows) were integrated into assessments on exotic species' abilities to expand their ranges into or within the state. The consideration of climate change impacts on the invasive potential of species is also important to the successful implementation of Strategic Action 2A2, the establishment of approaches to facilitate legislative, regulatory, and other actions needed to prevent new AIS introductions in Kansas and to promote rules that establish the state's authority to control these introductions.
- *Research.* Strategic Action 6A1 requires Kansas to support research that identifies, predicts, and prioritizes potential AIS introductions. Potential introductions are subject to the impacts of climate change. As temperatures, precipitation regimes, and nutrient availability fluctuate with a changing climate, previously limited AIS may be allowed to establish and flourish in the state. Kansas could support research that better understands how changing conditions may influence AIS spread in order to guide prevention efforts.

Louisiana
State Management Plan for Aquatic Invasive Species in Louisiana

Available at: http://is.cbr.tulane.edu/docs_IS/Louisiana-AIS-Mgt-Plan.pdf

General Description of Louisiana's Plan

The *State Management Plan for Aquatic Invasive Species (AIS) in Louisiana* was developed by the Louisiana AIS Task Force, which is led by the Louisiana Department of Wildlife and Fisheries. The plan describes the nature and extent of the AIS problem in Louisiana and proposes management actions to minimize the negative impacts of AIS. The plan's goal is to prevent and control the introduction of new nonindigenous species into Louisiana, to control the spread and impact of existing invasive species, and to eradicate established invasive species wherever possible. The plan outlines five objectives to meet these goals:

1. Coordinate all AIS management activities and programs in Louisiana and collaborate with regional, national, and international AIS programs.
2. Prevent and control the introduction/reintroduction of nonindigenous invasive species through education about species and pathways, targeting the general public, industries and user groups, government agencies, and nongovernmental organizations.
3. Eliminate locally established invasive species through monitoring, early detection, rapid response, and early eradication.
4. Control the spread of established species through cooperative management activities designed to minimize impacts when eradication is impossible.
5. Prevent the introduction of non-native species, or the spread of existing ones, through legislation and regulation.

The plan describes species of concern, pathways and media of introduction, and existing authorities and jurisdictions related to AIS. It outlines management actions related to the plan objectives listed above and includes a monitoring and evaluation plan.

Climate Change and Invasive Species in Louisiana

Climate model projections for the southeastern region of the U.S. predict that climate change will result in a 3°C increase in annual summer air temperatures and a 3.5°C increase in winter air temperatures. Additionally, Mississippi River discharge is projected to increase with climate change, which would most likely increase nutrient loads and water column stratification in the northern Gulf of Mexico, exacerbating the already serious problems of eutrophication and hypoxia (Mulholland, 1997).

There are conflicting predictions for precipitation level changes, with one major model predicting a 20 percent decrease in rainfall and another predicting a 20 percent increase (USGS, 2003). Sea levels are expected to rise with global warming, but the rate of increase also is uncertain. Rapid increases in sea level could result in significant coastal wetland loss, increasing open water areas and estuarine depths (Mulholland 1997). Wetland loss will reduce important habitat for migratory birds, crayfish, sport fish, and other species.

With rising temperatures and a potential decrease in precipitation, evaporation may also increase, which could result in decreased stream and lake levels. For example, Louisiana’s plan notes that the zebra mussel is not as widespread in the lower Mississippi as it is elsewhere in the country, in part due to the increased stream velocity in the spring that prevents many zebra mussel veligers from attaching to hard substrates. Lower stream flows may allow zebra mussels to become attached in the river and to establish larger communities.

The Louisiana Plan’s Consideration of Climate

The table below summarizes how the *State Management Plan for Aquatic Invasive Species in Louisiana* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i> 0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	3
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	3
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i> 0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	1
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i> 0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	3
Plan includes strategy for managing/updating monitoring data	0
<i>Revision:</i> 0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	0
<i>Funding:</i> 0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	2
Total score:	12

Although Louisiana’s plan does not specifically consider climate change, it does recognize that the state’s wet, subtropical climate and long growing season make it particularly sensitive to AIS invasion.

Building in Climate Change Information

Given the expected impacts of climate change in Louisiana, AIS staff should consider climate change predictions in plan objectives and actions to increase the effectiveness of prevention and management efforts. For example, climate change considerations could be incorporated into the following objectives and actions:

- *Leadership and Coordination.* AIS staff could incorporate climate considerations into the plan's first objective, the coordination of all AIS management activities or programs within Louisiana and collaboration with regional, national, and international AIS programs. Coordination with regional, national, and international efforts could involve monitoring how climate change alters the range and spread of AIS to better guide prevention efforts and communication with neighboring regions to identify encroaching species ranges.
- *Prevention.* Action 11 under Objective 2, which pertains to education on AIS and pathways, calls for support for the ongoing development of the Vulnerability Index for Invasive Species in Southeastern Louisiana, a GIS-based index and visualization of the portals and pathways of invasive species. The index currently serves as an educational tool but has the potential to help managers target scarce resources toward the most sensitive areas that are likely to experience bioinvasions. In order to remain accurate in the face of changing conditions, this index could incorporate predicted changes that will affect habitat, such as temperature and precipitation fluctuations.
- *Control and Management.* Action 3 under Objective 3, which relates to early detection/rapid response, calls for the development of a "Big River" monitoring program to detect and assess introductions of AIS, their movement within the state, and potential for establishment. Assessing species' potential for establishment should account for predicted changes in habitat that may occur as a result of climate change. Action 9 under Objective 3 proposes the development of a GIS database of invasive species ranges, habitats, and other relevant geographical data. The plan states that spatial distribution data could be correlated with temporal and hydrological condition data, as well as other data layers that could affect the range and rate of spread of invasive species. Climate change data on conditions, such as changes in temperature and stream flow, would increase the accuracy of these models.

**Maine
Action Plan for Managing Invasive Aquatic Species**

Available at: <http://www.maine.gov/dep/blwq/topic/invasives/invplan02.pdf>

General Description of Maine’s Plan

Maine’s approach to aquatic nuisance species (ANS) management emphasizes prevention first, followed by control and mitigation for AIS that cannot be prevented. The plan also includes measures to educate industry and the public on their respective roles in AIS prevention and management, as well as an Advisory List of Aquatic Invasive Species that identifies pathways and AIS threats. The plan places identified species in management categories that prioritize actions for species, including: prevention and eradication; selective control and/or impact management; no action; and dispute resolution.

Additional goals include: enhanced cooperation between tidal and marine water programs and management; continuous update of the plan and review of funding and support for the program; increased public awareness; strengthened watercraft inspections and controls; a revamped rapid response strategy; and an overhaul of the Maine ANS Inventory, Research, and Information Management System. Associated management tasks and implementation timetables are also included in the plan.

Climate Change and Invasive Species in Maine

Projected increases in annual surface temperatures in the northeastern region of the U.S. are predicted to average 5.3°C by 2070. Nearly all model simulations of future precipitation show consistent increases in winter precipitation and no change to a decrease in summer rainfall. By 2100, precipitation is projected to increase an average of 11 to 14 percent in the winter. Regional sea surface temperatures are anticipated to increase in accordance with regional air temperatures; these increasing temperatures have the potential to expand the range of warm water species northward and permit the expansion of invasive species into previously colder waters (Hayhoe, 2007).

Maine’s freshwater systems are relatively remote and currently face less of a threat from AIS than do its marine ecosystems, which are linked to the Great Lakes via the Saint Lawrence Seaway and experience Gulf Stream currents. As waters warm and ocean currents change with climate change, Maine’s fresh and marine waters could become more vulnerable to AIS. For example, species that cannot over winter may become able to survive in some parts of the states with warmer waters. In addition, species that previously never entered Maine’s waters could now arrive in the state as conditions change. Recreational boating also may increase with warmer temperatures, introducing species such as water chestnut that are not found in the state at this time.

The Maine Plan’s Consideration of Climate

The table below summarizes how the *Maine Action Plan for Managing Invasive Aquatic Species* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
--	-------

Understanding and incorporating potential impacts resulting from climate change:	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	1
Plan acknowledges climatic boundaries of species	2
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	2
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
Capacity to adapt to changing conditions:	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
Monitoring strategies:	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	0
Plan includes strategy for managing/updating monitoring data	0
Revision:	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	3
Funding:	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	0
Total score:	8

Maine’s plan directly acknowledges that the natural spread of AIS can be greatly accelerated by climate change; however, the plan’s prevention, control, and monitoring strategies do not reflect this consideration.

Building in Climate Change Information

Given Maine’s sensitivity to climate change, especially warmer waters and sea-level rise, the management plan should include climate change considerations specifically in its strategies and tasks. Maine understands that climate change and AIS may interact and exacerbate each other’s impacts. In updating this plan, the state could further incorporate climate change in a variety of sections and tasks, including the following:

- *Prevention.* The foundation of the plan’s AIS prevention strategy is to assess which species and pathways present the largest threat. Although the plan recognizes that climate change may impact pathways, it does not incorporate climate change considerations (i.e., changes to nutrient cycles, water temperatures, and sea-level rise) into its monitoring and prevention strategies. Incorporating these considerations into

ANS and pathway assessments will allow Maine to more accurately focus prevention efforts.

- *Early Detection/Rapid Response.* Strategy 4B1 calls for a more comprehensive and detailed approach to rapid response. In developing this approach, it will be important to consider how climate change may influence early detection and rapid response efforts. For example, a lake in Maine’s northern forests that was previously too cold for water chestnut to over winter may become warm enough to allow this ANS to become established. Equipped with this information, the rapid response team could better target their efforts.
- *Control and Management.* Task 4C2a calls for developing protocols to provide advance permitting for “additional control techniques for plants, coordinating with other agencies and federal land managers as necessary.” This task should be revised to recommend advance permitting for elevated herbicide use at sites that will likely be within the potential range of certain priority ANS under climate change.
- *Research.* Strategy 5B1 calls for anticipating ANS impacts and researching and developing tools to address them. Research on how climate change will affect established and potential ANS is critical to successful prevention, control, and eradication efforts. Research could reveal hotspots for invasions and predict the effects climate change will have on ANS spread and establishment capabilities. In addition, drawing from general research on climate change in the state of Maine could be useful to ANS managers as it could help identify effects of climate change on biodiversity and sensitive habitats.
- *Education and Public Awareness.* Strategy 2C recommends informing key groups on how they can prevent ANS introductions and spread. The plan specifically notes that people associated with water craft transport or releasing species should be targeted. Species transported by recreational or commercial boats or released through industries such as the aquarium industry may become increasingly able to survive in Maine as conditions change. Thus, it is imperative to include this information in education and outreach materials, so that people associated with these pathways understand the scope and seriousness of the problem.

Massachusetts Aquatic Invasive Species Management Plan

Available at: http://www.mass.gov/czm/invasives/docs/invasive_species_plan.pdf

General Description of Massachusetts's Plan

The Massachusetts' *Aquatic Invasive Species (AIS) Management Plan* was created by the Massachusetts Aquatic Invasive Species Working Group (an 18 member team made up of 14 state and federal agencies and academic institutions) and released in 2002. The plan lays out a five year strategy for AIS management. The overarching goal is to minimize ecological and socio-economic impacts of AIS in both marine and aquatic environments. The plan relies on eight general objectives to accomplish these goals. They are:

1. Coordinate AIS management efforts;
2. Prevent new introductions;
3. Monitor the introduction of new invaders and the spread of established organisms;
4. Detect and eradicate pioneering species posing high or unknown risk prior to establishment;
5. Control the spread and distribution of AIS in infested water and reduce risk of further dispersal;
6. Educate the public, resource managers, and industry representatives on their role in prevention of AIS;
7. Continue to research and identify new measures for the prevention and control of AIS; and
8. Identify needs for additional legislation relating to control of AIS.

The plan outlines ninety-nine specific tasks and includes a budget to ensure these tasks are implemented.

Climate Change and Invasive Species in Massachusetts

Projected increases in annual surface temperatures in the northeastern region of the U.S. are predicted to average 5.3°C by 2070. Nearly all model simulations of future precipitation show consistent increases in winter precipitation and no change to a decrease in summer rainfall. By 2100, precipitation is projected to increase an average of 11 to 14 percent in the winter.

Regional sea surface temperatures are projected to increase in accordance with regional air temperatures; these increasing temperatures have the potential to expand the range of warm water species northward and permit the expansion of invasive species into previously colder waters (Hayhoe, 2007).

Massachusetts is concerned about the potential establishment of various aquatic plants in the state including parrot feather, European frog-bit, and giant salvinia. These and other AIS are moving up the East Coast; however, they cannot survive Massachusetts' winter temperatures. As waters warm, these species may be able to over winter and become established in the state.

The Massachusetts Plan's Consideration of Climate

The table below summarizes how the *Massachusetts Aquatic Invasive Species Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	1
Plan acknowledges climatic boundaries of species	3
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	1
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	3
Plan includes strategy for managing/updating monitoring data	0
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	0
<i>Funding:</i>	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	2
Total score:	10

The Massachusetts plan does not explicitly mention climate change, but it acknowledges the importance of monitoring for changing conditions.

Building in Climate Change Information

Massachusetts will experience various impacts from climate change and should incorporate climate change concerns into its strategies and actions. The following provides several examples for accomplishing this task:

- ***Control and Management.*** Task 5B1 calls for an increase in research on effective biological control methods for AIS in Massachusetts' waters. Consideration of projected climate change impacts is necessary to ensure these controls will be effective under

changing conditions. In addition, when developing a management priorities list as specified in Strategic Action 5C, state agency staff should take into account how climate change will impact the spread and establishment ability of different ANS to best target these management efforts.

- *Restoration.* Task 5D4 calls for reintroducing native species as part of a restoration program for lakes and ponds. Given that climate change can greatly alter habitats, temperature levels, and the availability of nutrients, it will be important to consider how these impacts will affect native species and habitats and AIS. A restoration plan should focus on native species that will thrive or at least withstand climate change. By targeting restoration efforts in this way, habitats will be more robust and less vulnerable to potential invasions as conditions change. Integrating this information into a restoration plan/ program also will make restoration activities more successful.
- *Research.* Task 7A1 recommends that the state's leading scientists and AIS managers determine Massachusetts' research priorities. This task provides an opportunity for these scientists and managers to include research on climate change's impacts to ANS as a part of the list.
- *Education and Public Awareness.* Strategic Action 6C calls for developing outreach materials with information on transport vectors. Information about how climate change will impact these vectors and specific AIS should be included in these materials so that people associated with these vectors better understand the scope and seriousness of the problem.

Michigan Aquatic Nuisance Species State Management Plan: Update

Available at: <http://www.deq.state.mi.us/documents/deq-ogl-ANSPlan2002.pdf>

General Description of Michigan's Plan

The *Michigan Aquatic Nuisance Species (ANS) Management Plan* was published in 2002 and serves as an update to the state's 1996 *Nonindigenous Aquatic Nuisance Species State Management Plan*. The updated plan was prepared by the Michigan Office of Great Lakes and the Department of Environmental Quality. The Aquatic Nuisance Species Action Team, consisting of the Directors of the Michigan Departments of Environmental Quality, Natural Resources, and Agriculture, was convened by the Director of the Office of the Great Lakes to establish three committees (Legislation and Policy, Information and Education, Research and Monitoring) and make recommendations for the plan. The plan recommends three implementation actions:

1. Coordination of policies and enactment of legislation that will reduce the economic and environmental impacts of ANS in Michigan;
2. Development of information and education materials and activities addressing ANS prevention, control, monitoring, research and policy making; and
3. Establishment of a network of collaborative entities for research and monitoring of ANS in Michigan with the goal of providing high quality information to legislators, educators and policy makers.

These three actions have seven associated goals to guide their implementation. Each goal has associated objectives and activities. The plan recognizes that more work is needed in regards to preventing and controlling ANS, but it also notes the progress made since the last plan. There are many vectors that could bring ANS into the state, and the plan includes prevention and control strategies to better address this issue. The plan also focuses on monitoring and education.

Climate Change and Invasive Species in Michigan

Climate change will cause substantial impacts to Michigan waters. Some estimates predict that temperatures increases over the next century could result in an earlier peak snow melt in the spring and higher evaporation rates in the summer months. In combination, these factors could lead to lower inland stream flow levels in the summer and reduced water flow into the upper Great Lakes. These lower water levels may impede shipping traffic and prevent more introductions through ballast water releases; however, changes in water flows also could significantly alter native habitats making them more sensitive to ANS (Magnuson et al., 1997).

Certain AIS may shift their ranges in response to these climate change impacts. For example, Michigan is concerned about species such as the Asian carp finding their way into state waters. An electrical barrier in the canal separating the Mississippi River from the Lake Michigan currently prevents the carp from entering Michigan waters. If water levels are altered by climate change, then the efficacy of the barrier could be reduced, allowing the Asian carp to pass into state waters.

The Michigan Plan’s Consideration of Climate

The table below summarizes how the Michigan plan considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i> 0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	1
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i> 0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i> 0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	3
Plan includes strategy for managing/updating monitoring data	0
<i>Revision:</i> 0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	0
<i>Funding:</i> 0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	0
Total score:	4

The Michigan plan recognizes the need to closely monitor state waters and carefully coordinate efforts between states on control issues and information sharing. The plan update also refers to focusing prevention and management strategies on the most likely invaders. Although the plan does not include climate change considerations its strategies, its framework would allow for incorporation of this information.

Building in Climate Change Information

The Michigan plan does not currently include climate change concerns. However, there are numerous strategies and actions where climate change issues could be addressed. The following

recommendations present opportunities for Michigan to incorporate this information into its plan to improve ANS management in the state:

- *Leadership and Coordination.* Three of Michigan's borders are on the upper Great Lakes, and the state historically has taken the lead on invasive species issues such as ballast water regulation. Coordination with states in the region is a cornerstone of the plan. Information and Education Goal III calls for the active involvement of Great Lakes regional policymakers and user groups in promoting ANS prevention and control programs. Associated Activity B calls for improving regional coordination efforts. Michigan should take the lead on this effort and support sharing information between states, especially information on observed effects of climate change on ANS. This will help improve state and regional prevention and management efforts.
- *Prevention.* Objective 3 under the Legislative and Policy Goal calls for developing a risk assessment process for potential and existing ANS. Activity C under this objective recommends developing a list of waters where additional assistance and/ or effort could help reduce the spread of ANS in to them. Because climate change will impact flows, water levels, dissolved oxygen content, and nutrient cycling, it will be important to consider how these changes may impact high risk waters' susceptibility to ANS. Taking this information into consideration will help state managers more effectively target prevention activities and allocate resources.
- *Early Detection/Rapid Response.* Objective 4 under the Legislative and Policy Goal recommends considering the development of a regional ANS "Rapid Response Team" for areas with newly established ANS or areas threatened by potential introductions. Climate change may impact the ability of certain ANS to spread or become established; thus, it will be important to consider these effects when designing a rapid response plan.
- *Research.* Activity F under Research and Monitoring Goal I calls for the development of a hot list of potential invasives that includes their locations, characteristics, and invasion probability. Any list of potential hot spots will be more accurate if climate change considerations are taken into account during the decision-making process.

Missouri Aquatic Nuisance Species Management Plan

Available at: <http://mdc.mo.gov/documents/nathis/exotic/ANSplan05.pdf>

General Description of Missouri's Plan

Missouri's *Aquatic Nuisance Species (ANS) Management Plan* was created by the Missouri Department of Conservation in 2005. The plan addresses three phases of invasion: introduction, spread, and abatement of impacts. Five goals are outlined in the plan:

1. Inform business and community stakeholders and the general public about ANS, and enlist their participation in halting the introduction and spread of ANS;
2. Collaborate in the development and enforcement of state and national legislation and other regulations designed to prevent ANS;
3. Monitor the occurrence and distribution of ANS in Missouri waters and conduct research into ways to restrict their spread;
4. Develop and implement techniques and management actions to abate the harmful effects of ANS on native biological communities; and
5. Where economically and biologically feasible, abate harmful effects of ANS on socio-economic status and health of Missourians.

Each goal has associated objectives and tasks, all of which provide a course of action to address the three phases of invasion. The plan also includes an implementation table that identifies responsible agencies for each task, as well as funding needs.

Climate Change and Invasive Species in Missouri

Temperatures in the Great Plains region are predicted to rise as much as 3° F in the summer and 4° F in the winter by 2030. However, even small changes in temperature (1 to 2°C increase) or precipitation (5 to 10 percent decline) could have a significant effect on lake water quality, particularly salinity, and the availability of groundwater resources in the region (Covich, 1997).

With higher temperatures and evaporation rates, stream and lake levels may be lower in the summer. A large decrease in water levels could lead to shift in salinity and productivity in prairie pothole lakes and wetlands. Any increases in water temperatures, lowering of water levels, or increases in salinity will be highly detrimental to most native fish species (Covich, 1997)

Warming water temperatures not only impact native fish, but also may enable certain AIS to survive and spread into areas where they currently cannot over winter. For example, the state's *ANS Management Plan* notes that water hyacinth can not withstand the cold winters of Missouri. However, with warmer temperatures and the species' relatively wide temperature tolerance range, it could become a major problem in the state. Dotted duckweed is already found in some parts of Missouri, but it could also expand its range if temperatures warm throughout the state.

The Missouri Plan’s Consideration of Climate

The table below summarizes how the *Missouri ANS Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	3
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	3
Plan includes strategy for managing/updating monitoring data	3
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	0
<i>Funding:</i>	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	3
Total score:	12

Although the *Missouri ANS Management Plan* does not explicitly account for climate change or changing conditions, it does recognize that certain species adhere to climatic boundaries.

Building in Climate Change Information

Given the potential impacts of climate change in Missouri, various goals and objectives, and associated actions, may be less successful if climate change is not considered. Specifically, prevention and control efforts need to consider climate change impacts in order to accurately determine ANS threats and appropriate control methods. The following tasks and objectives could be revised to include climate change information:

- *Prevention.* Task IIA1 recommends continual review and revision of the state's *Approved Aquatic Species List* to have a baseline for determining which species can be safely brought into the state. The review should include an evaluation of how currently approved and proposed species may react to changes in habitat as a result of climate change (i.e., species that currently may not be considered a threat may pose a greater risk if Missouri habitats become more suitable for them). Incorporating this step will enable Missouri to have a more proactive and robust prevention program.
- *Control and Management.* When developing and implementing strategies to control and eradicate ANS, as outlined under Objective VB, careful consideration should be given to how changing conditions could impact control methods. For example, biological control methods could prove to be less effective under warmer temperatures or the biological control element could itself become invasive as conditions change.
- *Research.* Objective IIIB calls for conducting and supporting research on ANS life histories, habitat use, potential effects on native species, and how they are transported and introduced into new areas. This research should also include an analysis of how climate change may impact each of these factors. For example, ANS impacts to native species could be exacerbated by warmer waters that also damage a native species habitat. Climate change may also affect ANS pathways. As temperatures warm, there may be increased or prolonged levels of recreational use of Missouri's waterways. This could increase the possibility that species such as hydrilla and the New Zealand mud snail would be transported into or within the state by boats, or that the rusty crayfish would be introduced through bait releases.
- *Education and Public Outreach.* Objective IB calls for targeting education efforts at specific stakeholders and providing information on how ANS could harm their resource of interest. Incorporating information on how ANS and climate change could have cumulative impacts to their resource of interest, such as fisheries, would not only make the message stronger, but could lead to a stronger response on the part of the public in regards to prevention efforts.

Montana Aquatic Nuisance Species Management Plan

Available at: http://www.anstaskforce.gov/Montana-FINAL_PLAN.pdf

General Description of Montana's Plan

Montana's *Aquatic Nuisance Species (ANS) Management Plan* was written by the ANS Technical Committee "to minimize harmful ecological, economic, and social impacts of ANS through prevention and management of introduction, population growth, and dispersal into, within, and from Montana." The plan outlines current efforts to manage ANS in Montana, the expected impacts from ANS, and a classification system for nonindigenous species in the state, as well as appropriate management strategies for each class. The plan also lays out objectives to achieve the plan's goals:

1. Coordinate and implement a comprehensive management plan.
2. Prevent the introduction of ANS into Montana.
3. Detect, monitor, and eradicate pioneering ANS.
4. Control and eradicate established ANS that have significant impacts, where feasible.
5. Inform the public, policy makers, natural resource workers, industry, and other groups about the risks and impacts of ANS.
6. Increase and disseminate knowledge of ANS in Montana through compiling data and conducting research.

The plan includes implementation tables detailing which agencies are responsible for which objectives and expected funding from state and federal agencies. The report also includes a section on monitoring and evaluating the implementation of the plan.

Climate Change and Invasive Species in Montana

Temperatures in the Great Plains region are predicted to rise as much as 3° F in the summer and 4° F in the winter by 2030. However, even small changes in temperature (1 to 2°C increase) or precipitation (5 to 10 percent decline) could have a significant effect on lake water quality, particularly salinity, and the availability of groundwater resources in the region (Covich, 1997).

Evaporation of the state's water resources is also likely to increase with rising temperatures, resulting in lower river flow and lake levels, especially in the summer. The warmer climate also could cause earlier snowmelt in the spring, resulting in higher stream flows in the winter and spring and lower ones in the summer and fall. A large decrease in water levels could lead to shift in salinity and productivity in prairie pothole lakes and wetlands. Any increases in water temperatures, lowering of water levels or increases in salinity will be highly detrimental to most native fish species (Covich, 1997).

Species sensitive to water temperature could suffer from climate change. Increased water temperatures can be a stress factor for fish species in that higher temperatures can result in increased fish mortality from nonnative bacterial fish pathogens, such as *Aeromonas salmonicida*, which already are present in some Montana watersheds. The decline of native salmonids may facilitate the spread of nonindigenous fish such as bass and walleye (already

present in the state and used for sport fishing, but are still under careful management to prevent their spread).

The Montana Plan’s Consideration of Climate

The table below summarizes how the *Montana Aquatic Nuisance Species Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	0
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	1
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	3
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	0
Plan includes strategy for managing/updating monitoring data	0
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	3
<i>Funding:</i>	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	2
Total score:	9

Montana’s plan does not specifically consider the effects of climate change on its management objectives, but some elements in the plan allow for changing conditions to be considered in implementation of the plan.

Building in Climate Change Information

Given the impacts climate change is predicted to have on aquatic habitats in Montana, the state might consider incorporating information on these impacts into both implementation of the

current plan and subsequent revisions to the ANS Management Plan. The plan would be more robust in a changing climate if it were to account for the effects of climate change, such as increased water temperature and decreased water levels, on both native species' ability to survive and invasive species' ability to become established. Examples of ways in which the plan's strategies could incorporate such considerations include the following:

- *Leadership and Coordination.* Strategy 1B calls for participation in and support of regional, federal, and international efforts to control ANS. In order to better anticipate and manage the expanding ranges of ANS, regional efforts should be cognizant of and in communication about species' expanding ranges.
- *Prevention.* Strategy 2A establishes the task of describing invasion pathways and identifying high-risk water bodies. Analysis of invasion pathways should account for climate-sensitive vectors, such as increased recreational boating and the impact of increased water temperature on the health of native fish and the ability of nonnative fish to establish new populations. Identification of high-risk water bodies might consider the impacts on native and invasive species of changes such as reduced lake levels and decreased stream flows caused by increased evaporation. Strategy 2C, designed to prohibit, control, or permit the importation of nonindigenous aquatic species based upon their invasive potential, requires research on the invasive potential of aquatic plant species currently imported. This research should examine currently permissible species' ability to persist in the expected conditions resulting from climate change in order to obtain a complete assessment of invasive potential.
- *Research.* Strategy 6B, which relates to research on management alternatives and their effects on ANS and native species, calls for the investigation of the relationship between human-induced disturbance of aquatic and riparian systems and ANS invasion, establishment, and impacts. This is an ideal opportunity for Montana to research the effects of climate change on the state's water bodies and waterways and the influence of these changes on ANS invasions.

New York Nonindigenous Aquatic Species Comprehensive Management Plan

Available at: <http://www.dec.state.ny.us/website/dfwmr/habitat/noninsp.pdf>

General Description of New York's Plan

New York's *Nonindigenous Aquatic Species Comprehensive Management Plan* was written by the New York State Department of Environmental Conservation to prevent nonindigenous aquatic species (NAS) from being introduced into New York waters and to limit the spread of NAS already present. The plan's goals are to:

1. Reduce the potential for future introductions of NAS into New York waters.
2. Reduce the potential for NAS in New York waters to spread.
3. Minimize the harmful economic, ecological, and social impacts of NAS that have been introduced, or are proposed for introduction, into New York waters.
4. Educate the public on the importance of preventing NAS introductions and how the harmful impacts of NAS can be reduced or mitigated.

These goals are accompanied by a number of related objectives. The plan outlines the problems related to accomplishing the goals and actions to overcome these problems. The plan also discusses ways to encourage research on NAS; the responsibilities of federal, state, and local government; recommendations for implementation; and an implementation schedule.

Climate Change and Invasive Species in New York

Projected increases in annual surface temperatures in the northeastern region of the U.S. are predicted to average 5.3°C by 2070. Nearly all model simulations of future precipitation show consistent increases in winter precipitation and no change to a decrease in summer rainfall. By 2100, precipitation is projected to increase an average of 11 to 14 percent in the winter. Regional sea surface temperatures are projected to increase in accordance with regional air temperatures; these increasing temperatures have the potential to expand the range of warm water species northward and permit the expansion of invasive species into previously colder waters (Hayhoe, 2007).

Evaporation is likely to increase with the warmer temperatures, resulting in lower river flow and lower lake levels in the summer and fall. In general, the state is expected to experience higher stream flow in the winter and spring and lower stream flow in the summer and fall (Hayhoe, 2006). This may give a competitive advantage to the round goby, a problematic AIS in New York that can survive in degraded water conditions (USACOE). Impacts of climate change are likely to be greatest for aquatic biota most sensitive to the timing of high-spring flow, such as the Atlantic salmon (Hayhoe, 2007). Lobster populations, which similarly require colder waters, may migrate northward (Barron, 2000).

The New York Plan's Consideration of Climate

The table below summarizes how the *Nonindigenous Aquatic Species Comprehensive Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	0
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	3
Plan includes strategy for managing/updating monitoring data	0
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	0
<i>Funding:</i>	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	1
Total score:	4

Although New York’s plan does not consider climate change, it has strong provisions for monitoring new introductions of NAS.

Building in Climate Change Information

Given the effects of climate change predicted for New York, the plan would more effectively prevent and control NAS by considering anticipated climate change-related impacts. For example, the following goals and strategies outlined in the plan could incorporate climate change considerations:

- *Prevention.* Goal 1 calls for the identification of aquatic organisms that could potentially have adverse impacts in state waters, as well as the characteristics, habitat requirements, and potential adverse impacts of these organisms. Assessment of adverse impacts should take into account the changing conditions predicted by climate change models, which may make systems more vulnerable and/or exacerbate the effects of NAS. For example,

warmer water temperatures could negatively impact native trout fisheries, allowing both NAS to become more easily established and greater impacts on the fragile ecosystem.

Climate change considerations could also be incorporated into the plan to strengthen progress toward Goal 2, reducing the potential for NAS that have been introduced into state waters to spread to uncolonized waters. This goal calls for monitoring colonized waters and collecting data on NAS such as rate of growth, distribution, and impacts on native species. This data is to be correlated with habitat data to develop predictive models of where and how NAS introductions might occur and to develop strategies for preventing and controlling them. These models could incorporate predicted habitat changes that may result from climate change (such as changes in stream flow and water temperature and quality) to better predict NAS introductions.

North Dakota Aquatic Nuisance Species Management Plan

Available at: <http://gf.nd.gov/fishing/docs/nd-ans-plan-fnl-drft.pdf>

General Description of North Dakota's Plan

North Dakota's *Aquatic Nuisance Species (ANS) Management Plan* was written by a principal biologist with the North Dakota Game and Fish Department. It is based on recommendations provided by the Western Regional Panel and the ANS Task Force. Although North Dakota has relatively few ANS at present, there exists potential for many invasive species to spread into the state. Current prevention and control efforts are not very organized or well-funded; thus, the plan seeks to increase awareness of the state's ANS problem, as well as coordination among agencies and the public. Specifically, the goal of the plan is to "[p]revent the harmful ecological, economic, and social impacts from ANS being introduced into North Dakota." The plan outlines the risks associated with invasive species; related state authorities, regulations, and programs; and the state's primary invasive species problems and concerns. Five objectives are outlined to achieve the plan's goal:

1. Coordinate ANS activities and prepare/implement a comprehensive management plan;
2. Prevent introduction of ANS in North Dakota;
3. Detect pioneering ANS and monitor existing populations of ANS;
4. Conduct an educational campaign to prevent the spread of ANS;
5. Where feasible, control and eradicate pioneering or established ANS that have significant impacts on native or desirable species;
6. Inform policy makers about the risks and impacts of ANS; and
7. Increase the ANS knowledge base in North Dakota by compiling data, conducting research, and disseminating information publications.

The plan also includes information on public involvement, a budget and time frame, regulatory needs, and prioritized strategic actions.

Climate Change and Invasive Species in North Dakota

Temperatures in North Dakota are predicted to rise as much as 3° F in the summer and 4° F in the winter by 2030. However, even small changes in temperature (1 to 2°C increase) or precipitation (5 to 10 percent decline) could have a significant effect on lake water quality and the availability of groundwater resources in the northern Great Plains region (Covich, 1997).

With higher temperatures and evaporation rates, and possibly no large precipitation events, stream and lake levels may be lower in the summer. A large decrease in water levels could affect the salinity and productivity in prairie pothole lakes and wetlands. Any increases in water temperatures, lowering of water levels, or increases in salinity will be highly detrimental to most native fish species. (Covich, 1997)

The potentially significant changes in hydrology associated with rising temperatures could make North Dakota's native species and habitats more vulnerable to invasive species. For example, salt cedar, an AIS of concern already established in North Dakota, is tolerant of dry conditions

and could become a larger problem under climate change conditions as it out-competes native plants for water. Additionally, North Dakota’s plan includes Whirling disease (*Myxobolus cerebralis*) as a significant invasive threat, which may become more prevalent as a result of climate change, impacting salmon populations.

The North Dakota Plan’s Consideration of Climate

The table below summarizes how the *North Dakota ANS Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i> 0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	2
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	1
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i> 0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	1
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i> 0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	1
Plan includes strategy for managing/updating monitoring data	1
<i>Revision:</i> 0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	1
<i>Funding:</i> 0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	2
Total score:	9

North Dakota’s plan does not specifically consider the effects of climate change in its management objectives, but does make a general statement that “management actions are intended to be adaptable to changing circumstances.” The plan also recognizes that certain invasive species currently cannot survive in North Dakota due to its cold temperatures.

Building in Climate Change Information

Given the expected impacts of climate change in North Dakota, ANS staff should consider climate change predictions in its plan objectives, actions, and strategies to increase the effectiveness of prevention and management efforts. For example, staff could specifically include predicted conditions resulting from climate change when determining ANS invasive potential. North Dakota could also incorporate climate change considerations into the following objectives and actions:

- *Prevention.* A primary objective of the plan is to prevent ANS. Associated actions call for creating a list of ANS that will cause problems for North Dakota. Additionally, Strategy 2A2 calls for conducting risk analyses for each potential ANS introduction pathway or combination of pathways. In determining potential ANS, research should include species' ability to survive in the expected conditions resulting from climate change in order to obtain a complete assessment of invasive potential. Assessments should evaluate how potential invasive species might respond to predicted impacts such as flooding, decreased stream flows, and increased water temperatures. For example, ANS introductions from the aquarium trade are a potential problem North Dakota; thus, assessments could look at what aquarium fish species could thrive under the predicted temperature increases for North Dakota's waters. Climate change also has the potential to impact ANS pathways as waters warm, water levels change, or recreational patterns change. A major concern for North Dakota is the zebra mussel. If temperatures warm and more recreational boaters use North Dakota's waterways throughout the year, there will be an increased risk of introduction.
- *Monitoring.* Strategy 3A2 recommends conducting annual monitoring of high risk waters as a part of implementing a monitoring and early detection program. Considering climate change in these assessments may help managers determine which waters are most vulnerable to species invasions. When identifying high-risk water bodies, staff should consider how climate change impacts such as reduced stream and lake levels due to increased evaporation and increased water temperatures will affect both native and invasive species.
- *Control and Management.* Objective 5 calls for controlling and eradicating pioneering and established ANS. Research should be conducted on how different management strategies could be impacted by temperature, precipitation, and water level changes, and staff should consider climate change impacts on control and management methods in developing management plans.

Ohio Comprehensive Management Plan for Aquatic Nuisance Species

Available at:

<http://www.anstaskforce.gov/State%20Plans/Ohio%20Comprehensive%20Management%20Plan.pdf>

General Description of Ohio's Plan

Ohio's *Comprehensive Management Plan for Aquatic Nuisance Species (ANS)* serves as a handbook and provides guidance for Ohio's agencies to use when planning ANS management activities. The plan is designed to provide a framework for the state's future approach to ANS management and to build support for the work plan that is in development and funding requests. The plan was written to decrease the rate of introductions that have increased since the St. Lawrence Seaway was established in 1960 and transportation levels in the Great Lakes skyrocketed. Ohio recognizes that the ecological and socioeconomic costs of ANS will continue to rise in the future if it does not protect itself from further introductions. Specifically, the plan provides guidance on developing management actions to prevent, control, and limit the impacts of established and potential ANS in Ohio's inland waters.

Climate Change and Invasive Species in Ohio

Temperatures are projected to increase by 5 to 10°F throughout the northern portion of the Midwestern region of the U.S. throughout the 21st century. Precipitation is expected to increase by 10 to 30 percent across the region. Increasing temperatures are expected to increase evaporation, triggering a soil moisture deficit, reduction in lake and river levels, and more drought-like conditions in much of the region. For smaller lakes and rivers, reduced flows are likely to intensify water quality issues. In particular, eutrophication of lakes will likely increase due to increases in excess nutrient runoff from heavy precipitation events and warmer lake temperatures that stimulate algae growth (Easterling and Karl, 2000).

As water temperatures in lakes increase, significant changes in freshwater ecosystems will occur, such as a shift from cold water fish species, such as trout, to warmer water species, like bass and catfish. Warmer water would create an environment that is more susceptible to invasions by non-native species (Easterling and Karl, 2000).

Preventing further introductions will be a difficult task for Ohio managers under a changing climate. Water temperatures may increase easily due to the shallow waters of lakes. Nutrient rich ecosystems, such as Lake Erie, will be impacted by warmer temperatures, possibly causing uncontrollable growth. With these changes, it will be hard to identify new vectors and employ prevention tactics. If water table levels decrease, more shoreline could become exposed, making this area more vulnerable to purple loosestrife infestation. The presence of purple loosestrife will destroy native habitats possibly negatively impacting bird species. If this occurs, there could be a ripple effect throughout the ecosystem and a resulting decrease of biodiversity in the system.

The Ohio Plan's Consideration of Climate

The table below summarizes how the *Ohio Comprehensive Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	1
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	2
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	1
Plan includes strategy for managing/updating monitoring data	0
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	1
<i>Funding:</i>	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	0
Total score:	5

The Ohio plan demonstrates that the state has an understanding Lake Erie’s vulnerability to both habitat and trophic changes, as well as how this can lead to more invasive species. The plan is largely undeveloped in terms of an implementation plan and substantive details, but the clear presence of a framework for managing Ohio waters under a changing climate exists.

Building in Climate Change Information

Ohio is extremely vulnerable to ANS, as well as to the effects of climate change due to the characteristics of Lake Erie. These vulnerabilities make ANS management a sensitive situation that needs to be approached with careful monitoring and thorough prevention strategies.

- *Leadership and Coordination.* Ohio is aware of its sensitive position within the Great Lakes region, and the state is proactive in listing transport mechanisms that require regional attention in the plan’s management actions section. For example, Ohio

highlights transport mechanisms such as the flushing of natural gas pipelines from northerly regions with water as a potential ANS pathway that has not been adequately documented. As climate change alters nutrient cycles and decreases biodiversity, Ohio's aquatic habitats may become more sensitive to ANS arriving through these types of pathways.

- *Prevention.* Ohio's plan does not include strategies to address climate change impacts to state waters or what climate change impacts may affect potential ANS pathways. This important action could be implemented as a part of strategic action IA, which calls for researching the movement and transport of ANS on a global scale. Incorporating climate change considerations into these analyses will help the state accurately predict potential introductions and effectively target its prevention strategies.
- *Control and Management.* As the plan notes, Lake Erie is the most vulnerable water body to ANS and a potential vector for ANS. Any established species in this area must be kept from spreading to the rest of the state and to the Ohio River to control its widespread dispersal. Monitoring how habitats are impacted by climate change can help target control strategies and ensure they are successful.
- *Research.* Ohio has established a framework for successful ANS management that considers many of the necessary contributing factors to ANS spread. It also calls for coordinating prevention and control strategies. However, the data needed to help guide management actions within the context of climate change are lacking. A monitoring program that incorporates climate change considerations and uses this information to help identify areas of Lake Erie and inland lakes that are especially vulnerable to climate change will help the state properly allocate resources and implement management strategies effectively.

Oregon Aquatic Nuisance Species Management Plan

Available at: http://www.clr.pdx.edu/publications/files/OR_ANS_Plan.pdf

General Description of Oregon's Plan

Oregon's *Aquatic Nuisance Species (ANS) Management Plan* was prepared in 2001 by the Center for Lakes and Reservoirs at Portland State University with direction and participation from staff at numerous state agencies. The plan was written as a first step in developing a program in Oregon to specifically address ANS threats and problems. With a goal to prevent and manage ANS introductions, population growth, and spread to reduce ANS ecological, economic, and social impacts throughout the state, the plan provides a management framework, as well as goals, objectives, and actions, to prevent and minimize ANS. Six objectives are outlined to address and accomplish the plan's goal:

1. Coordinate and implement a comprehensive management plan;
2. Prevent the introduction of ANS into Oregon;
3. Detect, monitor, and eradicate pioneering aquatic invasive species;
4. Where feasible, control established nonindigenous species that have significant impacts;
5. Inform the public, policy makers, natural resource workers, private industry, and user groups about the risks and impacts of ANS; and
6. Increase and disseminate knowledge of ANS in Oregon through the compilation of data and by conducting research.

The plan also describes current state and federal ANS authorities, a system to classify ANS in Oregon, and management actions for those classes. Additionally, it includes an implementation table with a corresponding budget.

Climate Change and Invasive Species in Oregon

Average warming in the Pacific Northwest is projected to reach 3°F (1.7°C) by the 2020s and 5°F (2.8°C) by the 2050s. Annual precipitation projections are less certain; projected precipitation ranges from a small decrease (7 percent or 2 inches) to a slightly larger increase (13 percent or 4 inches). Heavier winter rainfall would increase soil saturation, landslides, and winter flooding. In addition, projected increases in mean sea level are expected to increase sediment erosion and redistribution on the open coast (Parson, 2000b). Projected precipitation increases will be concentrated in winter, with decreases or smaller increases in summer; for this reason, even the projections that show increases in annual precipitation show decreases in water availability (Parson, 2000b).

Climate change will likely bring continued changes in coastal and estuarine ecosystems through changes in runoff and higher water temperatures, potentially increasing the possibility of exotic species introductions or health risks from shellfish contamination. Salmon are likely to be negatively impacted by increased winter flooding, reduced summer and fall flows, and rising estuary and stream temperatures. It also is possible that earlier snowmelt and peak stream flow will deliver juveniles to the ocean before there is enough food to sustain them. Climate change is

highly likely to impede efforts to restore depleted stocks, and to stress currently healthy stocks (Parson, 2000b).

Various invasive aquatic plants identified in the plan, such as giant salvinia and hydrilla, destroy native fish habitat and alter water chemistry. These negative impacts would be compounded by warmer water temperatures that also will damage and reduce fish habitat (pushing them further north into cooler waters). Additionally, as water levels decrease in summer months, less water is available for domestic and agricultural purposes, as well as for hydropower. Species such as zebra mussels will exacerbate this problem, because they can block intake pipes that provide water.

The Oregon Plan’s Consideration of Climate

The table below summarizes how the *Oregon ANS Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	3
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	0
Plan includes strategy for managing/updating monitoring data	0
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	3
<i>Funding:</i>	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	3
Total score:	9

Oregon's *ANS Management Plan* does not explicitly mention climate change; however, the plan does recognize that some ANS of concern may not currently be a major threat to Oregon because of their climate tolerance. Additionally, updates and revisions to the plan must consider changing circumstances.

Building in Climate Change Information

If climate change is not taken into account in its plan, Oregon may not be adequately prepared to manage the cumulative and synergistic impacts of ANS and climate change. Specifically, the plan should identify how these impacts will affect prevention and management efforts. For example:

- *Leadership and Coordination.* Strategy 1A calls for coordination between all ANS management programs and activities within Oregon. Actions include conducting an annual symposium to discuss management alternatives, developing ANS assessment guidelines for watershed councils, and assigning priority classes to all established ANS in Oregon. Each of these actions should incorporate climate change considerations. The annual symposium should discuss how management alternatives may need to be incorporate current and predicted climate change impacts. This will also provide an opportunity for scientists and managers to share information. Climate change information may also be incorporated into ANS assessment guidelines and a prioritization scheme. For example, a species' ability to become established in Oregon or spread throughout the state may be impacted by water temperatures, water chemistry, and water levels; thus, how climate change will impact these factors should be considered in any assessment or prioritization process.
- *Prevention.* Action 2A2 recommends describing introduction pathways and identifying high-risk water bodies. In evaluating high-risk water bodies, climate change considerations should be incorporated into the analysis. Water bodies that are currently unaffected by ANS due to cooler temperatures may become open to invasion in the future based on predicted water temperature increases. Thus, integrating these considerations into the identification process will make prevention efforts more cost-effective, successful, and efficient.
- *Education and Public Awareness.* All education and outreach actions under Strategy 5A, which calls for educating the public about ANS (i.e., how they can prevent ANS introductions and reduce their impacts) should consider the effects of climate change. For example, the plan identifies giant salvinia is a potential threat to Oregon's waters. This plant is primarily transported by humans, especially recreational boat users. Based on the plant's biology, it should be able to survive climatic conditions in western Oregon. However, in the face of climate change, perhaps this species could become invasive in other regions as well. It is important that boat users understand this potential to invade the rest of the state, so that they may take cautionary measures.

Pennsylvania Aquatic Invasive Species Management Plan

Available at: <http://www.holstoncrisci.com/Newsletter/docs/3/PAAISMP.pdf>

General Description of Pennsylvania's Plan

The *Pennsylvania Aquatic Invasive Species (AIS) Management Plan* was written by the Aquatic Invasive Species Management Plan Committee (AISMP) for the Pennsylvania Invasive Species Council. The AISMP was composed of representatives from state agencies, academic institutions, and nongovernmental organizations. The plan was designed as a tool to identify needed activities and tasks for successful AIS management. The goal of the plan is to prevent and manage the introduction and spread of AIS into, within, and from Pennsylvania to minimize negative ecological, health, and economic impacts. The plan outlines eight objectives to meet this goal:

1. Provide leadership and coordination for AIS in Pennsylvania among local, state and federal agencies and organizations, and ensure that state policy effectively promotes the prevention, early detection and control of AIS in Pennsylvania. Establish leadership and coordination towards the same goal with the Mid-Atlantic and Great Lakes regions;
2. Identify vectors and mechanisms and minimize the introduction and spread of AIS into and throughout Pennsylvania;
3. Detect new introductions of AIS in Pennsylvania before they have a chance to become established in the ecosystem;
4. Develop a system for early response to eradicate or contain target species before the species can become permanently established;
5. Monitor and inventory existing infestations of AIS in Pennsylvania;
6. When feasible, control and eradicate established AIS that have significant impacts in Pennsylvania and reduce the harmful effects resulting from AIS infestations by managing those that cannot be eradicated;
7. Increase research efforts on AIS species, issues, and impacts to support AIS management, control, and eradication in Pennsylvania; and
8. Educate the general public and people involved in the business, trade, research, and government sectors about AIS issues so that they do not facilitate the introduction or spread of AIS species.

All objectives have associated strategies and actions, which are prioritized in the plan. The plan also includes strategies for evaluation and revision, as well as an implementation table.

Climate Change and Invasive Species in Pennsylvania

Projected increases in annual surface temperature in the Northeast average 5.3°C by 2070. Nearly all model simulations of future precipitation show consistent increases in winter precipitation and no change to a decrease in summer rainfall. By 2100, precipitation is projected to increase an average of 11-14% in the winter, while precipitation in the summer is expected to decrease slightly (Hayhoe, 2007).

Projected increases in annual surface temperatures in the northeastern region of the U.S. are predicted to average 5.3°C by 2070. Nearly all model simulations of future precipitation show consistent increases in winter precipitation and no change to a decrease in summer rainfall. By 2100, precipitation is projected to increase an average of 11 to 14 percent in the winter (Hayhoe, 2007).

Warming air and water temperatures, water level fluctuations, and water chemistry changes could affect ANS establishment and spread. According to the plan, hydrilla currently is found in three water bodies in the state. As temperatures rise, recreation activities may become more widespread and prolonged, which may result in more introductions of hydrilla into other parts of the state. Additionally, water levels may decrease as the climate changes, making less available for human consumption and use. Hydrilla forms thick mats that can block intake pipes, which could further hinder the provision of water. If climate change results in larger stream flows and altered water chemistry, the European rudd may out-compete native species as it is a hardy species that can survive in polluted waters.

The Pennsylvania Plan’s Consideration of Climate

The table below summarizes how the *Pennsylvania AIS Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	0
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	0
Plan includes strategy for managing/updating monitoring data	0
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	2

Funding: 0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	1
Total score:	3

Although Pennsylvania’s *AIS Management Plan* does not consider climate change, it has strong provisions for developing and conducting risk analyses to prevent introductions of AIS.

Building in Climate Change Information

Given Pennsylvania’s sensitivity to climate change impacts and the range of potential and already established AIS, it is important for state agency staff to incorporate climate change considerations into the next version of their plan. Furthermore, climate change concerns should be integrated into the following strategies and actions of the current plan:

- *Leadership and Coordination.* Action IC1 calls for partnering with states in the region to share data and coordinate management activities to prevent AIS introductions—“upstream” and “downstream” states in particular. By collecting information from adjacent and southern states, managers can better determine what species may spreading in response to climate changes and be better prepared to implement a rapid response program. Implementing Action IC6, which calls for participating in regional and national forums to ensure that Pennsylvania’s AIS activities are current, based on good science, and coordinated, will help facilitate this process.
- *Prevention.* Strategy 2A and associated Action 2A1 call for establishing a comprehensive process to identify AIS of concern using scientific methods and research-based risk analysis. Factors to be considered in the assessment include level of risk for introduction, potential to establish, ability to spread, and economic and ecological impacts or benefits. Climate change data should also be incorporated into the analysis because each of the factors listed may be affected by changes in climate. For example, AIS that currently are not established in Pennsylvania because they cannot over winter may establish if temperatures rise. Additionally, recreational boat use and fishing may increase with warmer temperatures, which could lead to increased AIS transport opportunities.
- *Control and Management.* Action 6B1 calls for cost-benefit analyses to prioritize AIS control activities for species and sites. Because control strategies can be sensitive to environmental conditions, cost-benefit analyses should incorporate an evaluation of how warmer water temperatures or water availability changes could influence the effectiveness and cost of control strategies.

South Carolina Aquatic Plant Management Plan Part I and II

Available at: <http://www.dnr.sc.gov/water/envaff/aquatic/plan.html>

General Description of South Carolina's Plan

South Carolina's Department of Natural Resources (SCDNR) in cooperation with the state's Aquatic Plant Management Council develops an Aquatic Plant Management Plan each year. The plans contain both a Procedural Plan and an Annual Management Plan. The purpose of the 2006 *South Carolina Aquatic Plant Management Plan* (Parts I and II) is to protect the state's public waters from the adverse effects of aquatic plant populations. The 2006 Procedural Plan gives an overview of the SCDNR's Aquatic Nuisance Species (ANS) Program and the procedure for developing the 2006 Annual Management Plan. It also identifies how the SCDNR implements the following actions:

1. Identify existing and potential aquatic plant problem areas;
2. Determine the most appropriate control system for each problem area identified;
3. Develop an operational strategy that describes how each control system would be applied;
4. Seek funding for implementation of the operational strategy; and
5. Monitor results and effects of the program and determine the need for modification.

The 2006 Annual Management Plan describes ANS problems and specific control strategies actions for various aquatic nuisance plants to be implemented by water body. Each section also includes long-term management strategies, needed funding, and potential sources of funding.

Climate Change and Invasive Species in South Carolina:

Climate models predict that climate change may increase annual summer air temperatures by 3°C and winter air temperatures by 4°C in the Southeast. Climate model results are much less certain for precipitation, but general indications are that there may be a 10 percent increase in summer precipitation and a 5 increase in winter precipitation. While sea levels are expected to rise with global warming, the rate of increase is highly uncertain. Rapid increases in sea level could result in significant coastal wetland loss, increasing open water areas and estuarine depths. The loss of coastal wetlands and marshes with rapid sea level rise has the potential to significantly reduce estuarine productivity because many estuarine species depend on wetlands as nursery areas and sources of organic matter (Mulholland 1997).

These climate change impacts may also influence AIS. For example, the Bear Island Wilderness Management Area is a low-lying coastal wetland currently threatened by several aquatic plant species, including cutgrass and phragmites. If sea-level rise results in increased coastal flooding, native species that cannot survive these harsh events may be replaced by these invasive plants once waters recede.

The South Carolina Plan's Consideration of Climate

The table below summarizes how the *South Carolina Aquatic Plant Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	0
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	0
Plan includes strategy for managing/updating monitoring data	1
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	2
<i>Funding:</i>	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	3
Total score:	6

South Carolina's plan does not consider climate change in its management and control strategies for aquatic nuisance plants.

Building in Climate Change Information

The goals of this plan are limited to aquatic nuisance plants in specific water bodies in the state. A further limitation of the plan is the absence of any climate change considerations.

Incorporating climate change concerns in to all sections of the plan may improve the outcome of the plan's control strategies. Additionally, the plan lacks prevention, early detection, or monitoring strategies, and relies solely on control measures. In order to successfully combat ANS, especially in light of climate change, it will be necessary for South Carolina to adopt the following recommended changes:

- *Leadership and Coordination.* The *South Carolina Aquatic Plant Management Plan* lacks leadership and coordination strategies to engage its neighbors on the East Coast. Coordination with bordering states, especially those to the south, will help managers understand what species may be moving north as temperatures rise. Climate change also could make coastal waters warmer, which would impact what ANS can become established and spread. Communicating with neighboring states will allow South Carolina to prepare for these potential new ANS rather than respond once they are already established.
- *Prevention, Early Detection/Rapid Response.* The South Carolina plan does not include prevention strategies. The plan is focused entirely on control methods. Because climate change will alter habitats and impact both natural and human-induced methods of introduction, prevention strategies that incorporate climate change concerns are the best mechanism to ensure the state's water bodies are effectively protected against new ANS introductions. In addition, early detection/ rapid response activities should be targeted based on new pathways and ANS predicted to be a problem under changing conditions.
- *Control and Management.* Given that climate change will affect sea-level rise, coastal erosion, depletion of water quality, and trends in the nutrient cycle in most of South Carolina's aquatic habitats, the Annual Management Plan's control strategies will need to take these changes into account to ensure they remain effective. Plans also should be expanded to incorporate aquatic nuisance wildlife and pathogens, and the impact climate change may have on them ANS and their control strategies.

Texas
State Comprehensive Management Plan for Aquatic Nuisance Species [Draft]

Available at:

http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_pl_t3200_1221_draft.doc

General Description of Texas's Draft Plan

The draft *Texas State Comprehensive Management Plan for Aquatic Nuisance Species (ANS)* is currently under review and awaiting approval by the Governor. Written by staff at the Texas Parks and Wildlife Department (TPWD), the plan focuses on control and management of ANS that have already been introduced in Texas and is based on a model plan provided by the Great Lakes ANS Panel. The plan outlines six primary goals:

1. Coordinate all ANS management activities within Texas and collaborate with regional, national, and international programs;
2. Prevent the introduction of new ANS into Texas waters;
3. Detect, monitor, contain, reduce or eradicate populations of ANS as quickly as possible with a minimum of environmental impact;
4. Educate the public and appropriate resource user groups to the importance of preventing ANS introductions and how the harmful impacts of ANS can be reduced;
5. Identify relevant problems, develop and conduct research, and disseminate research results dealing with ANS of concern in Texas; and
6. Take appropriate steps to ensure that federal and state rules and regulations sufficiently promote the prevention and control of ANS.

Strategic actions and tasks are associated with each goal. The plan discusses relevant state regulations, provides information of specific ANS of concern, and outlines the primary introduction pathways. A section on implementation lists specific tasks for fiscal years 2006 and 2007.

Climate Change and Invasive Species in Texas

The eastern region of Texas is predicted to experience an estimated increase of 4°F during the summer and 3.5°F in the winter. Climate model results are much less certain for precipitation in this region, but general indications are that there might be small changes in winter and substantial increases in summer. Evapotranspiration is projected to increase with rising temperatures, resulting in drier soils and decreased runoff during the growing season (Mulholland, 1997).

Increasing water temperatures and decreasing stream flow and groundwater levels may greatly damage native species and may benefit numerous AIS already in the state. For example, the *ANS Management Plan* notes that hydrilla and water hyacinth have caused great losses to irrigation and drinking water in a variety of areas. Increasing water temperatures will only enhance the growth potential of these more tropical AIS. Salt cedar also is noted as a problem in the plan. Salt cedar does well in drier conditions; thus, they may be able to out-compete native plants as conditions become drier.

The Texas Draft Plan’s Consideration of Climate

The table below summarizes how the draft *Texas State Comprehensive Management Plan for ANS* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
Understanding and incorporating potential impacts resulting from climate change:	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	0
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
Capacity to adapt to changing conditions:	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
Monitoring strategies:	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	2
Plan includes strategy for managing/updating monitoring data	3
Revision:	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	0
Funding:	
0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	0
Total score:	5

Texas’ plan does not consider climate change or changing conditions.

Building in Climate Change Information

Given Texas’ vulnerability to climate change and the impacts invasive species are already having on water availability and flooding, it is imperative that the plan incorporate climate change concerns. If the plan does not take these considerations into account, current ANS problems may be exacerbated. Specific examples of how climate change can be incorporated into Strategic Actions and Tasks include the following:

- *Prevention.* Various Tasks under Strategic Action 2A1, which calls for coordinating with other states, nongovernmental organizations, and Mexico to prevent ANS introductions, should be revised to include climate change considerations. For example, Task 2A1b recommends conducting scientific risk assessments to determine priority actions for new ANS threats and to revise earlier assessments. Incorporating climate change information may allow for a more accurate assessment of species' invasibility under changing conditions. For example, an ANS that may not be able to survive in Texas under current conditions may become established and spread within the state as temperatures rise, water availability changes, and/ or hydrology is altered. Task 2A1d, e, and f call for the TPWD to participate in: national conferences; the Gulf of Mexico, Mississippi River, and Western Regional ANS Panels; and the Gulf States Marine Fisheries Commission on ANS issues. Incorporating data from other states and regions into risk analyses will make them more robust and will help track species that may be spreading to Texas.
- *Early Detection/Rapid Response.* Strategic Action 3A1 calls for modifying existing monitoring programs to facilitate successful early detection. These monitoring programs should incorporate information from risk analyses that account for changes in climate to ensure that threats are adequately monitored. Task 3A1a recommends developing a GIS database to spatially display sightings and established ANS populations. This database also should include spatial data on potential pathways, entry points to the state, and possible distributions based on various climate scenarios. Integrating this information into maps will assist in prioritizing monitoring and early detection efforts.
- *Education.* Strategic Action 4B1 calls for education briefs to legislators and state and local officials on ANS threats and solutions. This action provides an ideal opportunity to educate law makers on the interactions between invasive species and climate change and the solutions that exist. Educating the law makers is essential in establishing sound policies that address ANS in the context of a changing climate.

Virginia Invasive Species Management Plan

Available at: http://www.dcr.virginia.gov/dnh/vaisc/documents/VISMP_final.pdf

General Description of Virginia's Plan

Virginia has not developed an aquatic nuisance species (ANS) management plan. However, the *Virginia Invasive Species Management Plan* includes a significant focus on ANS, in addition to terrestrial species, and echoes the general ANS Task Force plan design. In accordance with the Virginia Invasive Species Act of 2003, the plan was written by the Virginia Invasive Species Council in cooperation with the Council's Advisory Committee in 2005. The purpose of the plan is to provide state agencies with a framework for reducing ecological, economic, and human impacts from invasive species. To accomplish this goal, the plan outlines seven goals:

1. Coordinate state, federal, stakeholder prevention and management of invasive species infestations;
2. Prevent known and potential invasive species from entering the state by detecting and interrupting all unauthorized species introductions;
3. Strengthen and support an early detection network capable of identifying and reporting the appearance of invasive species before they can become established and control becomes less feasible;
4. Develop a rapid response capability to implement eradication or containment procedures for target species identified by early detection before the species can become permanently established;
5. Provide control of established invasive species through containment, abatement, and other management strategies to minimize environmental and economic impacts;
6. Support or conduct research and risk assessment necessary to assess, prioritize, and control invasive species; and
7. Provide current information on invasive species, their negative impacts to environmental and economic resources, and methods of prevention and control to the general public and special interest groups.

Under each goal, the plan identifies strategies and needed actions. An implementation table outlines responsible and cooperating agencies, time frames, and costs of planned efforts.

Climate Change and Invasive Species in Virginia

Like many other states, temperatures in Virginia are expected to increase by 3 to 4°F, depending on the season. With warmer temperatures, there will be less snow and more rain in the winter months and more evaporation in the summer months, which may lead lower stream flows and groundwater levels. Algae and eutrophication also may become more of a problem as waters warm. Increased precipitation levels could cause more flooding and run-off, which in turn could decrease oxygen levels and alter species composition. Sea levels also are predicted to rise, which could result in loss of habitat and salt water intrusion (Moore, 1997).

Warmer water temperatures could facilitate the establishment and spread of AIS into more areas of the state. For example, the tropical plant hydrilla, found in five counties in central and eastern

Virginia, may have the potential to spread into more western parts of the state as temperatures rise (USNRCS). Other species that are found further south could also migrate to Virginia and successfully over winter as air and water temperatures increase. Additionally, AIS that have a wider tolerance for environmental conditions, such as the northern snakehead, may out-compete native fish species and become more widespread if water chemistry and temperatures are influenced by climate change.

The Virginia Plan’s Consideration of Climate

The table below summarizes how the *Virginia Invasive Species Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i> 0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	2
Plan acknowledges climatic boundaries of species	1
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	1
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i> 0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i> 0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	0
Plan includes strategy for managing/updating monitoring data	0
<i>Revision:</i> 0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	3
<i>Funding:</i> 0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	0
Total score:	7

The *Virginia Invasive Species Management Plan* recognizes in its introduction that climate changes may cause non-native species that currently are not invasive in the state to become

invasive. The plan also recognizes that species adapt to changing conditions. However, it does not consider climate change impacts on its management actions.

Building in Climate Change Information

Because Virginia will experience various effects from climate change, the *Invasive Species Management Plan* should incorporate climate change considerations in its next revision, or if the state chooses to develop an ANS plan. The current plan does mention climate change and its potential to affect species' invasiveness. This demonstrates that state agencies are aware of the problem. In updating this plan, the state could further incorporate climate change in a variety of sections, including the following:

- *Early Detection/Rapid Response.* Action 3.1.1 calls for surveying and evaluating current monitoring programs and recommending ways to improve detection of invasive species. Identifying how changes in water temperature, water chemistry, and stream flow may influence species' invasibility will be critical to developing successful monitoring and early detection and rapid response programs. Task 3.2.2 recommends monitoring approved introductions and reevaluating these decisions. It will be important to consider changing conditions in evaluating approved species' invasibility.
- *Restoration.* Action 5.1.2 calls for developing restoration plans for various ecosystems, including aquatic, to establish conditions more suitable for native species. These restoration plans should take into account how climate change impacts may affect native habitats and species to ensure that restoration activities are appropriately designed. Restoring native habitats lessens vulnerability to ANS, especially in a changing climate under which many conditions, such as warmer waters and altered water chemistry and hydrology, favor ANS.
- *Research.* Actions 6.1.1 and 6.1.2 recommend identifying priority research needs for invasive species, as well as ongoing research by other states, federal agencies, and universities. Research priorities should include how climate change and invasive species will impact each other, how this will affect Virginia's native ecosystems, and how management strategies should be modified to account for the effects of climate change. Working with other states also will help Virginia to identify species that could be moving north. This information should be used to establish a process for assessing potential invasiveness of species that will likely be introduced, as recommended in Action 6.2.4.

Washington State Aquatic Nuisance Species Management Plan

Available at: <http://wdfw.wa.gov/fish/ans/2001ansplan.pdf>

General Description of Washington's Plan

Washington's 2001 *Aquatic Nuisance Species (ANS) Management Plan* was written by the Washington Department of Fish and Wildlife (WDFW) for the Aquatic Nuisance Species Committee as a revision to the 1998 plan. The 2001 plan addresses a wider range of possible introduction pathways than the 1998 plan. The 2001 plan's goal is to "fully implement a coordinated strategy designed to minimize the risk of further ANS introductions into Washington waters through all known pathways; and where practical, stop the spread of ANS already present; and eradicate or control ANS to a minimal level of impact."

Six objectives are identified to accomplish the goal:

1. Coordinate all ANS management programs within Washington and collaborate with regional, national, and international ANS programs;
2. Prevent the introduction of new ANS into Washington waters;
3. Detect, monitor, control or eradicate nonnative invasive species;
4. Educate appropriate resource user groups about the importance of preventing the introduction and spread of ANS, and how their harmful impacts can be reduced;
5. Conduct research on ANS priority species in Washington to better understand the risks and threats associated with invasions; and
6. Adopt rules and regulations that efficiently promote the prevention and control of ANS in coordination with federal regulations.

The plan also highlights accomplishments since the 1998 plan was published, including new state programs and legislation. Implementation tables for planned and future efforts are also included. Tables include which agencies are responsible for specific actions, as well as requested and dedicated funding. The plan also includes a table that outlines the status of these actions. In its appendices, the plan includes narrative descriptions of various ANS.

Climate Change and Invasive Species in Washington

Average warming in the Pacific Northwest is projected to reach 3°F (1.7°C) by the 2020s and 5°F (2.8°C) by the 2050s. Annual precipitation projections are less certain; projected precipitation ranges from a small decrease (7 percent or 2 inches) to a slightly larger increase (13 percent or 4 inches). Heavier winter rainfall would increase soil saturation, landslides, and winter flooding. Projected precipitation increases will be concentrated in winter, with decreases or smaller increases in summer; for this reason, even the projections that show increases in annual precipitation show decreases in water availability (Parson, 2000b).

Models project a larger sea-level rise on the Pacific than the Atlantic coast of North America. Risks of sea-level rise are greatest in southern Puget Sound, where low-lying areas are already at risk of inundation. A higher mean sea level is also likely to increase sediment erosion and redistribution on the open coast (Parson, 2000b). Climate change is expected to cause continued changes in coastal and estuarine ecosystems through changes in runoff and increased water

temperatures, potentially increasing the possibility of exotic species introductions or health risks from shellfish contamination. For example, the warm decade of the 1980s, following the shift to warm-phase Pacific Decadal Oscillation in the late 1970s, was characterized by a striking shift in the ecosystem of Willapa Bay: the exotic cordgrass (*Spartina*) began a rapid expansion that threatened local species for the first time. Climate change also is highly likely to impede efforts to restore depleted fish stocks and to stress healthy stocks (Parson, 2000b).

Alterations to the state’s hydrologic regime could negatively impact the amount of stream flow in both headwaters and downstream waters, which in turn could alter water temperatures and chemistry. As noted in the plan, water hyacinth can withstand a range of water conditions and temperatures. Predicted changes in water temperature and quality could positively influence water hyacinth spread and survival. Depending on winter water temperatures, however, it may not be able to over winter in the state. Another AIS of concern is the marine Asian crab. This species can tolerate a wide range of both salinity and water temperatures. With sea levels rising, salt water intrusion into freshwater areas could make the Asian clam a greater threat to Washington’s estuaries and tidal areas.

The Washington Plan’s Consideration of Climate

The table below summarizes how *Washington’s ANS Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i>	
0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	3
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i>	
0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	2
...information management goals and strategies	0
...education and public awareness goals and strategies	1
<i>Monitoring strategies:</i>	
0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	3
Plan includes strategy for managing/updating monitoring data	3
<i>Revision:</i>	
0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	

Plan includes strategy for updating and incorporating new information	3
Funding: 0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	2
Total score:	17

Although Washington’s ANS Management Plan does not explicitly mention climate change, it does recognize in its ANS descriptions that certain species have climatic boundaries. Additionally, it offers extensive strategies for preventing and monitoring ANS.

Building in Climate Change Information

Given the predicted effects of climate change in Washington, it is imperative that the state plan specify climate change-related actions and strategies. State staff could also incorporate climate change-related data, criteria, and models in implementing the existing tasks outlined in the plan. For example, the following Strategic Actions outlined in the plan could incorporate climate change considerations:

- *Prevention.* Strategic Action 2A3 calls for prohibiting, controlling, and permitting nonnative aquatic species based on their invasive potential. Task 2A3a calls for the development of a screening process to determine invasive potential. This process should be revised to incorporate climate change considerations. For example, an ANS that cannot currently over winter in the state may persist if its water temperature tolerance range overlaps with predicted temperature increases.

Task 2A3d calls for the WDFW and the ANS Coordinating Committee to develop and implement a process to identify threats to state waters, including threats from the spread of existing ANS, and to assess the environmental risks associated with each threat. The model should incorporate how climate change impacts may exacerbate threats from ANS. For example, water hyacinth could be better suited to survive in Washington if water temperatures become warmer due to climate change. Impacts from water hyacinth could also compound impacts from climate change. If climate change results in warmer summer temperatures and droughts, then water availability could be reduced. Water hyacinth could further reduce water supply for both domestic and industry uses by blocking intake pipes.

- *Control and Management.* Priorities for managing existing ANS (Strategic Action 3C2) should take climate change impacts into consideration. Species currently in Washington may spread and become a greater problem in response to climate change impacts such as warmer water temperatures or salt water intrusion. Being proactive will ensure efficient use of ANS control funds.
- *Education and Public Awareness.* Various Strategic Actions under the Education Objective should incorporate climate change considerations. In developing the statewide ANS website under Task 4A1c, the WDFW should include information on how climate change could impact ANS distribution and control efforts. Materials developed for teachers and various users groups should highlight how climate change may influence

which ANS become established and how climate change may affect prevention, management, and control efforts. Increasing awareness is the key to successful prevention.

**Wisconsin
Comprehensive Management Plan to Prevent Further Introductions and Control Existing
Populations of Aquatic Invasive Species**

Available at: <http://dnr.wi.gov/invasives/compstateansplanfinal0903.pdf>

General Description of Wisconsin's Plan

The Wisconsin Department of Natural Resources, the University of Wisconsin-Sea Grant program, and the Great Lakes Indian Fish and Wildlife Commission partnered to develop the *Wisconsin Comprehensive Management Plan*, which was released in 2003. The plan serves as a guiding document for the state to develop a coordinated response to aquatic nuisance species (ANS). The plan also is a part of a wider state effort to address ANS issues. Prevention is the primary focus of the plan, but it also addresses the need for adequate control mechanisms, reliable information, communication, and education.

The major goals of the Wisconsin plan are ANS prevention, control, and abatement. As of 2003, the Great Lakes were infested with 163 exotic species of fish, invertebrates, pathogens, and plant species. The Wisconsin plan outlines strategies to combat these existing ANS as well as to protect inland waters from similar threats. Like many other state plans, the *Wisconsin Comprehensive Management Plan* also acts as a funding proposal to the national ANS Task Force.

Climate Change and Invasive Species in Wisconsin:

Future climatic scenarios for the Great Lakes region of the U.S. predict air temperature increases in summer and winter and precipitation increases in winter. Species ranges and the state's aquatic and coastal ecosystems will change significantly as a result. Warmer temperatures could increase evaporation rates in the summer months, which would decrease stream and lake levels and diminish groundwater recharge. Warmer water temperatures in the Great Lakes could lead to reduced dissolved oxygen levels and increased algal blooms. The zoogeographical boundary for fish species may shift north by 500 to 600 kilometers, leading to invasions by warmer water fishes and extirpations of colder water fishes (Magnuson et al., 1997).

Problems associated with invasive species will be exacerbated under the projected climate change scenario in the Midwest. Temperature can limit the extent of zebra mussel colonization and has thus far kept populations in Lake Superior small. During the breeding season, when the water temperature is above 54°F (12°C), each mature female has the potential to produce several hundred thousand eggs. The longer this period, the more successful colonization will be. With summer water temperatures increasing in northern lakes, the currently small colonies are likely to become more widespread as lakes warm in the region (Easterling and Karl, 2000).

In addition, native species may be negatively impacted by climate change, such as the brown trout and crayfish species. As these species and their habitats are damaged, new and existing AIS will have an opportunity to become established and/ or spread into these more vulnerable areas. Wisconsin has identified a several AIS that could easily take over a water body if these native species decrease in number, such as purple loosestrife.

The Wisconsin Plan’s Consideration of Climate

The table below summarizes how the *Wisconsin Comprehensive Management Plan* considers and incorporates the predicted effects of climate change.

Aspects of plan that may consider climate change	Score
<i>Understanding and incorporating potential impacts resulting from climate change:</i> 0 = no; 1 = briefly mentions; 2 = includes general discussion; 3 = includes quantitative info and/or specific examples	
Plan specifically mentions climate change	0
Plan acknowledges climatic boundaries of species	1
Plan demonstrates understanding of species and/or ecosystem sensitivity to changing conditions	0
Plan identifies research on the potential effects of species responding to changing conditions	0
Plan acknowledges regional differences in expected climate changes	0
<i>Capacity to adapt to changing conditions:</i> 0 = no; 1 = implicitly (i.e. includes goals and strategies that can be used to account for changing conditions, but does not specify changing conditions as part of their purpose); 2 = yes, explicitly, in passing; 3 = yes, explicitly, and specifies associated goals and/or action items	
Plan accounts for changing conditions in its leadership and coordination goals and strategies	0
...prevention goals and strategies	0
...early detection/rapid response goals and strategies	0
...control and management goals and strategies	0
...restoration goals and strategies	0
...research goals and strategies	0
...information management goals and strategies	0
...education and public awareness goals and strategies	0
<i>Monitoring strategies:</i> 0 = no; 1 = yes, briefly mentions; 2 = yes, but unclear how information will be used; 3 = yes, and specifies associated goals and/or action items	
Plan includes strategy to monitor for changing conditions	0
Plan includes strategy to utilize monitoring data	3
Plan includes strategy for managing/updating monitoring data	0
<i>Revision:</i> 0 = no; 1 = yes, in passing; 2 = yes, and includes qualitative description; 3 = yes, and includes timeline and/or benchmarks for doing so	
Plan includes strategy for updating and incorporating new information	1
<i>Funding:</i> 0 = no; 1 = a source is specified for a portion of the required funding; 2 = a source is specified for a portion of the required funding along with strategies for obtaining remaining funding; 3 = a source is specified for 100% of required funding	
Plan identifies dedicated funding source for implementation	3
Total score:	8

Although Wisconsin’s plan does not explicitly consider climate change, it does recognize that habitat conditions require monitoring and that successful ANS management depends on regularly updated information on local and surrounding conditions.

Building in Climate Change Information

Given the significant effects of climate change that are predicted for Wisconsin, the state should integrate information about these predicted impacts when revising the plan to improve prevention and management strategies. The following recommendations identify several management actions and goals where climate change considerations should be incorporated:

- *Leadership and Coordination.* Prior to outlining management actions for Goal I, the plan states that partnerships with interstate and international groups will be formed to promote consistent regional approaches to AIS management. Strategy II E also calls for working with partner organizations and agencies to improve coordination efforts on aquatic invasive species. Because a species' ability to spread is affected in part by climate, Wisconsin and neighboring states should consider predicted changes in water and air temperatures throughout the region as a way to assess invasion threats and develop appropriate management strategies.
- *Prevention.* Goal I calls for implementing procedures and practices to prevent new introductions of AIS into Lakes Michigan and Superior, the state's boundary waters, and inland water systems. The primary pathways/ vectors that the plan focuses its prevention strategies on include the sale and distribution of bait, the aquaculture and aquarium industries, and ballast water discharges. Climate change impacts such as warming waters, altered hydrology, and nutrient level changes may impact the ability of certain aquarium species or bait fish to survive and become established in Wisconsin's waters. Incorporating these climate change considerations into prevention strategies will be critical to successful prevention efforts. Furthermore, these predicted impacts on potential AIS should be incorporated into monitoring efforts to ensure that the appropriate species and introduction points are targeted during early detection activities.
- *Control and Management.* Goal II of the management plan calls for implementing management strategies to limit the spread of already established populations of AIS into uninfested waters. State staff will need to consider how management and control strategies may be affected by climate change and adjust them accordingly. For example, current control methods for an AIS restricted to a small part of the state may be effective in preventing its spread throughout the rest of the state. However, as water temperatures warm that AIS's invasive potential could increase, especially as native species and habitats are damaged by climate change.

References

- Barron, E. (2000) Potential Consequences of Climate Variability and Change for the Northeastern United States. In: US National Assessment of the Potential Consequences of Climate Variability and Change. US Global Change Research Program, National Assessment Synthesis Team; pp- 109-134. Available online at <http://www.usgcrp.gov/usgcrp/Library/nationalassessment/04NE.pdf> [accessed May 1, 2007].
- Buddemeier, RW; Kleypas, JA; Aronson, RB. (2004) Coral reefs and global climate change: potential contributions of climate change to stresses on coral reef ecosystems. Arlington, VA: Pew Cent on Global Clim Change. Available online at http://www.pewclimate.org/docUploads/Coral_Reefs.pdf.
- Christensen, JH; Hewitson, B; Busuioc, A; et al. (2007) Regional climate projections. In: Solomon, S; Qin, D; Manning, M; et al., eds. Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom: Cambridge University Press; pp. 847-940.
- Covich, AP; Fritz, SC; Lamb, PJ; et al.(1997) Potential Effects of Climate Change on Aquatic Ecosystems of the Great Plains of North America. *Hydrol Processes* 11(8):993-1021
- Easterling, DR; Karl, TR. (2000) Potential Consequences of Climate Variability and Change for the Midwestern United States. In: US National Assessment of the Potential Consequences of Climate Variability and Change. US Global Change Research Program, National Assessment Synthesis Team; pp. 167-188. Available online at <http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overviewmidwest.htm> [accessed May 1, 2007].
- Harvell, CD; Kim, K; Burkholder, JM; Colwell, RR; Epstein, PR; Grimes, DJ; Hofmann, EE; Lipp, EK; Osterhaus, ADME; Overstreet, RM; Porter JW; Smith, GW; Vasta, GR. (1999) Emerging marine diseases-climate links and anthropogenic factors. *Science* 285(5433):1505-1510.
- Harvell, CD; Mitchell, CE; Ward, JR; Altizer, S; Dobson, AP; Ostfeld, RS; Samuel, MD. (2002) Climate warming and disease risks for terrestrial and marine biota. *Science* 296(5576):2158-2162.
- Hayhoe, K; Wake, CP; Huntington, TG; et al. (2007) Past and Future Changes in Climate and Hydrological Indicators in the US Northeast. *Clim Dyn* 28:381-407.
- Jones, RJ; Bowyer, J; Hoegh-Guldberg, O; Blackall, LL. (2004). Dynamics of a temperature-related coral disease outbreak. *Mar Ecol Prog Ser* 281:63-77.
- Joyce, LA; Ojima, D; Seielstaf, GA; et al. (2000) Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change for the Great Plains. US Global Change Research Program, National Assessment Synthesis Team; pp. 191-217. Available online at <http://www.usgcrp.gov/usgcrp/Library/nationalassessment/07GP.pdf> [accessed May 1, 2007].
- KDHE (Kansas Department of Health and Environment). Zebra Mussel: Their Inevitable Arrival in Kansas. Available online at http://www.kdheks.gov/befs/download/zebra_mussel_article.pdf [accessed May 1, 2007].
- Magneson, JJ; Webster, KE; Assel, RA; et al. (1997) Potential Effects of Climate Changes on Aquatic Systems: Laurentian Great Lakes and Precambrian Shield Region. *Hydrol Processes* 11(8):825-871.
- Moore, MV; Michael PC; Mather, JR; et al. (1997) Potential Effects of Climate Change on Freshwater Ecosystems of the New England/Mid-Atlantic Region. *Hydrol Processes* 11(8):925-947.
- Moser, S; Hayhoe, K; Wander, M. (2004) Climate Change in the Hawkeye State: Impacts on Iowa Communities and Ecosystems. Union of Concerned Scientists; pp.16. Available online at http://www.ucsusa.org/assets/documents/clean_energy/Climate_Change_in_Iowa_-Long-_Final-_and_Formatted.pdf.

Mulholland, PJ; Best, GR; Coutant, CC; et al. (1997) Effects of Climate Change on Freshwater Ecosystems of the South-Eastern United States and the Gulf Coast of Mexico. *Hydrol Processes* 11(8):949-970.

NYDEC (New York Department of Environmental Conservation). (2005) Final Report of the New York State Invasive Species Task Force. Available online at <http://www.dec.state.ny.us/website/dfwmr/habitat/istf/istfreport1105.pdf> 9 accessed May 1, 2007].

Parson, EA. (2000a) Potential Consequences of Climate Variability and Change for Alaska. In: US National Assessment of the Potential Consequences of Climate Variability and Change. US Global Change Research Program, National Assessment Synthesis Team; pp. 238-312. Available online at <http://www.usgcrp.gov/usgcrp/Library/nationalassessment/10Alaska.pdf> [accessed May 1, 2007].

Parson, EA. (2000b) Potential Consequences of Climate Variability and Change for the Pacific Northwest. In: US National Assessment of the Potential Consequences of Climate Variability and Change. US Global Change Research Program, National Assessment Synthesis Team; pp. 247-280. Available online at <http://www.usgcrp.gov/usgcrp/Library/nationalassessment/09PNW.pdf> [accessed May 1, 2007].

PIRAG (Pacific Island Regional Assessment Group). (2001) Pacific Islands Region. In: Preparing for a Changing Climate, The Potential Consequences of Climate Variability and Change. US Global Change Research Program; pp. 2-23. Available online at <http://www2.eastwestcenter.org/climate/assessment/ch2a.pdf> [accessed May 2, 2007].

Rouse, WR; Douglas, MSV; Hecky, RE; et al. (1997) Effective of Climate Change on the Freshwaters of Arctic and Subarctic North America. *Hydrological Processes* 11(8): 872-902.

SAG (Southwest Assessment Group). (2002) Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change. Available online at <http://www.ispe.arizona.edu/research/swassess/report.html> [accessed Apr. 30, 2007].

Seager, R; Mingfang, T; Held, I; Kushnir, Y; Lu, J; Vecchi, G; Huang, H-P; Harnik, N; Leetmaa, A; Lau, C; Li, C; Velez, J; Naik, N. (2007) Model projections of an imminent transition to a more arid climate in southwestern North America. *Scienceexpress*:1-4.

USACOE (U.S. Army Corps of Engineers). Round Goby – *Neogobius melanostomus*. Available online at http://el.erdc.usace.army.mil/ansrp/neogobius_melanostomus.pdf [accessed May 1, 2007].

USGS (U.S. Geological Survey). (2003) Grappling with the Unknown: How Much of a Change do Climate Models Project? *LaCoast*. Available online at <http://www.lacoast.gov/WaterMarks/2003-02/2howmuch/index.htm> [accessed May 1, 2007].

USGS (U.S. Geological Survey Northern Prairie Wildlife Research Center). (2006) Species Abstracts of Highly Disruptive Exotic Plants. Available online at [http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BUQME/\\$File/ks_impct.pdf](http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BUQME/$File/ks_impct.pdf) [accessed May 1, 2007].

USNRCS (U.S. Department of Agriculture - Natural Resources Conservation Service). Plants Profile. Available online at http://plants.usda.gov/java/county?state_name=Virginia&statefips=51&symbol=HYVE3 [accessed May 1, 2007].