

Preparing Oregon's Fish, Wildlife, and Habitats for Future Climate Change: *A Guide for State Adaptation Efforts*

Subcommittee on Fish, Wildlife, and Habitat Adaptation
Oregon Global Warming Commission



Prepared by:

Defenders of Wildlife
Oregon Department of Fish and Wildlife

Photographs by:

Bruce Taylor, Defenders of Wildlife
Page 7, Mule deer by Tupper Ansel Blake, courtesy of U.S. Fish and
Wildlife Service

For more information:

Holly Michael
Conservation Strategy & Special Projects Coordinator
Oregon Department of Fish and Wildlife
3406 Cherry Avenue N.E.
Salem, Oregon 97303
503-947-6000

Sara O'Brien
Private Lands Conservation Associate
Defenders of Wildlife
1880 Willamette Falls Drive #200
West Linn, Oregon 97068
503-697-3222

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EXECUTIVE SUMMARY

Climate change is the primary long-term challenge facing Oregon’s people, ecosystems, and economies. Immediate action is needed to prepare for and proactively adapt to the consequences of climate change. State-level preparedness will be critical in coping with projected changes such as increased temperatures, rising sea levels and increased storm surges, declining snowpack, more frequent extreme precipitation events, and an increased risk of drought and heat waves. These changes have already created a broad array of secondary effects in Oregon’s ecosystems.

As the effects of a changing climate become increasingly apparent, Oregon needs a strategy for preparing for, managing, and responding to climate change impacts. This document, prepared by the Oregon Global Warming Commission’s Fish and Wildlife Adaptation Subcommittee, outlines a plan for preparing for climate change in natural systems, with a specific focus on management of fish and wildlife populations and their habitats.

In light of the pressing need for techniques and strategies for adapting to climate change, the members of this subcommittee have outlined a set of basic guiding principles for managing fish, wildlife, and habitats in a changing climate:

1. Maintain and restore key ecosystem processes.
2. Establish an interconnected network of lands and waters that support fish and wildlife adaptation.
3. Acknowledge, evaluate, and weigh the risks involved with proposed management actions in the context of anticipated climate conditions.
4. Coordinate across political and jurisdictional boundaries.

Each of these guiding principles carries significant policy implications. In the short term, getting needed resources to agencies should be a high priority in any adaptation strategy. In the long term, however, more significant policy changes will be needed to help agencies manage the effects of climate change. Adaptation efforts should capitalize on existing policies and strategies whenever possible, but many existing plans and policies will need to be updated to account for climate change impacts. The subcommittee offers the following recommendations for developing policy to support fish and wildlife adaptation.

Address key adaptation funding needs.

- Invest in implementation of the Oregon Conservation Strategy.
- Designate a full-time staff lead on climate change in relevant state agencies.
- Use revenue from future cap-and-trade or carbon tax policies to help fund state adaptation efforts.
- Invest in agencies adaptation needs.

Review, revise, and add policies to prioritize adaptation.

- Direct and enable state agencies to address climate change adaptation.
- Review existing policies in the context of climate change.
- Develop a state policy supporting provision of ecosystem services.
- Authorize and encourage agencies to manage adaptively.

Develop new institutions for collaboration and integration.

- Create a state-wide monitoring framework.
- Highlight public education and outreach.
- Implement the relevant recommendations of the Western Governor's Association.

- Plan and prepare for long-term governance changes.

The guidelines and policy recommendations described here depend on the continual improvement of research and monitoring on climate change and its effects on fish, wildlife, and habitats. The subcommittee identified the following research priorities in this arena:

- Climate change vulnerability assessments;
- Monitoring and evaluation of management actions;
- Long-term research on climate trends and ecosystem responses;
- Regional downscaling of climate models.



PREPARING OREGON'S FISH, WILDLIFE, AND HABITATS FOR FUTURE CLIMATE CHANGE: A GUIDE FOR STATE ADAPTATION EFFORTS

Climate change is the primary long-term challenge facing Oregon's people, ecosystems, and economies. With increasing concern about global climate change, efforts to reduce greenhouse gas emissions are gaining momentum. But even if these mitigation efforts are swift and effective, there will be an inevitable lag between when we reduce emissions and when we see the effects in the climate system and in the natural world. While reducing emissions is critical, some additional warming is unavoidable.

The impacts of climate change will be significant and far-reaching. Oregonians can expect to see increased temperatures, rising sea levels, declining snowpack, more frequent extreme storms, and an increased risk of drought and heat waves. Ecological systems are likely to be hardest hit, but damage to these systems will also have serious social and economic consequences. A changing climate will threaten the provision of ecosystem services that all residents and economic sectors depend on, and wildlife-related industries such as commercial fishing and wildlife-based recreation will be especially hard-hit.

Immediate action is needed to cope with the changing climate. Oregon should develop a comprehensive plan for climate change adaptation, to plan for and proactively manage the effects of climate change. The term climate change adaptation describes efforts to reduce the impacts of climate change on social, economic, and ecological systems and to manage the risk associated with a changing climate.

This document, prepared by the Oregon Global Warming Commission's Fish and Wildlife Adaptation Subcommittee, outlines a plan for climate change adaptation in the context of managing fish and wildlife populations and their habitats. It was developed for use by the full Global Warming Commission, the Oregon Fish and Wildlife Commission, other natural resource agencies and their commissions and boards, the Governor's office, members of the state legislature, and the general public. This document reflects the consensus of the Fish and Wildlife Adaptation Subcommittee and is not intended to represent the views of any other agency or commission. Appendix A lists subcommittee members and other contributors.

While further research is required to provide the details of what Oregon can expect from global climate change, the need for action is pressing and immediate. Our current body of knowledge is sufficient to begin making meaningful decisions about adaptation. State agencies and others are already dealing with affected fish and wildlife populations; they urgently need a strategy for coping with present and future impacts that will provide sufficient guidance but also allow for flexibility in the face of changing information and a changing environment. This document reviews the state of our knowledge about climate change as it relates to fish and wildlife populations and provides policy recommendations and research priorities for building a state fish and wildlife adaptation strategy.¹

SECTION I.

PROBLEM STATEMENT

Climate change is already occurring, and its impacts are being felt in ecosystems and communities around the world. However, changes are expected to accelerate through at least the next century. The Pacific Northwest region is expected to experience an additional 1-5°F of warming by 2050.² Temperature predictions beyond 2050 are less certain because they depend largely on future trends in emissions. Precipitation projections are also somewhat less certain, but most researchers expect a modest increase in winter precipitation and a modest decrease in summer precipitation, with overall annual precipitation expected to remain within the range of natural variability.³ In Oregon, the physical impacts of these climate trends are expected to include major changes to water cycles: reduced snowpack, earlier snow melt, increased and earlier peak stream flows, and reduced summer stream flows. Models also anticipate increases in the frequency, size, and intensity of wildfires in some ecosystems, as well as rising sea levels in at least some locations on the Oregon coast.⁴

These changes have already created a broad array of secondary effects in Oregon's ecosystems. Current and anticipated ecological effects include:⁵

Effects of rising temperatures:

- Longer, more intense fire seasons and increased fire damage in many ecosystems;
- Increased evaporation and decreased soil moisture;
- Decline, extirpation, or extinction of many native fish and wildlife species and populations, especially those dependent on high-elevation, coldwater, or wetland habitats and populations at the southern extent of the species' range;

- Shifts in species' range, especially to northern areas or higher elevations;
- Earlier arrival of spring conditions and associated changes in the timing of ecological events such as migration, reproduction, and flowering, all leading to a mismatch in life cycles of interdependent species;
- Exposure to new or increased levels of pests and pathogens, including increased insect damage in some forest ecosystems;
- Conditions favoring the introduction, spread, and dominance of non-native invasive plant and animal species.

Effects of changing precipitation patterns:

- Decreased water availability and quality in freshwater systems, including increased water temperature and sediment levels in streams;
- Degradation or destruction of habitat for native fish and other aquatic species;
- Increased flood and streambed scouring events in winter;
- Drying of wetlands and headwater streams.

Effects of sea-level rise and increased storm surges:

- Increased coastal erosion;
- Sediment deposition in estuaries;
- Coastal and river-mouth flooding;
- Saltwater intrusion into freshwater wetlands and water tables;
- Loss of tidal, coastal wetland, and estuary habitats.

In many cases, a given ecosystem response actually results from a complex interaction of climate change and other factors. For example, changes to fire regimes can be linked not only to rising temperatures but also to increased plant productivity, hydrologic stress to plants, invasive species, and damage by pests and diseases (see

sidebars).⁶ The effects of climate change interact with and exacerbate existing human-caused stresses to natural systems, such as habitat loss due to land use change, over-allocation of water and other natural resources, spread of invasive species, altered disturbance regimes, landscape fragmentation, and declines in air and water quality.

Because of the many complex, interrelated changes associated with climate change, 21st century fish and wildlife managers will need to adapt their management techniques and strategies. They will need to learn to cope better with uncertainty, incomplete information, and a rapidly changing environment, and they will need to find better ways to tap into existing information on climate change and its impacts. Failure to do so will lead to the permanent loss of species and ecosystems, disruptions to ecosystem services such as clean air and water and flood control, and significant declines in resource-dependent industries such as fisheries, timber, agriculture, and tourism and recreation.



Changing Forests -- Climate, Land Use, and Fire

Recent evidence shows a clear link between climate change and larger and more frequent forest fires in the western United States. Researchers have found a clear increase in large wildfire activity that begins in the mid-1980s and is strongly tied to climate patterns. This increase is evident even in areas where land use changes have been minimal.

Earlier spring snow melt, longer fire seasons, and higher spring and summer temperatures associated with global climate change are believed to exacerbate fire activity in many – but probably not all – forests. Other climate-related mechanisms may also contribute to the problem. Increased wind speeds can fuel larger and more intense fires, and in many systems the spread of invasive species can play a similar role. In many forests, past fire suppression and changes in land use will further exacerbate changing fire regimes.

Fire plays an important role in nearly all North American forests, and preventing all fire is not a beneficial or practical goal. However, changing fire regimes will likely affect fish and wildlife species, air quality, and watersheds in new and unpredictable ways. They will require land managers, policy makers, and the general public to make difficult decisions about fuel management, fire suppression, and development in fire-prone forests.



Complex Climate Responses in Eastern Oregon**Grass- and Shrublands**

The level of CO₂ in today's atmosphere is about 34% greater than in preindustrial times. Increasing atmospheric CO₂ is a major cause of global climate change, but it is also directly affects how plants grow, function, and compete for water and other resources. Generally, higher concentrations of CO₂ are associated with greater plant productivity and more efficient water use. This may seem like good news, but it also appears to be changing competition between species, resulting in shifts in species composition, increasing fires, and the invasion of woody plants and annual grasses into other ecosystems.

In eastern Oregon, mid-elevation grasslands and shrublands are deteriorating due to several interrelated factors. Juniper are expanding at middle elevations and non-native annuals such as cheatgrass are expanding at lower elevations, squeezing out the native grass and shrub species – and associated wildlife – in between. Increased levels of atmospheric CO₂ help the invading species outcompete native shrubs and perennial grasses. Increased productivity and changes in temperature and precipitation appear to be driving more frequent and larger fires, which in turn favors annual grasses. Annual grasses produce more biomass, which also tends to accelerate fire regimes. Paradoxically, the spread of juniper at middle elevations decreases fire frequency. As a result, a given area may experience both increased and decreased fire frequency at different locations, creating a new set of challenges for managers.

These changes combine with human development and land use change to create a very real threat to eastern Oregon's grassland and shrubland systems and their associated wildlife, which include a high diversity of grassland-dependent raptors, songbirds, and small mammals, as well as the well-known Greater sage-grouse. Future management decisions should acknowledge and address the important roles climate change, fire, and invasive species play in shaping Eastern Oregon landscapes.

SECTION II.

GUIDING PRINCIPLES FOR FISH AND WILDLIFE ADAPTATION

In light of the need for techniques and strategies for climate change adaptation, the members of this subcommittee have outlined a set of basic guiding principles for managing fish, wildlife, and habitats in a changing climate. These principles highlight both the challenges fish and wildlife managers will likely face and the strategies that can help them meet these challenges. The Global Warming Commission, the Oregon Department of Fish and Wildlife, the state Fish and Wildlife Commission, other natural resource agencies (including the Departments of Forestry, Water Resources, State Lands, Environmental Quality, and Parks and Recreation) and their commissions and boards, the Governor's Office, the state legislature, and others can consider these guidelines as they establish new policies, institutions, and strategies to promote climate change adaptation.

1. Maintain and restore key ecosystem processes.

Basic ecosystem processes such as fire and flood cycles play a critical role in maintaining diverse landscapes. Maintaining and restoring these processes will help build resilient ecosystems that will help buffer humans, fish, and wildlife from the effects of climate change. For example, nearly all of Oregon's ecosystems evolved with fire, a normal process that is essential to species diversity and nutrient cycling. Today, however, the frequency and intensity of fires have changed in some systems, leaving them more susceptible to the effects of climate change described in Section 1. Similarly, hydrological cycles are important to maintaining the resilience of ecosystems, and

maintaining dynamic streams and rivers will help minimize the effects of climate change on many fish and wildlife species (see sidebar).

Climate change will affect ecosystem processes within a context of pre-existing human-caused stresses. Land-use change, landscape fragmentation, habitat destruction, pollution and other threats to water quality and quantity, introduction of invasive species, and other anthropogenic processes have already endangered many species and driven some to extinction. For species and systems already at risk, climate change may prove to be one stress too many. Dealing with existing stressors on ecosystem processes may be among the most valuable and least risky strategies available for climate change adaptation, in part because we have more knowledge about causes, effects, and solutions.

Managing ecosystems to maintain and restore these key processes will help to keep future management options open and greatly increase our capacity to deal with uncertainty and change. Existing policy and planning frameworks that acknowledge and address the importance of ecosystem processes can provide a useful starting point for addressing climate adaptation needs. For example, the Oregon Conservation Strategy contains little direct information on climate change adaptation, but it does provide an important framework for maintaining and restoring ecosystem processes and building resiliency.



Flooding as a Key Ecological Process

Oregon's streams and rivers have been substantially affected by human activities. Development in floodplains, over-allocation, damming, runoff, and disturbances to riparian areas have all degraded water resources. In many streams and rivers flooding is now controlled, channels have been simplified, native vegetation has been removed, dams alter flow and block fish passage, and water quality and quantity have declined. Climate change is adding another layer of human influence, and all of these pre-existing stresses on water resources make the state's ecological, social, and economic systems more vulnerable to the effects of climate change.

Degraded streams and rivers affect a wide variety of fish and wildlife species. The changes described above are combining with climate change to create streams and rivers that are too warm to sustain healthy populations of some coldwater species, including Oregon's many species of salmon, steelhead and trout. Rivers with simplified channels also lack the small patches of coldwater habitat – alcoves and gravel bars – of more complex natural channels. Coldwater fish are left without their needed habitat, and warmwater invasive species begin to take over.

The following actions can help make streams and rivers more resilient to climate change and other human impacts:

- Maintain natural flow regimes by minimizing withdrawals for municipal, agricultural, and industrial uses.
- Protect and restore native plant communities in riparian areas. Riparian vegetation helps buffer streams and rivers against unnatural upslope disturbances and flood events, provides shading to prevent river water warming, and provides habitat for many aquatic species.
- Protect and restore channel complexity to provide habitat for aquatic species, create a natural buffer for flood events, and restore groundwater recharge. Reconnect river channels and their flood plains.
- Maintain dynamic streams and rivers, allowing for both peak flow events and seasonal low flow.

Flooding as a Key Ecological Process,*continued from page 7*

- Limit introduction and spread of invasive species, especially warm water invasive species.
- Manage watersheds to maintain and restore habitat “stepping stones” so that aquatic species can disperse through river networks and move to their best available habitat.

Maintaining and restoring key hydrological processes will require the state to limit new development in floodplains and create incentives to rebuild outside the floodplain. Healthy river ecosystems are always changing and are built by flood events interacting with the landscape. Focusing on protecting intact ecosystems and limiting inappropriate development can significantly improve the quantity and quality of our water resources while limiting political and economic costs.

2. Establish an interconnected network of lands and waters that support fish and wildlife adaptation.

Effectively managing fish, wildlife, and habitats in the context of climate change will require an ambitious approach that includes both core conservation areas, which are managed primarily for conservation values, and areas that are managed for multiple values while providing habitat for fish and wildlife species. Core conservation areas include both public lands and private lands managed by land trusts, conservation organizations, or individuals for conservation purposes. However, other private landowners often manage lands for production as well as conservation values. Incentive programs and other mechanisms can help encourage these landowners to create buffer zones around core areas or provide enough habitat connectivity for fish and wildlife to move among core areas.

Climate change makes the need for strategic conservation efforts on both public and private lands ever more pressing. Past conservation decisions did not always take into account the need for habitat connectivity, which will prove to be especially important under changing climate conditions. Mobile species can move to more suitable habitat, but they will do so in unpredictable and chaotic ways, and narrowly-defined “wildlife corridors” will not be sufficient. Managers should avoid creating any new barriers to dispersal, and some existing barriers will need to be removed.

Habitat connectivity at the scale needed for climate change adaptation will require land-management agencies, land conservation groups, and incentive programs to plan their conservation interventions strategically, collaboratively define priority lands and strategy, invest in these priorities first. Although the habitats and species found in a given area may change over time, managing lands to sustain ecological processes will help make the larger surrounding landscapes more resilient to the effects of climate change. Careful management can help ensure that these places continue to provide needed ecosystem services support healthy populations of plants and animals.

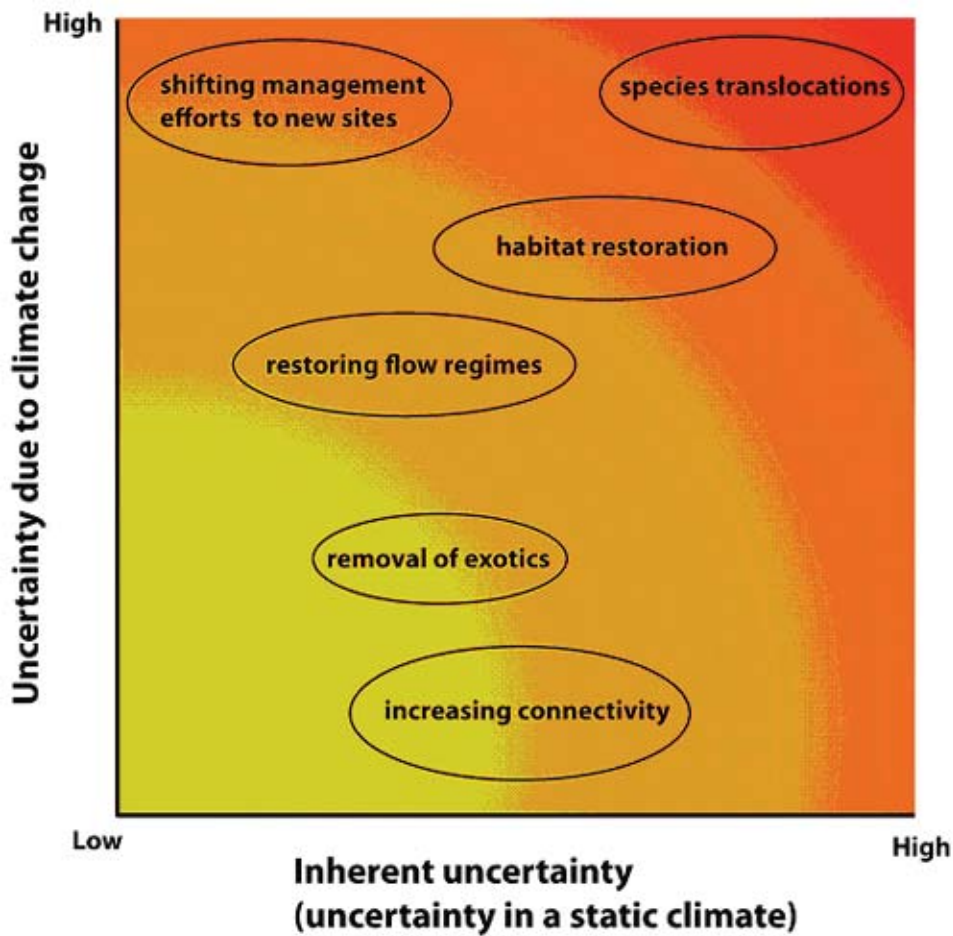
Past accomplishments in conserving fish, wildlife, and their habitats are important and will help provide the foundations for this network. However, a lack of coordination among diverse stakeholders has made it difficult to act strategically. Decisions about what land needs to be managed primarily or partially for conservation purposes should be coordinated at least at the state level. The Oregon Conservation Strategy provides a useful starting point for this process, but much work remains to be done (see sidebar page 12).

3. Acknowledge, evaluate, and weigh the risks involved with proposed management actions in the context of anticipated climate conditions.

Every management action carries some risk, and some actions are inherently riskier than others. The risk may be to an individual, a species, or the functioning of an entire watershed or ecosystem, and it may be due primarily to uncertainties about future climates or to other ecological factors (see figure below).

Some conservation actions, especially those that simply prevent future threats to relatively intact ecosystems, are likely to benefit species no matter what future climates look like. These are often referred to as “no-regrets” strategies. For example, increasing habitat connectivity or controlling non-native invasive species will likely benefit native fish and wildlife species and their habitats regardless of future climate conditions. In many cases, good conservation actions will prove to be good adaptation actions. In other words, much of our existing knowledge about how to conserve

Risk Associated with Management Activities



From Lawler, JJ, TH Tear, C. Pyke, R. Shaw, P. Gonzalez, P. Kareiva, L. Hansen, L. Hannah, K. Klausmeyer, A. Aldous, C. Bienz, and S. Pearsall. In press. Resource management in a changing and uncertain environment. *Frontiers in Ecology and the Environment*.

species, systems, and processes will continue to be relevant and useful under future climate conditions.

However, the success of some conservation actions will depend on the validity of climate predictions. Because of the uncertainty inherent in these predictions, such actions may be among the riskiest. Aggressive management techniques, such as transporting a species to its potential future range, creating new habitat based on projections of future range, or introducing new species into a changing habitat carry a great deal of risk and should not be undertaken lightly.

The most effective management strategies will likely include some combination of high- and low-risk approaches. Climate change may force managers and policymakers to raise the level of risk that is acceptable, in order to cope with the dangers of inaction. In many cases, a decision to take no action may carry the greatest risk of all.

4. Coordinate across political and jurisdictional boundaries.

Because climate change will affect all ecosystems, adaptation will require significant collaboration and coordination among federal, tribal, state, and local governments and agencies, private landowners, nongovernmental organizations, and others. In many cases, failing to coordinate adaptation strategies will result in unnecessary duplication of efforts and inefficient resource allocation. This coordination will be difficult, in part because it must take place at many levels simultaneously. Entities must work together within regions, states, and watersheds, and doing so effectively may require the creation of new institutions.

Integration among state agencies is particularly important, because many state agencies will not have sufficient resources to meet their own needs for climate change research, education, and exten-

sion. An interagency strategy is needed to identify research needs, coordinate data collection, and ensure data collected across jurisdictions are available and accessible to others.

SECTION III. POLICY RECOMMENDATIONS

There is an immediate need to increase the resources available to manage climate impacts on fish and wildlife and their habitats. Fish and wildlife managers are already experiencing the effects of climate change, and current funding and staffing levels within state agencies are insufficient to cope with either current or future changes. Getting needed resources to agencies should be a high priority in any adaptation strategy.

In the long term, however, more significant policy changes will be needed for agencies to manage the impacts of climate change on species, habitats, and ecosystems. Adaptation efforts should capitalize on existing policies and structures whenever possible, but many existing plans and policies will need to be updated to account for climate change impacts. Adapting to future climate changes will also require new policy solutions, institutions, and governance structures. Climate conditions that are rapidly changing, more variable, and less predictable will eventually require some agencies to expand or adjust their mandate, mission, organization, and management tools. Agencies, managers, and decision-makers may feel overwhelmed by the scale and uncertainty involved with dealing with climate change.

Governments and agencies that acknowledge the situation and begin adapting as soon as possible will be ahead of the curve in dealing with climate-induced changes. They will be better prepared for surprises, more able to avoid catastrophic effects, and more successful in coping

Policy Recommendations for Fish and Wildlife

Adaptation

Address key adaptation funding needs:

- Invest in implementation of the Oregon Conservation Strategy.
- Designate a staff lead on climate change in relevant state agencies.
- Use revenue from future cap-and-trade or carbon tax policies to help fund state adaptation efforts.
- Invest in building agencies' capacity for adaptation.

Review, revise, and add policies to prioritize adaptation:

- Direct and enable state agencies to address climate change adaptation.
- Review existing policies in the context of climate change.
- Authorize and encourage agencies to manage adaptively.
- Develop a state policy supporting provision of ecosystem services.

Develop new institutions for collaboration and integration:

- Create a state-wide monitoring framework.
- Highlight public education and outreach.
- Implement the relevant suggestions of the Western Governor's Association Wildlife Initiative.
- Plan and prepare for long-term governance changes.

with unavoidable changes. The Fish, Wildlife, and Habitat Adaptation Subcommittee of the Oregon Global Warming Commission offers the following recommendations for developing policy to support fish and wildlife adaptation.

Address key adaptation funding needs

- *Invest in implementation of the Oregon Conservation Strategy.*

Fish and wildlife adaptation to the adverse effects of climate change will depend greatly on our ability to manage for resilient ecosystems. The Oregon Conservation Strategy is a key tool in this context, and its implementation should take a high priority in state adaptation efforts (see sidebar on p. 12). The strategy was developed to provide an overarching framework for state conservation efforts, and it covers the diversity of species and ecosystems throughout the state. It provides guidance to agencies and others in prioritizing conservation actions and should not be duplicated or replaced by development of a stand-alone fish and wildlife adaptation strategy. Instead, climate change adaptation should be integrated into the existing strategy. All resource agencies should work to integrate adaptation into their existing plans and ongoing activities; increased funding will be needed to more fully implement the strategies.

As part of its upcoming revision process, the strategy should explicitly identify priority ecosystems and lands and key ecosystem processes under future anticipated climate conditions, and it should assess the connectivity of priority lands and the vulnerability of ecoregions, habitats, and species to anticipated climate changes.

- *Designate a staff lead on climate change in relevant agencies.*

The State of Oregon should designate at least one full-time staff lead on climate change adaptation for each state natural resource agency. This staff position should be responsible for incorporating climate change adaptation into the agency's regular portfolio and collaborating with other

agencies and organizations as needed. As a first step, the state should direct the staff lead to conduct a review of existing policies and procedures in the context of climate change adaptation. In the future, many more similar positions will be needed, and coping with climate change will play a key role in most ongoing agency activities. In the short term, agencies may need to re-evaluate their priorities and redirect staff resources to address the challenges ahead, rather than the priorities of the past.

Because of the scope of current and future adaptation needs and limited options for funding, agencies will also need support from other institutions, including research universities, federal agencies, and non-profit organizations. They may wish to create an advisory body on climate change adaptation to provide information and guidance to staff, commission members, and the interested public.

- *Use revenue from future cap-and-trade or carbon tax policies to help fund state adaptation efforts.*

Existing funding for state wildlife agencies has historically been heavily dependent on sales of hunting, fishing, and trapping licenses and tags. Given the rapidly expanding need for fish and wildlife management in a changing climate, and declining revenues in license sales, state wildlife agencies are facing a critical shortfall in funding.⁷ Without permanent, dedicated funding in place it will be impossible for any agency to approach the monumental tasks associated with adaptation.

Revenue from future mitigation efforts will be one appropriate source for such funding. Any state, regional, or national cap-and-trade or carbon tax system established should set aside a significant portion of auction or tax revenue for fish and wildlife and other forms of climate change adaptation. Similarly, emissions offset programs on

The Oregon Conservation Strategy

The Oregon Conservation Strategy, developed as the state's first overarching strategy for conservation actions, will provide a useful framework for prioritizing fish and wildlife adaptation needs. It represents a statewide effort at setting conservation priorities and is linked to a congressionally-mandated national effort. The strategy covers diverse species and spatial scales, and it is designed to be adaptive and flexible in order to deal with emerging conservation issues. Furthermore, it already emphasizes many of the elements of climate change adaptation, including maximizing connectivity, managing for biodiversity, and limiting non-climate stresses.

As climate change makes complex systems even more difficult to manage, fish and wildlife agencies will have to go through an open and unambiguous process to determine where scarce resources predicted climate changes on species and habitats. The Oregon Conservation Strategy outlines human activities that affect key ecosystem processes, identifies priority habitats and species, and then uses this information to identify and map Conservation Opportunity Areas where these priorities can best be addressed through voluntary conservation efforts. While these elements should be reviewed and revised to more directly address climate change, the Oregon Conservation Strategy provides an important tool for contextualizing and managing these issues and for reaching consensus on statewide conservation priorities. With sufficient funding and an inter-agency commitment to implementation, the Oregon Conservation Strategy could form a key first step in developing a statewide adaptation strategy.

forests and agricultural lands should, whenever possible, be used to stimulate improvements in management that support provision of ecosystem services and fish and wildlife adaptation. Given the scale of climate change and its effects, it is crucial that state and local efforts be supported in part with federal funds.

- *Invest in building agencies' capacity for adaptation.*

Climate change adaptation needs are too important and too comprehensive to be addressed on an ad hoc basis or as an unfunded mandate. The State of Oregon should establish a source of funding specifically dedicated to supporting agencies' climate change adaptation efforts. The governor and the legislature should allocate these funds as needed to support adaptation needs identified by the Global Warming Commission, the interagency coordinating committee described above, the agencies' commissions, and the agencies themselves.

Review, revise, and add policies to prioritize adaptation.

- *Direct and enable state agencies to address climate change adaptation.*

The state of Oregon should direct and enable agencies to incorporate climate change considerations and adaptation planning into normal activities and planning processes. Decisions made at all levels and in all sectors of government can positively or negatively affect fish and wildlife adaptation to climate change, but climate projections and ecosystem responses to climate are rarely explicitly considered in these processes. A clear mandate is needed that climate considerations, including impacts on fish, wildlife, and habitats, should be integrated into future agency activities. As noted above, this mandate will require significant investment to build agencies' capacity to meet adaptation needs.

- *Review existing policies in the context of climate change.*

While existing policies can be useful in guiding fish and wildlife adaptation efforts, they also often contain assumptions that are no longer valid in the context of a highly variable and rapidly changing climate. Most of these policies fail to consider climate change and its effects on species and systems in identifying and prioritizing management actions. Some aim to reconstruct past conditions on the landscape or promote other goals which may be unreasonable or impossible under current and future climate patterns. Changes will likely be needed to ensure that climate impacts are addressed in policy and that existing policies do not conflict with the realities of managing fish and wildlife in a changing climate. The first step toward developing climate-responsive policies is to conduct a formal review of relevant policies in the context of ongoing and anticipated climate changes. Conducting this review within the state university system would capitalize on existing resources.

- *Authorize and encourage agencies to manage adaptively.*

Adaptive management is a method for making natural resource management decisions in a context of incomplete information, uncertainty, risk, and change. It is a way of gradually accruing the information needed for decision-making without indefinitely postponing needed actions. Management decisions are designed to provide data and feedback, which are in turn used to inform future decisions or policies. At its most basic level, adaptive management consists of coupling management actions with monitoring and evaluation of results. In order to succeed at any form of adaptive management, managers

must create scientifically sound alternative management plans that anticipate future results and then monitor the actual results closely and be prepared to change future actions as indicated. Public trust and the policy environment will play a major role in determining the success of these efforts.

The first step toward enabling adaptive management is to specifically authorize it through legislation. State agencies currently lack statutory authority to manage adaptively. Agencies should be both authorized and encouraged to incorporate adaptive management into their existing programs. Ultimately, broader policy changes may also be needed to enable and support agencies in using adaptive management practices. Future environmental and natural resource policies may need to incorporate greater flexibility to allow managers to use adaptive management strategies. Such changes are likely to be controversial and will depend on building trust among policymakers, agencies, and the public. As a first step, barriers to adaptive management should be removed and policies should be enacted to create a coordinated, interagency monitoring system to support management decisions.

- *Develop a state policy supporting provision of ecosystem services.*

Ecosystem services are the benefits that humans enjoy as a result of natural systems and key ecological processes, including fish and wildlife habitat, water quantity, filtration of air and water pollution, pollination, control of pests and diseases, control of invasive plants and animals, maintenance of soil productivity, and avoidance or offset of greenhouse gas emissions. These services form the backbone of all of the state's social, ecological, and economic systems. Policies that address the provision of ecosystem services offer a unique opportunity to address the

guidelines described in Section 2 by identifying a set of values for conservation that cuts across ecosystems, species, land ownerships and uses, and jurisdictions. Maintaining, restoring, and enhancing ecosystem services is a low-risk strategy in that it supports the benefits humans derive from natural systems regardless of future climate conditions. It will also direct conservation actions toward the resources that help buffer both human and natural communities from the effects of climate change as ecosystems and landscapes shift in unexpected ways. Oregon should develop a policy or set of policies to explicitly address the provision of ecosystem services under changing climate conditions.

Develop new institutions for collaboration and integration

- *Create a state-wide monitoring framework.*

Monitoring will play a vital role in fish and wildlife adaptation and in prioritizing future conservation needs. This role is especially significant in the context of rapidly changing ecosystems and uncertainty about future climate conditions. Agencies will need to expand their monitoring efforts to address climate change without jeopardizing long-term monitoring programs that remain relevant and useful regardless of climate impacts.

To make the most efficient use of available funding, monitoring efforts should be coordinated and shared among all relevant agencies. Monitoring across boundaries and jurisdictions will form the basis for decision-making in a variable and rapidly changing environment. A single agency or group should be assigned responsibility for developing an overarching, state-wide monitoring framework for natural resources. This kind of framework is urgently needed to guide the generation of data needed for adaptive management, as

well as to collect and make available existing data. Basing this monitoring effort in one of the state's universities would help promote collaboration and capitalize on existing resources, but the effort will require the mutual cooperation of agencies and research institutions to ensure that both new and existing monitoring needs are addressed. Existing long-term monitoring sites are especially useful for tracking climate impacts over time and should not be disrupted (see Section 4).

The responsible agency or group should build on previous work by the Biodiversity Monitoring Workgroup, the Western Governors' Association, state and federal agencies, conservation groups, and others to identify monitoring needs, coordinate data collection, and make sure data collected across jurisdictions are available and accessible to others. Monitoring should be conducted to support specific decision-making needs, and data should be stored and made available through a single clearinghouse. Permanent dedicated funding and the engagement of agency leadership will be needed to ensure the viability of the monitoring framework over time.

- *Highlight public education and outreach.*

The success of fish and wildlife adaptation efforts will depend greatly on the support and participation of private citizens. In order to build consensus on the need for both mitigation and adaptation, the state should conduct a major public education campaign that highlights the reality of climate change, the anticipated impacts on natural resources and resource-dependent industries, and the public's role in adaptation and mitigation efforts. The Global Warming Commission has established a Communication and Outreach Committee to help address these needs.

- *Implement the relevant recommendations of the Western Governors' Association Wildlife Initiative.*

The Climate Change Working Group associated with this initiative has outlined a number of barriers to identifying and maintaining functioning wildlife corridors in the face of climate change, as well as recommendations for overcoming these barriers. Their recommendations include establishment of a Wildlife Adaptation Advisory Council to facilitate climate-impact assessments and address other research needs, development of new revenue streams to support wildlife adaptation to climate change, and directing other state agencies to work with state wildlife agencies to support viable wildlife populations under a changing climate.⁸

- *Plan and prepare for long-term governance changes.*

In the long term, climate change is likely to fundamentally change the way governments and other institutions function. The challenges now facing these institutions are unlike any previous ecological or social problems. Coping effectively with these challenges may require significant structural changes in governance. As the effects of climate change build and accelerate, the state must work to build its capacity to adapt. In state government, a commission or lead agency will be needed to coordinate and direct adaptation efforts. In order to accommodate the immediate need for adaptation activities, this group must have the support of the legislature, state boards and commissions, and the governor's office in directing agencies to address adaptation needs. Similar efforts will be needed at the local, regional, national, and international levels to build significant adaptation efforts as climate change and its impacts accelerate.

SECTION IV

RESEARCH AND MONITORING NEEDS

The guidelines and policy recommendations described here depend on the continual improvement of research and monitoring on climate change and its effects on fish, wildlife, and habitats. The Global Warming Commission tasked its Science and Technology Committee with helping to determine climate change research priorities for the state. These priorities should include research relevant to fish and wildlife adaptation. The Fish, Wildlife, and Habitats Subcommittee identified the following research priorities in this arena:

Climate change vulnerability assessments:

State- or regional-scale assessments of climate change vulnerability are needed to help support agencies' prioritization and management decisions. These assessments should be aimed at determining which species and ecosystems will likely be most affected, and they should help guide decisions about how to best manage the most negatively affected species and systems.⁹ The Oregon Conservation Strategy provides a useful framework for conducting these studies.

Monitoring and evaluation of management actions: There is an urgent need to tie existing and proposed management techniques with on-the-ground results. Evaluating management actions will be critical to coping with future climate uncertainties, and there is a particular need for research that shows how climate change affects management results. For example, without much more information on the ecological effects of species translocation, no definitive analysis can be made of the costs and benefits involved. Integra-

tion of research and project monitoring will help guide adaptation efforts and maximize the effectiveness of funds spent, and it will also help minimize the risks inherent to managing in a changing climate.

Long-term research on climate trends and ecosystem responses: To provide needed information on climate impacts on ecosystems and species, research and monitoring efforts will need to be conducted over longer time periods than are currently common. Long-term funding and institutional support will be needed to encourage long-term research. Existing long-term ecological research such as OSU's Andrews Long-term Ecological Research site, Forest Service Experimental Forests, and the Oregon Department of Fish and Wildlife's Lifecycle Monitoring Sites can be a cornerstone of such efforts.

Regional downscaling of climate models:

Global or even continental-scale models are too coarse to effectively guide more localized adaptation strategies. Agencies and policymakers need as much information as possible on anticipated climate changes at the regional and finer scales. At the regional scale, however, climate is significantly affected by processes other than global greenhouse gas emissions, and much more research is needed into regionally-relevant climate processes and feedbacks at a range of scales. The creation of a set of regional-scale climate scenarios for use in adaptation planning would be particularly helpful for use in decision-making at the state level.

Finally, for research and monitoring to effectively guide fish and wildlife adaptation efforts, an explicit connection must be drawn between climate research and decision-making, including not only policymakers but also agencies, managers, and landowners. Ultimately, a new institution may be required to fill this role, and several researchers

have suggested the development of a National Climate Service.¹⁰ Similarly, the Western Governor's Association has suggested the development of a regional clearinghouse for wildlife adaptation information.¹¹ Oregon should support the development of such new institutions to the extent that they will meet key research and information needs related to climate change adaptation. In some cases, however, expanding the mandate of existing institutions and providing them with needed resources may be more efficient than creating new ones.

CONCLUSION

Three salient themes seem to recur within most discussions of fish and wildlife adaptation to climate change. First, although human-induced climate change is a new phenomenon, and the scale of current and expected change is unique over at least several hundreds of thousands of years, many of the specific problems and solutions involved are familiar. While presenting new and unexpected challenges, climate change is also exacerbating old ones. In terms of fish and wildlife adaptation, these include land-use change, landscape fragmentation, pollution, invasive species, changes to disturbance regimes, and many others. Fortunately, this means that many of the old tools for conserving wildlife and habitat remain relevant and continue to gain importance. Unfortunately, it also means that we must now deal with these ongoing problems within the context of climate uncertainty and a host of new threats that are uniquely caused by the changing climate. In this context, it is important to acknowledge both the usefulness of old ideas and tools and the need for new ones.

The need to develop methods for coping with uncertainty is another major theme throughout discussions of climate change adaptation. Adap-

tive management represents one such method, but other approaches are needed. One other approach is to focus on provision of ecosystem services or protection of key ecosystem processes as a framework for conservation. Another is to reduce uncertainty as much as possible through improved modeling and ongoing scientific research. However, researchers agree that some degree of uncertainty will always be inherent in our understanding of natural and biological systems. This uncertainty is a basic trait of thinking about and planning for the future and should not be confused with a simple lack of information. Ultimately, coping with uncertainty may require fundamental changes to our ways of thinking, planning, and managing our environment.

Finally, nearly every element of fish and wildlife adaptation to climate change highlights the need to prioritize conservation actions. There is an immediate need to increase the resources available to manage climate impacts on fish and wildlife and their habitats. However, the challenges involved are so vast that virtually no level of time or funding will allow for all of them to be meaningfully addressed. Thus, an explicit statement of conservation priorities is needed to ensure that adaptation efforts are as strategic, coordinated, and effective as possible. This prioritization should not be confused with a triage situation, in which emergency decisions are made that often create new long-term problems even as they solve short-term ones. Instead, managers, policy-makers, and the general public will need to agree on a set of long-term goals that help target conservation actions and guide decisions relevant to fish and wildlife management. This document aims to provide a first attempt at outlining what those goals might look like, but several iterations of this process will likely be needed before consensus can be built on the details of prioritization and implementation.

APPENDIX A

Members of the Oregon Global Warming Commission's Fish, Wildlife, and Habitat Adaptation Subcommittee

Allison Aldous
Director of Research and Monitoring, The Nature
Conservancy in Oregon

Bob Altman
Northern Pacific Rainforest Bird Conservation Region
Coordinator, Partners in Flight
American Bird Conservancy

Paula Burgess
Director of North America Programs, Wild Salmon Center

Alan Christensen
Project Manager, Western Rivers Conservancy

Char Corkran
Northwest Ecological Research Institute

Cindy Deacon-Williams
Director of Aquatic Science and Education
Programs, National Center for Conservation
Science and Policy

Dan Edge
Professor of Wildlife Ecology, Oregon State University
Department of Fisheries and Wildlife

Roy Elicker (Co-Chair)
Director, Oregon Department of Fish and Wildlife

Stan Gregory
Professor of Fisheries, Oregon State University Department
of Fisheries and Wildlife

Lori Hennings
Senior Natural Resource Scientist, Metro

David Hulse
Professor of Landscape Architecture, University of Oregon

Eric Lemelson
Managing Owner, Lemelson Vineyards

Roy Lowe
Manager, Oregon Coast National Wildlife Refuge Complex,
US Fish and Wildlife Service

Peter Paquet
Fish and Wildlife Division Manager, Northwest Power
Planning Council

Mark Petrie
Waterfowl Science Team Leader, Ducks Unlimited

Tom Spies
Research Ecologist, USDA Forest Service, Pacific Northwest
Research Station

Tony Svejcar
Rangeland Scientist/Research Leader, USDA Agricultural
Research Service

Sara Vickerman (Co-Chair)
Senior Director, Biodiversity Partnerships, Defenders of
Wildlife

Steve Zack
Conservation Scientist/Coordinator, Pacific West Program
Wildlife Conservation Society

Other Contributors

Bob Davison
Senior Scientist, Endangered Species and Wildlife
Conservation, Defenders of Wildlife

Joshua Lawler
Assistant Professor, College of Forest Resources, University
of Washington

Holly Michael
Conservation Strategy and Special Projects
Coordinator, Oregon Department of Fish and Wildlife

Michael Pope
Oregon Conservation Strategy Implementation Coordinator,
Oregon Department of Fish and Wildlife

Sara O'Brien
Private Lands Conservation Associate, Defenders of
Wildlife

NOTES

¹ Previous documents discuss the changes anticipated in the Pacific Northwest, potential effects on fish and wildlife, and general concepts to guide management, so we will provide only a brief overview of these topics in the first section of this strategy document. Among others: Climate Leadership Initiative, Institute for a Sustainable Environment. 2008. *Preparing the Pacific Northwest for Climate Change: A Framework for Integrative Preparation Planning for Natural, Human, Built, and Economic Systems*. University of Oregon; Lawler, J.J., M. Mathias, A.E. Yahnke, and E.H. Girvetz. 2008. *Oregon's Biodiversity in a Changing Climate*. Report prepared for the Climate Leadership Initiative, University of Oregon. Information and recommendations contained here are based on a formal literature review, speakers at a workshop of the Oregon Global Warming Commission's Natural Resources Committee conducted on August 5, 2008, and input from members of the Oregon Global Warming Commission's Fish and Wildlife Adaptation Subcommittee.

² This regional projection by Mote et al. (2005) is based on the projections of the Intergovernmental Panel on climate change, which focuses on changes at the global scale.

³ Mote, P.W., E. Salathé, and C. Peacock. 2005. *Scenarios of future climate for the Pacific Northwest*. Report prepared for King County, WA by the Climate Impacts Group, University of Washington, Seattle, WA..

⁴ Lawler, J.J., M. Mathias, A.E. Yahnke, and E.H. Girvetz. 2008. *Oregon's Biodiversity in a Changing Climate*. Report prepared for the Climate Leadership Initiative, University of Oregon.

⁵ Brennan, E.J. 2008. *Reducing the Impact of Global Warming on Wildlife: The Science, Management, and Policy Challenges Ahead*. Defenders of Wildlife. Washington, D.C.; Climate Leadership Initiative, Institute for a Sustainable Environment 2008. *Preparing the Pacific Northwest for Climate Change: A Framework for Integrative Preparation and Planning for Natural, Human, Built, and Economic Systems*. University of Oregon; Independent Scientific Advisory Board. 2007. *Climate Change Impacts on Columbia River Basin Fish and Wildlife*. Independent Scientific Advisory Board for the Northwest Power and Conservation Council, Columbia River Basin Indian Tribes, and National Marine Fisheries Service; Lawler, J.J., M. Mathias, A.E. Yahnke, and E.H. Girvetz. 2008. *Oregon's Biodiversity in a Changing Climate*. Report prepared for the Climate Leadership Initiative, University of Oregon; Pyke, CR, R Thomas, RD Porter, JL Hellmann, JS Dukes, DM Lodge, and G Chavarria. 2008. *Current practices and future opportunities for policy on climate change and invasive species*. *Conservation Biology* 22(3): 585-592; Saunders, S, C Montgomery, T Easley, T Spencer. 2008. *Hotter and Drier: The West's Changed Climate*. Rocky Mountain Climate Organization and Natural Resources Defense Council; Sheikh, PA, ML Corn, JA Leggett, and P Folger. 2007. *Global Climate Change and Wildlife*. Congressional Research Service Report #RS22597; US Climate Change Science Program and the Subcommittee on Global Change Research. 2008. *Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources*. Final Report, Synthesis, and Assessment Product 4.4.

⁶ Brooks, ML, CM D'Antonio, DM Richardson, JB Grace, JE Keeley, JM DiTomaso, RJ Hobbs, M Pellant, and D Pyke. 2004. Effects of invasive alien plants on fire regimes. *Bio-science* 54 (7):677-688; Fried, JS, MS Torn, and E Mills. 2004. The impact of climate change on wildfire severity: A regional forecast for northern California. *Climatic Change* 64 (1-2):169-191; Westerling, AL, HG Hidalgo, DR Cayan, and TW Swetnam. 2006. Warming and earlier spring increase western US forest wildfire activity. *Science* 313 (5789):940-943.

⁷ Western Governors' Association. 2008. Wildlife Corridors Initiative (Climate Change Committee). Available at: <http://www.westgov.org/wga/publicat/wildlife08.pdf>.

⁸ Western Governors' Association. 2008. Wildlife Corridors Initiative (Climate Change Committee). Available at: <http://www.westgov.org/wga/publicat/wildlife08.pdf>.

⁹ Lawler, JJ, M. Mathias, A.E. Yahnke, and E.H. Girvetz. 2008. Oregon's Biodiversity in a Changing Climate. Report prepared for the Climate Leadership Initiative, University of Oregon.

¹⁰ E. L. Miles, A. K. Snover, L. C. Whitely Binder, E. S. Sarachik, P. W. Mote, and N. Mantua. 2006. An approach to designing a national climate service. *Proceedings of the National Academy of Sciences* 103 (52): 19616-19623.

¹¹ Western Governors' Association. 2008. Wildlife Corridors Initiative (Climate Change Committee). Available at: <http://www.westgov.org/wga/publicat/wildlife08.pdf>.