Safeguarding Washington's Fish and Wildlife in an Era of Climate Change:

A Case Study of Partnerships in Action

2013

NATIONAL WILDLIFE FEDERATION

Washington Department of FISH and WILDLIFE

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Contents

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I. Introduction 1

II. Climate Change Impacts in Washington 3

III. Developing and Applying Climate Science 6

- Assessing the Vulnerability of Washington's Species and Habitats 6
- Identifying Climate-Smart Wildlife Corridors 21

IV. Developing State-and Region-wide Adaptation Strategies for Species and Ecosystems 25

V. Integrating Climate Change into Existing Conservation Work 27

VI. Lessons Learned and Next Steps 31

- Some Lessons Learned 31
- Next Steps 34

VII. Concluding Thoughts 35

VIII. Literature Cited 36

I. Introduction

Fish and wildlife are at the heart of Washington State's rich ecological, economic, and cultural heritage. The incredible diversity of species and the habitats that sustain them helps to define Washington's distinct character and in part reflects the long standing conservation ethic of its citizens – one that has endured the challenges posed by a growing human population, increasing demands for land, water, and other natural resources, and now the very real threat of climate change.

A growing body of scientific evidence indicates that climate change is already having a significant impact on natural systems across the region, and further changes are likely in the coming decades (CIG 2009; Mote and Salathé 2010). Notably, climate change is likely to exacerbate many of the other natural and anthropogenic stressors we face in Washington, from invasive species and pollution, to floods, droughts, wildfires, and coastal erosion. It also will bring new sets of impacts and stressors, posing additional threats to ecological systems.

Recognizing these challenges, both the National Wildlife Federation (NWF) and the Washington Department of Fish and Wildlife (WDFW) have been leading a multi-faceted effort to address climate change in its mission to safeguard the state's wildlife and natural habitats for current and future generations. WDFW has established goals for agency actions in both climate change mitigation (i.e., measures

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Jim Cummins

Washington Department of Fish & Wildlife

to reduce greenhouse gas emissions) and adaptation (i.e., measures to prepare for and cope with current and future climate change and its associated impacts). NWF and WDFW are also committed to fostering a greater understanding of climate change and its relevance to the state's ecological systems through educational efforts both within the agency and in the community at large.

In 2009, NWF and WDFW held a workshop for state fish and wildlife managers to help them begin to consider principles and approaches for addressing climate change in relevant conservation strategies, the results of which were summarized in the report *Setting the Stage: Ideas for Safeguarding Washington's Fish and Wildlife in an Era of Climate Change* (Glick and Moore 2009). From 2010 -12, NWF and WDFW worked as part of a steering committee to develop a statewide, multi-sector, climate change adaptation strategy, which ultimately included a chapter on conservation of Washington's wildlife species, habitats, and ecosystems. The agency is also engaging in an ongoing process to identify ways to integrate climate change into on-the-ground conservation activities and strategies, including *Washington's State Wildlife Action Plan,* which provides an important blueprint for achieving the goal of safeguarding the state's wildlife and natural habitats in the face of multiple pressures (WDFW 2005).

This report is intended to serve as a case study for ways in which state agencies and NGOs can work together to forward meaningful climate change adaptation strategies, and it highlights several of WDFW and NWF's collective efforts to date, including the successes, lessons learned, and opportunities for moving forward.

II. Climate Change Impacts in Washington

Climate change has become a defining issue for conservation throughout the United States, and relevant state agencies across the country – including in Washington – have been developing and implementing strategies to address associated risks they face in efforts to protect valued fish and wildlife resources. As a state blessed with and dependent upon an incredible diversity of ecological systems, from old growth forests and vast arid lands to high alpine habitats and a broad expanse of coastal and freshwater ecosystems, Washington will be affected by climate change in a multitude of ways. Average temperatures in the Pacific Northwest have risen about 0.7º C (1.3º F) over the past century (1895-2011), and models project an additional 3.3 to 9.7º F increase over the region by 2070-2099 (with the lower number depending on whether greenhouse gas emissions eventually decline) (Kunkel, et al. 2013; Mote and Salathé 2010). Precipitation patterns across the Pacific Northwest are also projected to change. While models are less certain than for temperature, results suggest an increase in average winter and fall precipitation, a decrease in summer precipitation, and an increase in extreme precipitation (heavy downpours) by the end of this century (Kunkel et al. 2013; Mote and Salathé 2010; Salathé et al. 2010). Average snowpack in Washington is also projected to decline, and peak snowmelt is expected to occur earlier in spring,

Washington Department of Fish & Wildlife

which will alter hydrology in basins where snowmelt is an important contributor to streamflow (Kunkel et al. 2013; Salathé et al. 2010). In addition, as a coastal state, Washington will be directly affected by accelerating sea-level rise (NRC 2012), changes in sea surface temperatures and coastal upwelling patterns (Deser et al. 2010; Field et al. 2006; Johnstone and Dawson 2010), and ocean acidification (Feely et al. 2008).

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The risks from climate change and associated impacts will vary across different species and ecological systems. Some species and their habitats may, in fact, benefit from changes in climate, while others will be adversely affected. Furthermore, the significance of the impacts will depend on the extent and rates of relevant climatic drivers, which themselves will depend on the rate of mitigation that society is able to achieve through global reductions in greenhouse gas emissions (Warren et al. 2013).

Among the many consequences for Washington's natural systems, several issues highlighted in recent scientific studies stand out as key vulnerabilities:

- Climate change is expected to affect forests across the state, both directly and indirectly. A major concern for forest systems is the potential for synergisms between multiple disturbances, including pest and disease outbreaks and susceptibility to wildfires, the extent and severity of which are expected to increase with climate change (Bentz et al. 2010; Hicke et al. 2006). The distribution and composition of the state's forests are also likely to change, although the shifts are expected to occur over longer time scales than those associated with wildfires and other disturbances (Littell et al. 2010).

- Many of the state's coastal wetlands, tidal flats, and beaches are likely to decline in quality and extent due to an accelerating rate of sea-level rise, particularly where upland migration of habitats is hindered by bluffs or anthropogenic structures such as dikes, or where natural sources of sediments are limited (Glick et al. 2007). Loss of key habitats could have a significant impact on associated species such as shorebirds and forage fish, as well as place coastal infrastructure and communities at greater risk from coastal storms (Kreuger et al. 2010; Redstone Strategy Group LLC 2008).

- A combination of factors renders the Pacific Coast especially vulnerable to ocean acidification, as naturally more-corrosive deep ocean waters brought to the surface through upwelling combine with waters whose pH has been reduced by anthropogenic carbon dioxide (CO_2) (Feely et al. 2008). Higher acidity erodes the basic building blocks for the shells and skeletons of marine invertebrates, which are a foundation of the marine food web (Barton et al. 2012; Orr et al. 2005). Evidence suggests that acidifying ocean conditions may already be affecting some species (Feely et al. 2012; Hauri et al. 2009; Wootton et al. 2008).

- Climate change is already having a significant impact on the state's freshwater aquatic systems, including higher average water temperatures and altered hydrology, and projections for the future suggest more dramatic changes to come (Elsner et al. 2010). Among the numerous species of fish and wildlife that depend on these systems, the region's salmonids stand out as especially vulnerable given that they are expected to face climate change impacts throughout their complex life cycle (Glick and Martin 2008; Mantua et al. 2010).

- Changes in precipitation patterns and wildfire regimes associated with climate change are projected to exacerbate existing threats to the state's sagebrush steppe and other grassland and shrubland systems, altering native species composition and contributing to an expansion of invasive species (Bates et al. 2006; Chambers and Pellant 2008).

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These and other changes have galvanized concern among government agencies, non-governmental organizations, the business community, and the public and have been an impetus for numerous adaptation efforts to ensure that our significant conservation investments will endure for future generations. Within WDFW, a concerted effort is underway to advance this agenda by:

1. Developing and applying climate science and climate change models to regional issues and needs.

2. Providing leadership for state and regional efforts to develop adaptation goals and strategies for wildlife species and ecosystems.

3. Working to integrate climate considerations into existing conservation programs and initiatives of the agency (**http://wdfw.wa.gov/conservation/climate_change/climate_change_at_wdfw.html**).

III. Developing and Applying Climate Science

Developing meaningful adaptation strategies for fish and wildlife conservation requires an understanding of regional and localized impacts of climate change, as well as how these impacts may affect species and ecosystems. As the science of climate change has progressed over the past few decades, our knowledge of climate change and its impacts – both those that have occurred and those that are projected for the future – has increased significantly. Considerable improvements in "downscaled" climate models and research on impacts to natural systems and species already offer a tremendous amount of useful information, and investments in additional research will ensure that our body of knowledge will continue to grow. This section highlights two projects in which WDFW and its partners have been engaged to advance relevant science to help the agency develop effective solutions: 1) an assessment of the vulnerability of Washington's species and habitats to climate change, and 2) a project to identify "climate-smart" conservation corridors.

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Assessing the Vulnerability of Washington's Species and Habitats

WDFW has been working with the University of Washington, the U.S. Geological Survey (USGS), NWF, and other key collaborators in the region to conduct a climate-ecological vulnerability assessment for the Pacific Northwest (Thompson et al. 2013). The assessment covers an area that extends beyond the borders of Washington, Oregon, and Idaho and involves scientists, natural resource managers, and conservation planners. The project includes several components, including a digital database of climate-change sensitivities for species and habitats of concern throughout the Pacific Northwest (now completed for 205 species and 49 ecological systems), Habitat Suitability Models (which will include historical and future climate suitability maps for 350 terrestrial animals, 11 tree species and 100 ecosystem types), and Species Population Models (spatially explicit modeling of 12 focal species).

One element of the assessment process includes projecting exposure to changes in temperature, precipitation, and other bioclimatic variables across the region and simulate potential impacts on plants, animals, and ecological systems. For example, researchers are applying downscaled climate change data for a range of variables, such as average and extreme precipitation, growing degree days, and snow water equivalent, to model potential changes in vegetation and animal species distributions under future climate scenarios in 2050 and 2080. As part of this study, WDFW staff identified 15 focal species for a more detailed assessment that includes continuous time series of simulated distributions and abundances from the present-2099: Canada lynx *(Lynx canadensis),* fisher *(Martes pennanti),* Ord's kangaroo rat *(Dipodomys ordii),* pygmy rabbit *(Brachylagus idahoensis),* mountain goat *(Oreamnos americanus),* Townsend's ground squirrel *(Urocitellus townsendii),* wolverine *(Gulo gulo),* black-rosy finch *(Leucosticte atrata),* Clark's nutcracker *(Nucifraga columbiana)*, greater sage-grouse *(Centrocercus urophasianus),* northern goshawk *(Accipiter gentilis),* white-headed woodpecker *(Picoides albolarvatus),* Columbia spotted frog *(Rana luteiventris),* western (boreal) toad *(Anaxyrus boreas),* and western rattlesnake *(Crotalus oreganus)* (Thompson et al. 2013).

This report highlights just one element of this vulnerability assessment, the Climate Change Habitat Sensitivity Database, which was funded and supported by NWF as a way to leverage the existing work of the research project and also provide additional resources for integrating climate change into the revision of Washington's State Wildlife Action Plan. Further discussion of the methods and results of other components of the Pacific Northwest Climate Change Vulnerability Assessment to date is available at **http://climatevulnerability.org.**

Climate Change Sensitivity Database

Initial work on this assessment entailed the development of an on-line Climate Change Sensitivity Database that includes detailed information on climate-change sensitivities for a number of species and ecological systems across the region. The database, which is available at **http://climatechangesensitivity.**org, is currently maintained by both the University of Washington and The Nature Conservancy. It allows users to access and query relevant sensitivity information, references, and rankings for species or systems of interest. It also allows for authorized users (i.e., those who create an account in the system) to enter new systems into the database and

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comment on existing systems, which will facilitate access to new science and other information on an ongoing basis.

it is important to note that while we focus on sensitivity in this report, it is just one component of assessing vulnerability to climate change. As highlighted in Box 1, page 9, two other components are the degree of exposure to climate change, and a measure of the adaptive capacity. Understanding how these components are related can help to inform management decisions. For example, some actions can be undertaken to reduce the sensitivity of species or systems of interest; some can help reduce exposure to climate change and associated impacts; and some can enhance adaptive capacity. The full vulnerability assessment being undertaken in the region is addressing each of these components, which will ultimately help inform strategies to reduce relevant vulnerabilities.

Below, we provide an overview of the process undertaken to develop the sensitivity database for key ecosystems in Washington to demonstrate how the online assessment tool can be enhanced and used by others for both species and ecological systems.

Assessing the Sensitivity of Ecological Systems to Climate Change in the Pacific Northwest: A Demonstration of the Online Assessment Tool

In support of the region-wide climate change vulnerability assessment, NWF and WDFW worked with the University of Washington to develop and incorporate information on climate change sensitivity of key ecological systems into the climate change sensitivity database, as identified by relevant experts in the region. Focal areas included 72 relevant ecological systems (based on classifications defined under the Washington Natural Heritage Program, **http://www1.dnr.wa.gov/nhp/refdesk/communities/ecol_systems.html), i**ncluding: 28 forested systems, 23 freshwater systems, 15 aridland systems, and 6 marine systems.

For each of the major target systems, project partners conducted one-day expert workshops (from 2011 to 2012) to work through the sensitivity assessment process. Participants were provided with four background science summaries on climate change impacts for each of these systems, developed by NWF and WDFW in advance of the state climate change adaptation planning process (described in the next section) (Morgan and Siemann 2011a,b,c,d), as well as an overview of key sensitivity categories to be addressed during the workshop (highlighted below). They were then divided into groups of 5 to 8 individuals based on their expertise relative to the specific systems being addressed to complete the relevant questions for the target systems. In cases where not all systems could be addressed during the day-long session, assessment team leads followed up with individual experts that were familiar with a given system and asked them to input the sensitivity information directly into the online database.

Box 1. The Components of Vulnerability

Vulnerability to climate change is a function of three components: the *sensitivity* of a particular system to climate changes, its exposure to those changes, and its *capacity to adapt* to those changes (IPCC 2007). Sensitivity refers to the degree to which one's conservation target is likely to be affected by or responsive to climate change. For example, species-level sensitivities may be characterized by physiological factors such maximum temperature tolerances among fish and moisture requirements for amphibians, or ecological linkages such as dependence on certain disturbance regimes like wildfire for seed germination – each of which may be affected by climate change. Similarly, some ecological systems may be directly sensitive to changes in temperature or precipitation, which may alter the composition of associated species, or indirectly sensitive, such as streamflows tied to snowpack and snowmelt timing.

However, even if your conservation target is inherently sensitive to climate change and associated impacts, its vulnerability also depends on the character, magnitude, and rate of changes to which it is or could be exposed (i.e., its exposure). This is where managers must consider recent trends and projections for relevant climate change variables in your study region. In many cases, understanding the inherent sensitivities of your target species or systems from the start can help you refine the types of climate change exposure variables to look at – for instance, if you know that your target species is sensitive to temperature but not precipitation, you may not need to consider precipitation data in your analysis. Or, you may have a system for which looking just at how average annual temperature or total precipitation will change will be less useful when sensitivities have to do with snowpack, fall drought, or summer streamflow. The climate change sensitivity database described here is intended to inform just such decisions.

A third important component of vulnerability is *adaptive capacity,* which refers to the ability of a species or system to accommodate or cope with climate change impacts with minimal disruption. For natural systems, adaptive capacity is often considered to be an intrinsic trait that may include potential for genetic/evolutionary changes and "plastic" ecological, behavioral, or physiological responses, such as the ability of a species to move in search of more favorable habitat conditions or modify its behavior as climate changes. These intrinsic factors could, in principle, be assessed as elements of sensitivity – as some are in this database. However, it is important to recognize that adaptive capacity also may be a factor of external conditions, such as the existence of structural barriers like roads and buildings, bulkheads, or dikes that may limit the ability of that species or system to move. These features may be missed if you are only considering adaptive capacity as a matter of intrinsic sensitivity, although in the sensitivity database described here, some of the factors are incorporated into the assessment as non-climate, or "other" stressors. For more information about climate change vulnerability assessment, see *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment* (Glick et al. 2011), which is available at: http://www.nwf.org/vulnerabilityguide.

Key Sensitivity Categories

Direct Sensitivities

Ecological systems can be directly sensitive to changes direct climatic variables (i.e., temperature and precipitation) (Lawler et al. 2011). For example, if the system only exists within a relatively narrow climatic zone, it will likely be more sensitive to changes in temperature and/or precipitation than those with a broader tolerance for those variables. Additionally, if a system exhibits large changes in

composition or structure in response to relatively small changes in temperature or precipitation, then it is considered more directly sensitive to climate change. Conversely, if large changes in temperature and precipitation result in a small amount of change in composition and structure, then the system is less directly sensitive. Experts were asked to rank how sensitive each system was to temperature and precipitation, separately, including consideration of both means and extremes of those two aspects of climate.

Indirect Sensitivities

Indirect sensitivities are defined in the database as sensitivities to drivers that are themselves affected by climate change. For example, changing climate will affect fire regimes, hydrology, and sea levels. Systems that are susceptible to changes in these drivers will be indirectly sensitive to climate change. More examples of indirect factors that may cause a system to be more sensitive include insects, disease, wind, water chemistry, coastal erosion, flooding, wave action, currents, and storms. Systems that exhibit large changes in composition or structure in response to small changes in these factors are likely to be more sensitive to climate change. Conversely, systems that change only slightly in response to large changes in these factors are less sensitive.

Other Stressors

System sensitivity can be greatly affected by the degree to which other, non-climate related stressors or threats, such as land-use change, make the system more sensitive to climate change. It is assumed that systems that are greatly affected by these other stressors will likely be more sensitive to climate change. In some cases, these may result in reduced adaptive capacity of a particular species or system, even though they are considered here as elements of sensitivity. Experts were asked to identify non-climate related threats such as land-use change, invasive/exotic species, pollution, and harvest that would likely predispose a system to be more sensitive to climate change.

Other Sensitivities

The three simple categories of sensitivities listed above – direct and indirect sensitivities, and non-climate other stressors – likely capture most of the ways in which systems can be sensitive to climate change. However, there may be other (climate change-related) sensitivities that would not be captured by this simple classification. For example, some marine systems are sensitive to changes in ocean chemistry, such as acidification of ocean waters, which is the result of absorption of excess atmospheric carbon dioxide from the atmosphere. Experts were therefore asked to identify any other crucial factors that were not already addressed in their assessment.

Overall User Ranking

After the experts identified and ranked the sensitivity factors above, they were asked for their overall opinion of how sensitive the system is to climate change. This user ranking was used as a quality control metric. For instance, if, based on the four sensitivity factors listed above, the system had a low sensitivity score but the experts gave the system a high overall user ranking, it is likely that either an important factor in the assessment was missed or that the

experts may have misinterpreted one of the questions. For each of the sensitivity factors, the experts provided a sensitivity score ranging from zero (insensitive) to seven (high sensitivity) along with a confidence score ranging from one (low confidence) to five (high confidence). If the experts identified one or more factors for other sensitivities, then they were also asked to specify what weight these factors should have on the overall sensitivity of the system from 0.2 to 5 relative to the other three factors. For example, a weight of 1.5 means that this other sensitivity factor is 1.5 times the weight of any previous factor (e.g., direct sensitivity). Experts were also asked to provide more detailed information including references when possible. This information was then entered into the online database and an overall climate change sensitivity score was calculated using a multiplicative index for each of the 72 systems, using the following equation:

Sensitivity = (Direct Sensitivities [(temperature + precipitation)/2] + Indirect Sensitivities + Other Stressors + (Other Sensitivities * weight)/21 +(7 * weight)) * 100

Results of Expert Discussion and Input

The following sections provide a brief summary of the results of the expert-based information identified for each of the systems assessed. For greater detail on the specific types of ecological systems assessed and the underlying information that led participants to determine the relative sensitivities, see the relevant workshop notes (available on the sensitivity database website noted above).

Forest Systems

Of the 28 forested systems assessed, two were identified by participants to be the most sensitive to climate change: "Aspen Forest and Woodland" and "Columbia Plateau Western Juniper Woodland and Savanna" (see Table 1, page 12). Both systems have similar rankings for indirect sensitivities and other stressors categories, but differ in their sensitivity to temperature and precipitation. In particular, Aspen Forest and Woodland was identified to be more sensitive to temperature and precipitation means and extremes than Columbia Plateau Western Juniper Woodland and Savanna. For example, the experts identified that Aspen Forest and Woodland is secondarily limited by low temperatures and growing season length. Therefore an expansion into higher elevation habitat is possible as temperatures increase (Rehfeldt et al. 2009). Columbia Plateau Western Juniper Woodland and Savanna was identified as being slightly less sensitive than Aspen Forest and Woodland because it can persist in considerably warmer climates than where it is currently found in Washington. In fact, Columbia Plateau Western Juniper Woodland and Savanna has expanded into many sites in Oregon where it was historically excluded by fire (NatureServe 2013).

"North Pacific and Rocky Mountain Hardwood-Conifer Swamp" was determined to be the least sensitive forest system to climate change. One reason for its relatively low sensitivity is because this system is not very sensitive to indirect factors, such as disturbances. Although an increase in frequency of intense wind storms could

Table 1. Sensitivity scores for forested systems. Overall User Ranking and Confidence Overall User Ranking are in percentages.

System	Temperature Sensitivity	Precipitation Sensitivity	Indirect Factors	Other Stressors	Sensitivity Score	Overall User Ranking	Confidence Overall User Ranking
Aspen Forest and Woodland	6	7	6	5	83	86	60
Columbia Plateau Western Juniper Woodland and Savanna	3	5	6	5	71	29	40
Rocky Mountain Subalpine Spruce-Fir	6	3	5	5	69	86	60
Managed North Pacific Hypermaritime Sitka Spruce Forest-Western Red-cedar-Western Hemlock Forest	5	4	6	4	69	57	80
North Pacific Oak Woodland	2	3	5	7	69	71	60
N. Rocky Mountain and East Cascade Ponderosa Pine & Oak-Ponderosa Pine	6	6	4	4	67	86	60
Rocky Mountain, Columbia, Great Basin Lower Montan & Foothill Riparian Woodland and Shrubland	5	3	6	4	67	57	60
N. Rocky Mountain Dry-Mesic Montane Mixed Conifer; degraded from altered fire regimes, logging, & grazing	6	5	5	3	64	71	80
North Pacific Broadleaf Landslide Forest and Shrubland	3	3	5	5	62	57	60
Managed North Pacific Maritime Dry & Mesic-Wet Douglas-fir-Western Hemlock Forest	3	3	4	6	62	71	80
North Pacific Lowland Riparian Forest and Shrubland	4	2	6	4	62	71	80
North Pacific Montane Riparian Woodland and Shrubland	3	3	7	3	62	71	60
North Pacific Dry Douglas-fir-Madrone Forest and Woodland	2	2	4	7	62	71	80
N. Rocky Mountain Mesic Montane Mixed Conifer Forest	6	5	5	2	60	71	60
East Cascades Mesic Montane Mixed-Conifer; degraded from altered fire regimes, logging, & grazing	5	4	6	2	60	86	80
North Pacific & Northern Rocky Mountain subalpine parkland	7	3	3	4	57	86	60
North Pacific Dry-Mesic and Mesic Western Hemlock-Silver Fir Forest	6	4	6	1	57	71	60
Northern Rocky Mountain Western Larch Savanna; degraded from altered fire regimes, logging, & grazing	5	4	5	2	55	57	80
Unmanaged North Pacific Hypermaritime Sitka Spruce Forest-Western Red-cedar-Western Hemlock Forest	4	4	5	2	52	57	60
Rocky Mountain Lodgepole Pine Forest	3	3	6	2	52	57	60
Rocky Mountain Subalpine-Montane Riparian Shrubland & Woodland	4	3	5	2	50	43	60
Unmanaged North Pacific Maritime Dry & Mesic-Wet Douglas-fir-Western Hemlock Forest	3	3	4	3	48	43	80
North Pacific Lowland Mixed Hardwood-Conifer Forest and Woodland	2	3	2	5	45	57	60
East Cascades Mesic Montane Mixed-Conifer; restored and fire re-introduced	3	3	4	2	43	43	60
N. Rocky Mountain Dry-Mesic Montane Mixed Conifer; restored and fire re-introduced	3	2	3	3	40	43	60
North Pacific Mountain Hemlock Forest	6	3	3	1	40	71	60
Northern Rocky Mountain Western Larch Savanna; restored and fire re-introduced	3	2	2	3	36	29	60
North Pacific & Rocky Mountain Hardwood-Conifer Swamp	2	4	1	3	33	43	60

increase windthrow of tall conifer trees in this system, most of the sites that it inhabits are protected from prevailing winds.

The majority of high sensitivity scores (i.e., factors that were ranked as 5, 6, and 7) for forest systems included indirect factors and sensitivity to temperature (Figure 1). This pattern suggests that these factors drive the overall sensitivity of forest systems and is important for future planning and priority setting. For example, indirect factors, such as disturbances, are the primary driver of sensitivity of forest systems (Figure 1) and are largely composed of fire, insects, and wind (Figure 2). If future projections of more frequent and intense wildfires and an increase in suitable climatic conditions for insects, such as the mountain pine beetle (Dendroctonus ponderosae) are accurate, these more sensitive forest systems may be impacted the most (Hicke et al. 2006; Rogers et al. 2011). Additionally, sensitivity to temperature is the second largest contributing factor to the overall sensitivity of forest systems and there is good agreement from general circulation models (GCMs) that temperature in the region will continue to increase in the future (Kunkel et al. 2013; Mote and Salathé 2010).

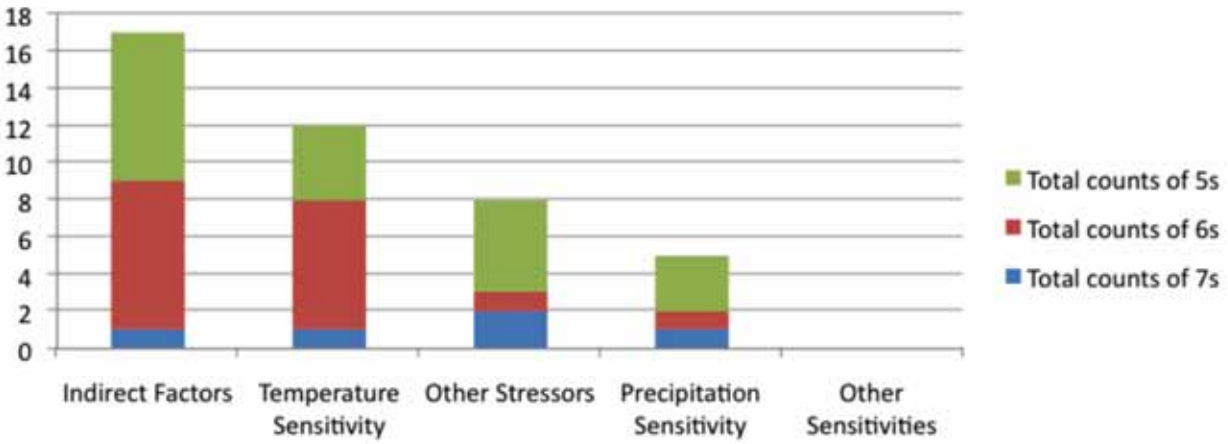

Figure 1. Total counts of "high" rankings (i.e., rankings of 5, 6, and 7) for 28 forest systems.

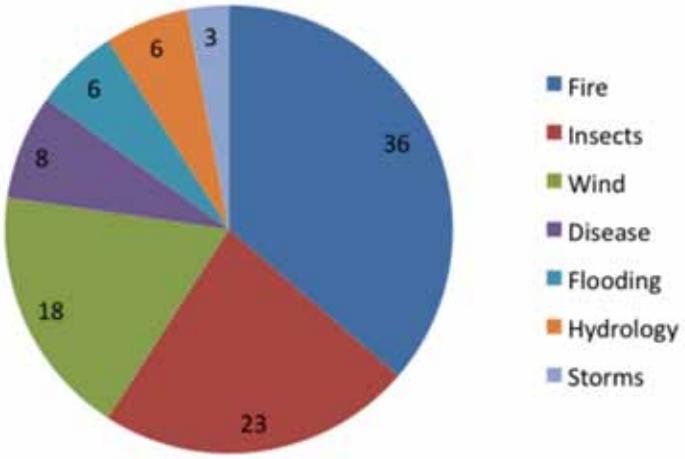

Figure 2. Percentage of indirect factors identified for the 28 forest systems.

Freshwater Systems

For freshwater systems, "Shallow, Oligotrophic Lakes" (lakes with low levels of nutrients and algal biomass) were identified as being the most sensitive to climate change (see Table 2). This system has high rankings for all categories but because of its shallow depth (< 10 meters), these lakes are particularly sensitive to increases in temperature, which could increase productivity and push the systems towards a mesotrophic state. Shallow, Oligotrophic Lakes are also highly sensitive to a reduction in precipitation and drought, which could reduce their volume beyond critical thresholds and either change them to wetlands or cause them to dry up completely.

Table 2. Sensitivity scores for freshwater systems. Overall User Ranking and Confidence Overall User Ranking are in percentages.

System	Temperature Sensitivity	Precipitation Sensitivity	Indirect Factors	Other Stressors	Sensitivity Score	Overall User Ranking	Confidence Overall User Ranking
Lakes - Oligotrophic, Shallow	7	7	6	7	95	100	40
Rivers - Transitional, Non-floodplain, Forested & Unforested	7	7	3	7	81	100	80
Wetlands - Depressional (surface runoff & groundwater), Seasonal, Forested & Unforested	6	6	4	6	76	86	80
Rivers - Transitional, Floodplain (braided & non-braided), Forested & Unforested	6	7	3	6	74	100	80
Rivers - Rainfall, Non-Floodplain, Forested & Unforested	6	5	3	7	74	86	100
Wetlands - Riverine, Seasonal, Forested & Non-forested	6	6	4	5	71	86	60
Rivers - Rainfall, Floodplain (braided & non-braided), Forested & Unforested	5	5	3	7	71	86	
Wetlands - Depressional (surface runoff & groundwater), Semi-permanent/Permanent, Forested & Unforested	5	5	4	5	67	71	80
Lakes - Mesotrophic, Shallow	5	5	3	5	62	86	40
Lakes - Mesotrophic, Medium depth	5	4	3	5	60	71	40
Wetlands - Riverine, Semi-permanent/Permanent, Forested & Non-forested	4	4	3	5	57	57	60
Wetlands - Slope/Groundwater, Seasonal, Forested & Non-forested	4	4	3	5	57	57	60
Rivers - Snowmelt, Non-Floodplain, Forested & Unforested	5	4	3	4	55	71	60
Rivers - Snowmelt, Floodplain (braided & non-braided), Forested & Unforested	4	4	3	4	52	71	60
Lakes - Eutrophic, Shallow	3	3	4	4	52	43	40
Wetlands - Slope/Groundwater, Semi-permanent/ Permanent, Forested & Non-forested	2	3	4	4	50	43	60
Lakes - Eutrophic, Medium depth	3	3	3	4	48	43	40
Rivers - Groundwater, Floodplain & Non-floodplain, Braided & Non-braided), Forested & Unforested	3	3	4	3	48	43	60
Lakes - Oligotrophic, Medium depth	5	5	3	2	48	86	40
Rivers - Glacial, Floodplain & Non-floodplain (braided & non-braided), Forested & Unforested	6	6	2	2	48	71	80
Lakes - Oligotrophic, Deep	4	3	2	3	40	71	40
Lakes - Mesotrophic, Deep	4	3	2	3	40	57	40
Lakes - Eutrophic, Deep	2	2	2	2	29	29	40

By contrast, "Deep, Eutrophic Lakes" (lakes with high levels of nutrients) were determined to be the least sensitive freshwater systems to climate change. One reason for their relatively low sensitivity is because this system has relatively high habitat diversity, which could help buffer against climate change because systems with greater diversity are generally more resilient to extreme events or disturbances.

Sensitivity to temperature and other stressors received the majority of the high sensitivity scores for freshwater systems (Figure 3). Relatively small changes in temperature and precipitation can lead to significant changes in associated species composition, which can reverberate throughout freshwater systems. For example, if summer flows are lower in magnitude and longer in duration due to reduced snowmelt, this would reduce the spatial, temporal, and thermal range of habitat that is available for aquatic species (e.g., salmonids may not be able to spawn anymore in drying reaches) (Mantua et al. 2009).

Land-use change, water use, pollution, and invasive species were identified to be the most important other stressors affecting the sensitivity of freshwater systems. Of these stressors, land-use change accounted for nearly half (i.e., 43%) of the total stressors identified (Figure 4, page 16). In fact, land-use change was identified as a contributing factor to climate change sensitivity for each freshwater system. For example, it was identified that increasing the amount of impervious surfaces within the watershed could result in more water being directed into "Shallow, Mesotrophic Lakes" (i.e., lakes that have characteristics that fall within eutrophic and oligotrophic lakes), and that this would drastically change the water depth, siltation, and the composition of biota.

Aridland Systems

"Inter-Mountain Basins Semi-Desert Shrub Steppe," which in Washington occurs as patches in the hottest, driest portions of the Columbia Basin (WDNR 2011a) and "Northern Rocky Mountain Foothill Conifer Wooded Steppe," which occurs at the ecotone

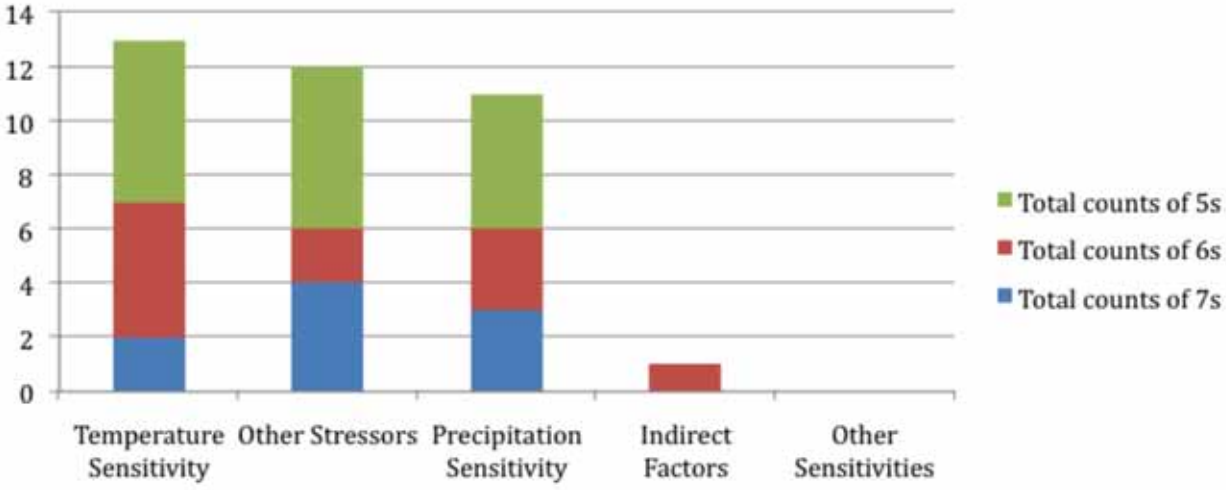

Figure 3. Total counts of "high" rankings (i.e., rankings of 5, 6, and 7) for 23 freshwater systems.

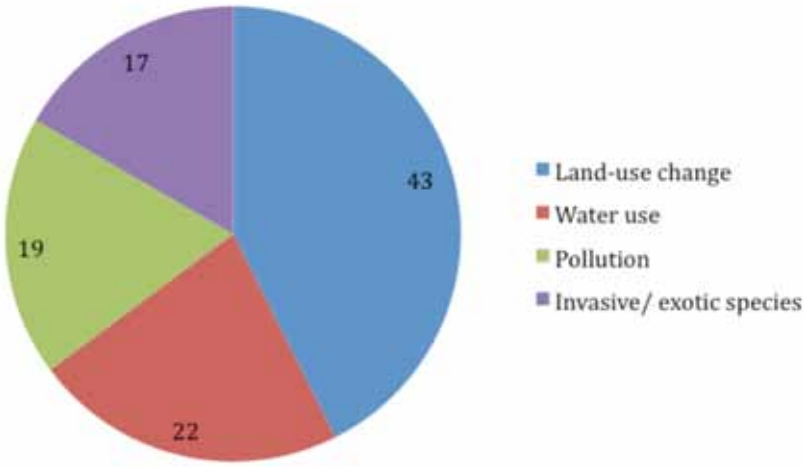

Figure 4. Percentage of Other Stressors identified for the 23 freshwater systems.

between the lower treeline and grasslands or shrublands on warm, dry, exposed sites (WDNR 2011b) were identified as the most sensitive aridland systems (see Table 3, page 17). These two systems have similar direct sensitivities to precipitation and other stressors, but differ in their direct sensitivity to temperature. For example, Inter-Mountain Basins Semi-Desert Shrub Steppe was identified as having a lower sensitivity to temperature compared to Northern Rocky Mountain Foothill Conifer Wooded Steppe because the dominant plant species within the former system [i.e., spiny hopsage *(Grayia spinosa)* or winterfat *(Krascheninnikovia lanata)* with chamisa *(Ericameria nauseosa)*] can tolerate some temperature change without much adverse affect. By contrast, the dominant species within the Northern Rocky Mountain Foothill Conifer Wooded Steppe system [i.e., ponderosa pine (*Pinus ponderosa* and Douglas fir (*Pseudotsuga menziesii*)] are more sensitive to temperature changes. Another difference between these two systems is the sensitivity to indirect factors (Ryan and Archer 2008). For instance, changes in the fire regime (intensity and frequency) will influence shrub cover within the Inter-Mountain Basins Semi-Desert Shrub Steppe severely, pushing this system more towards a grassland system or potentially an annual grassland system (comprised on non-native annual species such as cheatgrass). Changes in fire regime will also affect composition in the Northern Rocky Mountain Foothill Conifer Wooded Steppe system by favoring non-native species, but increases in insect outbreaks may be a larger driver of change. For example, increased activity of bark beetles could lead to increased tree stress and ultimately widespread mortality.

Interestingly, the "Columbia Plateau Low Sagebrush Steppe" system was identified as the least sensitive to climate change among the 15 aridland systems that were assessed. This system has relatively low sensitivity to all factors; however, grazing already has a significant impact on the system, predisposing it to be somewhat sensitive to climate change by enhancing invasion of invasive grasses prone to wildfire. It should also be noted that this system has the lowest average confidence score compared to the other 14 aridland systems.

Other stressors, indirect sensitivities, and direct sensitivity to precipitation changes account for the majority of high rankings for aridland systems (Figure 5, page 18). Many of these dry systems can only exist within a relatively narrow range of precipitation and small changes in rainfall or snow will lead to large changes in composition and structure. Additionally, land-use change, invasive species, and grazing were identified to be the most important other stressors affecting the sensitivity of aridland systems (Figure 6, page 18). Many of these non-climate stressors, such as livestock grazing, are already affecting species composition and predispose some of these systems to be more sensitive to climate change. Furthermore, fire was identified as the lead indirect factor causing aridland systems to be sensitive to climate change in 11 of the 15 systems assessed.

Table 3. Sensitivity scores for aridland systems. Overall User Ranking and Confidence Overall User Ranking are in percentages.

System	Temperature Sensitivity	Precipitation Sensitivity	Indirect Factors	Other Stressors	Other Sensitivities	Weight	Sensitivity Score	Overall User Ranking	Confidence Overall User Ranking
Inter-Mountain Basins Semi-Desert Shrub Steppe	3	6	7	6			83	86	80
Northern Rocky Mountain Foothill Conifer Wooded Steppe	6	7	5	5			79	86	80
Inter-Mountain Basins Semi-Desert Grassland	3	6	5	6			74	86	80
Inter-Moutain Basins Big Sagebrush Shrubland	3	5	5	5			67	57	60
Inter-Mountain Basins Big Sagebrush Steppe	3	3	5	5			62	71	80
Columbia Plateau Steppe and Grassland	3	3	5	5			62	71	80
Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	3	3	6	4			62	57	60
Columbia Basin Foothill & Canyon Dry Grassland	3	4	3	5			55	43	60
Active and stabilized dunes	2	4	4	4			52	57	60
Columbia Basin Palouse Prairie	3	5	2	5	3	1	50	57	80
Inter-Mountain Basins Montane Sagebrush Steppe	5	4	3	3			50	57	40
Northern Rocky Mountain Lower Montane, Foothill, and Valley Grassland	3	5	2	2	3	1	39	43	80
Inter-Mountain Basins Cliff and Canyon	2	3	3	2			36	29	80
Columbia Plataeu Scabland Shrubland	2	3	2	2			31	43	80
Columbia Plateau Low Sagebrush Steppe	2	2	2	2			29	29	40

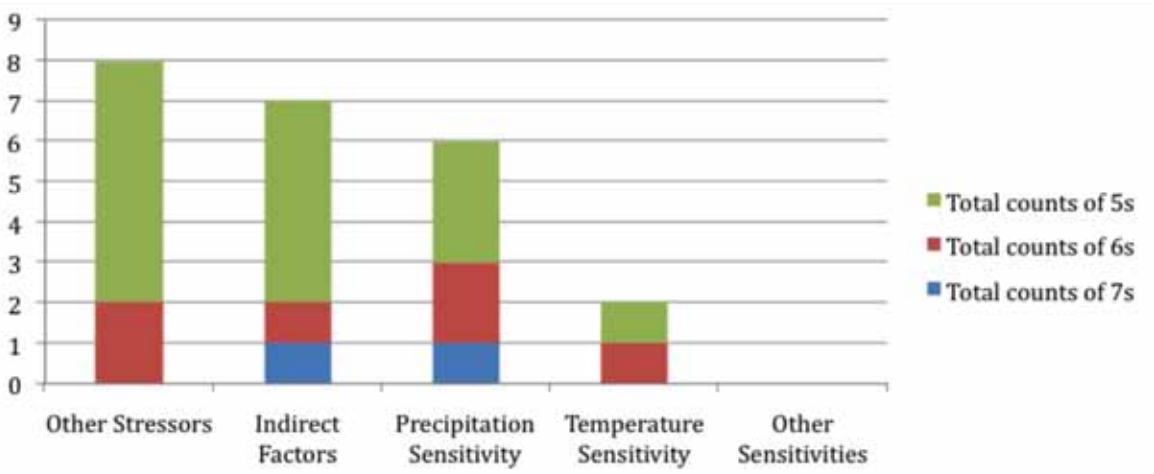

Figure 5. Total counts of "high" rankings (i.e., rankings of 5, 6, and 7) for 15 aridland systems.

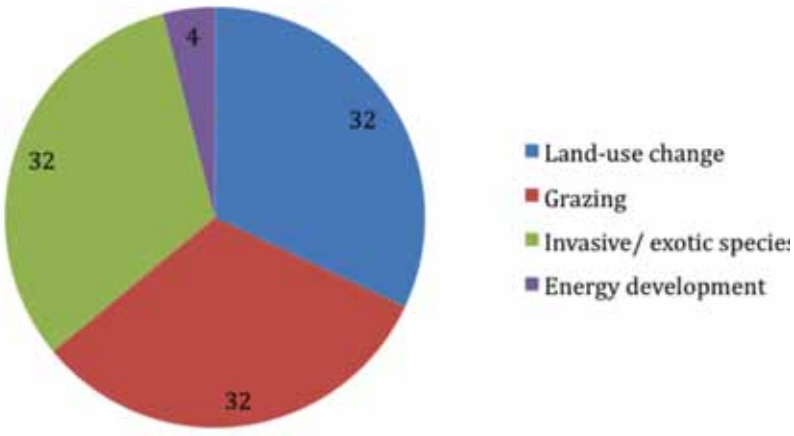

Figure 6. Percentage of Other Stressors identified for the 15 aridland systems.

Marine Systems

Experts identified six different marine systems of which to assess sensitivity. Of those, "Beaches and Bluffs" were the most sensitive to climate change (see Table 4, page 19). The relatively high sensitivity score for Beaches and Bluffs was primarily due to indirect sensitivities, other stressors, and other sensitivities. Leading indirect factors included sea-level rise, wave action, storms, and coastal erosion. Three main non-climatic stressors that greatly affect Beach and Bluffs include: land-use change (such as development, armoring, and shoreline modification), harvesting of sand, and pollution. Additionally, the marine experts noted that Beaches and Bluffs will experience more impacts as the regional human population grows and that these systems need human assistance to migrate in response to the indirect factors highlighted above. Marine experts therefore determined that human perception and

attitude towards these systems will ultimately influence how sensitive they are to climate change. Although important for sediment production for beaches and erosion for bluffs, direct sensitivity to precipitation had less of an influence on the overall sensitivity ranking for this system. Additionally, it was identified that beaches are more sensitive to temperature because it affects vegetation, organic matter decay, and nutrient cycling. However, temperature also had less of an influence on the overall sensitivity ranking.

"Rocky Shores" were determined to be the least sensitive marine system assessed. Although sensitivity to precipitation was identified to be relatively low, sensitivity to temperature was noted to be high – marine experts identified temperature as a significant driver of rocky near shore systems. Related to temperature, the location and timing of tides are also important factors to consider for this system and it was determined that there is greater temperature sensitivity in Puget Sound where the low tides are closer to

Table 4. Sensitivity scores for marine systems. Overall User Ranking and Confidence Overall User Ranking are in percentages.

System	Temperature Sensitivity	Precipitation Sensitivity	Indirect Factors	Other Stressors	Other Sensitivities	Weight	Sensitivity Score	Overall User Ranking	Confidence Overall User Ranking
Beaches and bluffs	4	4	6	7	6	1.5	83	100	100
Deltas and Estuaries	4	6	4	7	7	1	82	71	80
Lagoons and bays	5	3	6	6	5	1	75	71	80
Subtidal shallow	3	1	4	7	7	1	71	71	80
Pelagic	3	4	4	7			69	86	80
Rocky shores	6	2	5	3			57	71	80

Washington Department of Fish & Wildlife

noon compared to the outer coast where the low tides are at cooler times during the day. For example, the rocky intertidal system can be very warm at noon in Tacoma, Washington, but is typically underwater on the outer coast.

Other stressors, other sensitivities, and indirect sensitivities account for the majority of high rankings for marine systems (Figure 7). For these systems, temperature and precipitation are not expected to play nearly as large a role in determining how sensitive a system is to climate change, illustrating that marine systems are not as directly sensitive to climate change. Instead, it was determined that there are many indirect and non-climatic stressors that predispose marine systems to be more sensitive. Some of the key indirect factors that were identified for marine systems include: water chemistry, sea-level rise, coastal erosion, flooding, wave action, currents, storms, and diseases.

As mentioned above, the Climate Change Sensitivity Database is just one element of the broader Pacific Northwest Climate Change Vulnerability Assessment and similar assessments across the region, which will provide conservation and natural resource managers with key information to assist in adaptation planning.

Using Results to Inform Management

By identifying the specific factors that contribute to the sensitivity of habitats to climate change, this database can help managers narrow down which elements of exposure will be most relevant to focus on as they work to determine the overall vulnerability of target species or ecological systems. In addition, understanding some of the specific reasons why a particular species or system is vulnerable – including those factors associated with sensitivity – will be especially important in informing management decisions. For example, knowing that certain forest types are more sensitive to increased disturbances such as wildfires, managers may consider focusing on strategies such as selective thinning in those areas to reduce fire severity (Stephens et al. 2009). Similarly, knowing that the region's coastal bluffs are especially sensitive to factors such as

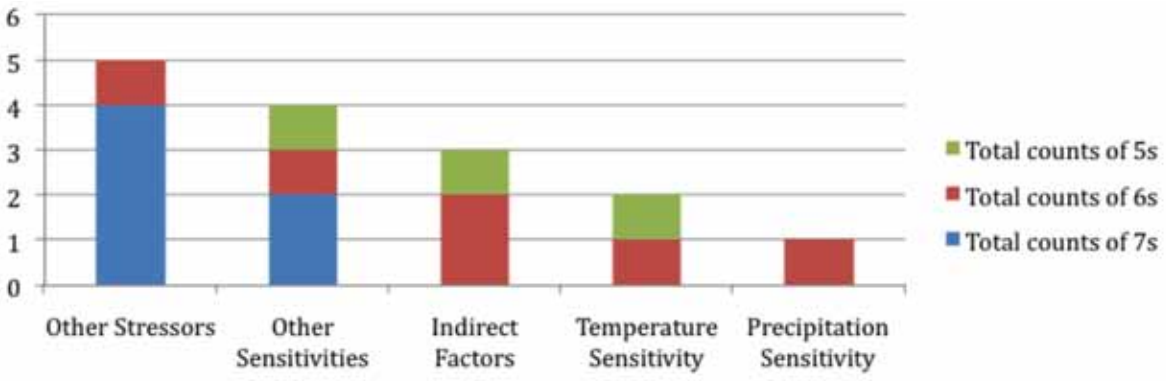

Figure 7. Total counts of "high" rankings (i.e., rankings of 5, 6, and 7) for six marine systems.

Washington Department of Fish & Wildlife

sea-level rise and erosion, expanding or protecting areas of land buffer between the edge of a bluff and homes or other infrastructure could reduce the risk to those structures during storm events (WECY 2011a).

Identifying Climate-Smart Wildlife Corridors

Another area in which WDFW is facilitating science is through the Washington Wildlife Habitat Connectivity Working Group (WHCWG). This interdisciplinary partnership is co-chaired by WDFW and the Washington State Department of Transportation (WSDOT), and was formed to address habitat fragmentation and reduced connectivity across the state due to agricultural and urban development, transportation infrastructure, and other factors. In general, maintaining and enhancing habitat connectivity is widely considered as an important climate change adaptation strategy (Heller and Zavaleta 2009). Indeed, *Washington State's Integrated Climate Response Strategy* (WECY 2012) and the *National Fish, Wildlife and Plants Climate Adaptation Strategy* (National Fish, Wildlife, and Plants Climate Adaptation Partnership 2012) feature habitat connectivity measures prominently in their recommended adaptation strategies.

Traditionally, habitat connectivity has been fostered as a way to enhance gene flow among isolated populations and promote re-colonization of species into historical habitat areas (Krosby et al. 2010). Interest in connectivity in the context of climate change builds on these purposes, but also is intended to facilitate species' movement over the landscape in response to changing conditions. It is important to recognize, however, that identifying priority connectivity areas is not a panacea, and that the effectiveness of these areas in achieving a desired conservation outcome will depend on a range of factors, including the size of the landscape, the location, size, and habitat composition of the region, the behaviors of target species and the ability to secure appropriate restrictions on land use (Krosby et al. 2010). For example, not all species will be able to move, nor will those that can move do so at a comparable pace or distance (Hannah 2008). Nevertheless, evidence that a number of plant and animal species are shifting or expanding their ranges as the planet has warmed provides a strong indication that such movements are likely to continue in the future, where possible (Chen et al. 2011; Kelly and Goulden 2008).

Washington Department of Fish & Wildlife

Accordingly, WHCWG has undertaken a project to look at potential wildlife corridors in the state through a climate change lens (Nuñez 2011; WHCWG 2011). Specifically, the group is working to identify so called "climate gradient corridors" across the state, based on the premise that climate-sensitive species are more likely to move through habitat areas that continue to have favorable climate gradients (based on factors such as altitude, temperature and precipitation, and topography) as relevant climatic conditions in their current ranges change (Diaz and Cabido 1997; Dunne et al. 2004). For example, species that inhabit cooler areas, such as alpine habitats, are unlikely to travel through areas where temperatures are significantly higher than their upper threshold.

An initial analysis for Washington State entailed several key simplifying assumptions: 1) species ranges will move to track suitable climates, with species tending to move down temperature gradients (e.g., to higher elevation and/or latitude) as temperatures rise; 2) climate gradients between core habitat areas will remain largely constant, largely due to unchanging topography; and 3) species are more likely to move through natural

areas, with fewer anthropogenic barriers (Nuñez 2011). Here, climate gradient corridors were identified using "cost-distance modeling" based on both changes in temperature and temperature-plus-landscape integrity, building on data layers identified by WHCWG in a previous analysis (WHCWG 2010). The landscape integrity layer represents natural areas that have relatively low levels of human modification. This resulted in the identification of two networks of landscape integrity core areas that are connected by corridors falling along Washington's major temperature gradients: one for temperature only (Figure 8a) and one for temperature-plus-landscape integrity (Figure 8b).

Figure 8. a) Temperature-Only and b) Temperature-Plus-Landscape Integrity Corridor Networks. The temperature-only corridor network (Fig. 8a) seeks to find routes of most unidirectional change in temperature between warmer and cooler core areas, while the temperature-plus-landscape integrity corridor network (Fig. 8b) also seeks to avoid areas of low landscape integrity (e.g., roads, agricultural areas, urban areas).

Although further research is necessary to provide information at a finer scale and offer guidance for prioritizing areas of importance for protection, this analysis provided several important insights. In

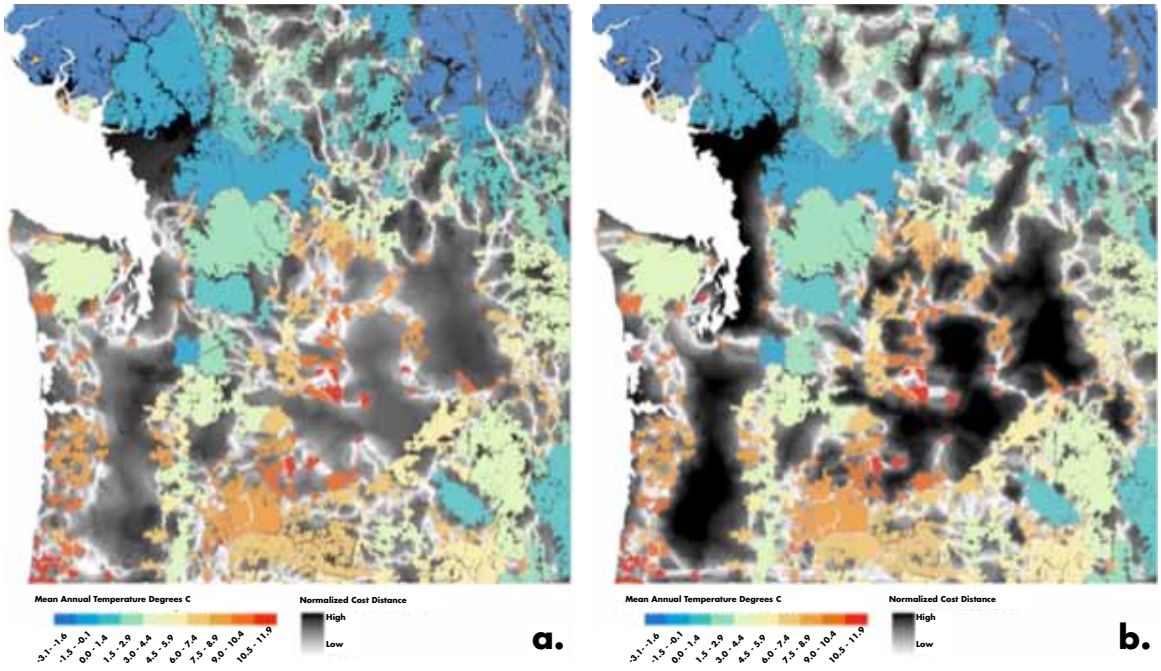

Figure 8. a) Temperature-Only and b) Temperature-Plus-Landscape Integrity Corridor Networks. The temperature-only corridor network (Fig. 8a) seeks to find routes of most unidirectional change in temperature between warmer and cooler core areas, while the temperature-plus-landscape integrity corridor network (Fig. 8b) also seeks to avoid areas of low landscape integrity (e.g., roads, agricultural areas, urban areas).

Washington Department of Fish & Wildlife, Jim Cummins

particular, the climate-gradient corridors between warmer and cooler gradients are not predominantly oriented south-to-north, as one might assume. Rather, temperature gradients in the region tend to be more closely linked to changes in elevation than changes in latitude. In addition, in the temperature only analysis, higher elevation regions with steeper climate gradients and greater topographic complexity generally had narrower available corridors than those in lowland areas, which means that the area through which species might move is more limited. However, the higher elevation areas are less likely to face significant loss of landscape integrity due to land-use when compared to lower elevation areas, where land-use intensity is the primary driver of corridor width and placement. These initial, course-scale maps provide a stepping stone for additional climate-related analyses that is ultimately aimed at informing wildlife management and land-use planning decisions both now and in the future.

IV. Developing State- and Region-wide Adaptation Strategies for Species and Ecosystems

Over the past several years, considerable work has been underway in Washington to develop and implement a climate change adaptation strategy across multiple sectors of concern, including fish and wildlife. This culminated in the 2012 release of a comprehensive state-level adaptation strategy, *Preparing for a Changing Climate: Washington State's Integrated Climate Response Strategy* (WECY 2012, available at: **http://www.ecy.wa.gov/climatechange/ipa_responsestrategy.htm**). Throughout the process of developing the strategy, WDFW led a multi-stakeholder advisory group (officially called a Topic Advisory Group, or TAG), including NWF staff and other governmental and non-governmental stakeholders, to develop recommended adaptation actions relevant to species, habitats, and ecosystems across the state. The year-long endeavor was a model for the engagement of scientists and conservation practitioners in a collaborative effort to understand the known and potential ecological consequences of climate change and identify strategies to address those impacts, with an emphasis on near-term actions to advance them.

As part of this effort, NWF partnered with WDFW to compile a series of four reference documents that summarize information from the scientific literature on climate change and its impacts on key ecological systems of concern: marine and coastal habitats; forest, alpine, and western prairie habitats; shrub-steppe and grasslands habitats; and freshwater aquatic and riparian habitats (Morgan and Siemann 2011a,b,c,d, available at: **http://wdfw.wa.gov/publications/**). These papers provided important scientific background and context for advisory group members to identify specific physical and chemical changes, examples of potential ecological consequences of those changes, and examples of potential impacts on ecosystem services. Based on this information, participants identified a suite of possible adaptation options among each of the four ecological systems and then synthesized those into some common themes and strategy recommendations applicable for all habitat types. The detailed findings are available in a report available at **http://www.ecy.wa.gov/climatechange/2011TAGdocs/E2011_interimreport.pdf** (WECY 2011b). The

five general recommended strategies for species and ecosystems included in the state's final adaptation plan are:

- *Strategy B-1. Conserve habitat necessary to support healthy fish, wildlife, and plant populations and ecosystem functions in a changing climate, and protect connectivity areas between critical habitats to allow the movement of species in response to climate change.*

- *Strategy B-2. Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems be more resilient to the effects of climate change.*

- *Strategy B-3. Manage species and habitats to protect ecosystem functions and provide sustainable cultural, recreational, and commercial use in a changing climate.*

- *Strategy B-4. Integrate climate adaptation considerations for species and ecosystems into natural resource and conservation planning, land use and infrastructure planning, and resource allocation and public investment initiatives.*

- *Strategy B-5. Build capacity and support for the adoption of response strategies that help protect and restore ecosystem function and services at risk from climate change.*

Within these general strategies, there are several specific near-term actions that are relevant to the mission and responsibilities of WDFW as it considers climate change in its ongoing work, such as: identifying opportunities and priorities for habitat connectivity; incorporating climate change considerations into existing and new management plan for protecting sensitive and vulnerable species; updating other natural resource conservation plans to address climate change considerations for species and ecosystems. This is where an integrated approach to developing and implementing climate change adaptation efforts becomes essential, including developing targeted vulnerability assessments and associated management strategies, as is described in the following section.

Success will require leadership at multiple levels, ongoing collaboration and stakeholder engagement, and effective communication...

Bringing all of the strategies highlighted here to fruition will be a challenge. In a recent survey of climate change adaptation efforts across the United States, there are still relatively few examples of plans reaching the implementation stage (Bierbaum et al. 2012). This is in part due to the nascence of climate change adaptation in the conservation field. But there are also a number of barriers (both perceived and real), such as uncertainty, future versus current benefit, limited conservation resources, institutional barriers (e.g., short planning horizons), public perception, and lack of political will, that may make implementation of adaptation strategies especially challenging (Bierbaum et al. 2012; Ekstrom et al. 2011; Moser and Ekstrom 2012). Success will require leadership at multiple levels, ongoing collaboration and stakeholder engagement, and effective communication – all of which are important elements of WDFW's climate change efforts moving forward.

V. Integrating Climate Change into Existing Conservation Work

One way to advance adaptation strategies from the assessment stage to implementation is to actively integrate consideration of climate change and associated impacts into existing planning and management activities. This has become an important focus of WDFW's climate change adaptation efforts, as the agency is looking at how to incorporate climate change into various activities, including land acquisition, restoration projects, technical assistance and grant-making, species management and recovery efforts, permitting, and infrastructure design and management. The heart of the effort is to identify specific decisions or activities which are sensitive to climatic changes, and to develop adaptation options that will increase the opportunities of success over the long term. Ultimately, this work will help inform the update of Washington's State Wildlife Action Plan, which is scheduled to be completed by 2015, as well as the continued development and implementation of other fish and wildlife management measures across the agency.

One of the tools WDFW is using to integrate climate change into its activities is workshops that bring scientists together with managers to work though some of the key questions involved in considering specific conservation priorities through a climate change lens. One such workshop applied a simple methodology developed by NWF and EcoAdapt to help in the design of climate-smart restoration projects, based on a project for the Great Lakes region (Glick et al. 2011).

The framework was initially applied at a workshop conducted with restoration practitioners for an area of prairie and oak woodland habitat in Washington. The workshop began with an overview of the science of climate change in the region, including presentations highlighting the potential impacts of climate change on prairie-oak ecosystems, drawing from peer-reviewed literature (e.g., Bachelet et al. 2011; Dunwiddie and Bakker 2011). Participants were then guided through several steps to identify the implications of climate change for achieving their restoration goals and objectives. Here, the idea is not just about climate change as a separate issue but within the context of the many existing stressors already at play.

Results of the workshop are highlighted briefly in Table 6, page28. The ideas generated can be considered a critical first step in developing management strategies to meet existing restoration goals for the system or, perhaps, underscore the need to revise those goals in light of the new challenges. It is important to emphasize

Table 5. Climate-Smart Restoration Worksheet for Oak Prairie Habitats at Scatter Creek Wildlife Area.

Scope and Objectives	
What are your current restoration goals?	Improve habitat quality for target species (plants and animals); enhance ecosystem function of oak woodlands and prairies.
What are your restoration targets?	Upland prairie, wet prairie, oak woodland, butterfly species (Taylor's checkerspot, mardon skipper, Puget blue, rose checkermallow), golden paintbrush, mules ear, vesper sparrows.
What is the current status of your restoration targets (e.g., what are the limiting factors)	Degraded habitats, rare species are reduced in number or extirpated, disturbance regime interrupted, extreme fragmentation, annual plants reduced in numbers.
What restoration approaches are you planning/ implementing to improve the status of your targets?	Controlling exotic species and tree encroachment through burning, herbicides; reintroducing specific plants and target species.
Components of Vulnerability	
Sensitivity	
How and to what degree are your restoration targets sensitive to climate conditions/variables?	Targets vary in sensitivity. Some of the butterflies are highly sensitive (or benefit). Birds unknown (data may be available elsewhere).
How and to what degree are your restoration approaches sensitive to climate variables?	Ability to implement prescribed fire is affected by weather conditions; herbicide treatment window restricted by increased winter moisture; new plantings sensitive to weather conditions.
Exposure	
How are climate conditions projected to change in the area?	Wetter winters, warmer winters, risk of reduced soil moisture in summer, risk of prolonged summer drought.
Is there evidence of climate change already being observed in the area?	Possible earlier shift in timing of summer drought.
Adaptive Capacity	
What is your system's adaptive capacity relative to climate change?	Some species (e.g. grasses) can tolerate wider range of climate conditions, while others (e.g. forbs) may not. Butterflies may shift host plants. Invasive species may be able to take advantage of disturbances and gain a foothold.
Vulnerability Summary	
What are the key issues contributing to vulnerability overall? What are the major sources of uncertainty?	Climate change will impact the feasibility of doing some treatments, as well as the effectiveness of those treatments. Additional invasives are a risk, although the potential impacts are uncertain; sensitivity of plants may lead to changes in habitat composition. High sensitivity of some target butterflies to extreme events and shifts in phenology.

Potential Adaptation Options	
Key Vulnerabilities	*Possible Management Strategies*
Changes in feasibility and effectiveness of treatments.	Explore options for using fire differently (e.g., changing the timing of burns); more resources for fire management (e.g., people) may be necessary; take advantage of windows of opportunity. Explore different herbicides that perform better under projected climate variables.
Additional invasives, changes in habitat composition.	Increase control of invasive grasses; change ratio of grass to forb seed; change frequency of seeding to increase probability of success given extreme events. At a landscape scale, consider wetlands (non-functioning) to be wet prairie, perhaps function as model of habitat heterogeneity. Consider translocation of species/habitat elsewhere. Consider whether oak woodlands are more or less important under climate change.
Sensitivity of butterflies.	Focus restoration in areas of high habitat heterogeneity (forest edge, swales), which may offer broader range of possible host plants. Use diverse seed sources (address in seed collection, review seed collection protocols).

that there are no "right" answers. Ultimately, management decisions will be driven by a range of criteria (e.g., technical or institutional feasibility, costs and benefits, etc.), many of which will be values-based. Nevertheless, this process offers a lens through which managers can think about their existing work from a climate change perspective – in other words, it can help managers start asking the right questions.

Another workshop focused on the Skagit River Watershed in the northwest corner of Washington State, and was designed to engage agency staff working in fisheries management and restoration in the basin. The workshop began with a series of presentations from climate scientists, biologists, and geologists studying the effects of changing flows on salmonids at different stages of their life cycle, effects of projected sea-level rise, and changing sediment flows on critical estuarine habitats.

Small groups then worked to identify key decisions the agency makes in several areas: harvest management, hatcheries, restoration, acquisition, hydraulic permits, and fish passage. For each decision, the small group of participants decided which activities were vulnerable to climatic changes, and for those with relatively

Washington Department of Fish & Wildlife, Jim Cummins

high vulnerability, identified adaptation options and relevant policy changes and science needs to fully implement an adaptation option. For example, the harvest management group decided that the method used to develop yield models was highly sensitive to climate change because it is based on past data and assumes static conditions that could possibly lead to over-estimated production. In response, the group suggested the need to test new models with new base periods and use more recent, shorter-term data sets. In order to advance this approach, the agency would need to work closely with the tribal co-manager and all recreational and commercial harvesters and conduct additional research on the parameters in existing data sets that may be most vulnerable.

VI. Lessons Learned and Next Steps

The activities described in this report reflect the important efforts of WDFW working on its own and in partnership with NWF and others to build its capacity to address the challenges climate change presents to Washington's fish, wildlife, and the ecosystems on which they depend. The ideas and approaches presented herein also can serve as a summary of progress to date and an opportunity to reflect on what has worked well and where the agency and its partners are learning to adjust and refine their approach. The following section presents some key lessons learned thus far and plans for moving forward in what is necessarily an iterative, learning-based process.

Some Lessons Learned

1. Adaptation to climate change does not necessarily require a wholesale new approach to conservation, but the "inquiry" – asking the climate question – is a critical step.

From a manager's perspective, the thought of having to address climate change may seem overwhelming given that there are already so many conservation challenges to address and, typically, limited resources (staff, time, and funding) to do so. However, it is important to recognize that investing in climate change adaptation does not necessarily require additional conservation resources or approaches other than those already at hand. Indeed, mainstreaming climate change adaptation into existing conservation efforts may simply be a matter of changing fundamental assumptions such as use of static climate or historical habitat ranges as benchmarks. It has been the experience of NWF, WDFW, and others involved in the state's climate change adaptation efforts that the process of planning for climate change need not differ greatly from the planning efforts with which conservation practitioners are already familiar. What is different is the need to look at each of the planning steps through a climate change lens. This requires managers to go through an explicit process for incorporating climate change into their planning, such as through assessing the vulnerability of conservation targets, and conservation actions to climate change. Using a climate change lens also applies to decisions about what management approaches to take. The general toolbox of conservation approaches is likely to remain largely the same (e.g., reduce existing stressors, improve habitat connectivity, enhance biological diversity, protect ecosystem processes and function, etc.). But the risks associated with climate change may require managers to reconsider the types of approaches used in certain cases, as well as how they should be designed. With these perspectives in mind, the idea of climate change adaptation

has become much less daunting to WDFW agency staff and other relevant conservation practitioners in the region.

Focusing on applying the climate lens to conservation actions or management decisions also allows for managers to more precisely identify the research or science needed to address the vulnerabilities of those actions or decisions, as well as target appropriate education for staff or highlight the engagement and support needed by stakeholders.

2. Many climate-smart conservation decisions can be made based on existing knowledge and uncertainties.

There is already considerable scientific understanding of climate change in the Pacific Northwest, including recent trends and future projections, and a substantial effort is being made at both governmental and non-governmental levels to increase access to relevant scientific information. This existing science has been both an impetus and a resource for the development of *Washington State's Integrated Climate Response Strategy* and other general adaptation efforts across the state and region, and in many cases it will be relevant and sufficient for informing more-specific management decisions. In addition, WDFW staff and others involved in adaptation efforts to date acknowledge and accept that decisions must be made even though some elements of climate change and its potential impacts on species and ecosystems remains uncertain. By its very nature, there will always be some degree of uncertainty about how, when, and where climate change will affect natural systems. Increased monitoring and research will help close the gap in knowledge, but we will never know exactly when and where we will experience all impacts. It is therefore prudent for managers to make decisions regardless of – or perhaps even because of – uncertainty. Notably, managing under uncertain conditions is not new to conservation practitioners, particularly where information about future conditions must be considered. This is true not just for climate change, but for factors such as land use, population trends, the state of the economy, availability of new technologies, and so on. As with these other problems, understanding and working with uncertainty through approaches such as scenario-based management planning and adaptive management will be a necessary part of the climate change adaptation process (Moser and Ekstrom 2011). For example, participants at the workshop to address climate change in prairie-oak habitat identified several possible management strategies that would be robust under a range of future climate conditions, such as using diverse seed sources for replanting efforts and focusing on habitat heterogeneity, which can increase the resilience of the system as some species thrive and others decline.

3. Often, understanding *why* relevant species and habitats are vulnerable to climate change is more useful in informing management decisions than a relative ranking or list of which species or systems are vulnerable.

Vulnerability assessments can provide two important types of information needed for adaptation planning: 1) identifying which species or systems are likely to be vulnerable and 2) understanding why

they are vulnerable. Determining *which* conservation targets are more or less vulnerable enables managers to better set priorities for action, while understanding why they are vulnerable provides a basis for developing appropriate management and conservation responses. For example, using a climate change vulnerability index to rank various Species of Greatest Conservation Need under a State Wildlife Action Plan by relative vulnerability may lead managers to consider re-prioritizing their recovery efforts. However, as a number of conservation practitioners who have applied climate change vulnerability indices have learned, understanding the *underlying reasons* for a particular species' or habitat's vulnerability, not just a relative ranking, may be even more important in informing management responses. Accordingly, as WDFW has found, the narratives underlying index results (such as those provided by the Climate Change Sensitivity Database) are likely to be critical resources as climate change adaptation efforts in the region progress. Moreover, it is important to consider that while vulnerability assessments can provide information about the levels and sources of vulnerability of species or systems to help in setting priorities, the assessments alone will not dictate what those priorities should be. The choice of whether to focus conservation efforts on the most-vulnerable, the most-viable, or a combination of the two will necessarily be based not only on scientific factors, but also social, economic, and legal values (Raymond and Brown 2011). As in the development of any conservation strategy, this will be the challenge for WDFW and its partners in addressing the realities of climate change.

4. Climate change should be considered within the context of other, non-climate stressors.

The impacts of climate change do not exist in isolation, but combine with and exacerbate many of the other factors that are of conservation concern, from habitat fragmentation and pollution to competing demands for natural resources such as forests and water. Understanding the synergisms and linkages between multiple stressors is a necessary element of climate-smart conservation. However, if climate change is treated separately from other fish and wildlife management issues, such as might inadvertently occur when it is being considered in a stand-alone adaptation planning process, other relevant conservation challenges may be underrepresented or overlooked altogether. One of the key lessons learned in building the Climate Change Sensitivity Database is that other non-climate stressors can themselves be important factors in determining the degree to which a species or ecological system is sensitive to climate change. For example, management practices such as fire suppression may increase the sensitivity of a forest system to drought and disturbances associated with climate change. And often, other anthropogenic stressors (e.g., the existence of roads or coastal armoring) are important factors in reducing adaptive capacity. Climate change is likely to exacerbate some of the other problems managers must deal with – heavier downpours, for instance, may increase pollutant loadings into aquatic habitats. In each of these cases, asking the climate question is essential.

Next Steps

The activities described in this report are examples of an ongoing effort to develop a meaningful climate change adaptation agenda for fish and wildlife in Washington and across the country. WDFW is committed to continuing to provide leadership in developing and implementing climate-smart conservation measures, including enhancing the scientific understanding of climate change and its impacts on the region's ecological systems and helping managers and other stakeholders integrate climate change into relevant activities on the ground. The agency's ongoing work is organized around the following focus areas:

Science

WDFW and its partners will continue to identify, prioritize, and secure funding from multiple sources for science and research needs to increase the understanding of climate change and its impacts on the region's natural systems, as well as seek information and resources required to help the state implement relevant climate change adaptation options.

Education

WDFW will continue to build capacity for climate change adaptation action within the agency by providing learning opportunities for all staff, providing access to tools and resources, and developing targeted training as needed to implement specific adaptation projects.

Integration

Another key priority for WDFW is to help staff and managers incorporate climate considerations into their work. Toward this, the agency envisions providing practical, hands on guidance organized around demonstration projects, workshops, and experiential learning. Demonstration projects are intended to span a broad range of activities within the agency, and currently include designing stream crossings to accommodate for future climate change, incorporating climate considerations into grant guidelines for nearshore and coastal restoration projects, assessing the vulnerability of hatcheries and other infrastructure to changing climate conditions, and developing a climate change component for wildlife area management plans. The agency will also be applying the products of the vulnerability assessment described in this report by integrating climate sensitivity into the identification and prioritization of species of greatest conservation need associated with *Washington's Wildlife Action Plan.*

Collaboration

Developing an effective response to the challenges of climate change requires a collaborative approach, between researchers and managers and across disciplines and jurisdictions. WDFW's work to date would not have been possible without the generous support and guidance provided by many of its partners, and the collaborative efforts which have resulted in several of the projects described in this report. The agency is committed to continuing and advancing partnerships to share expertise, leverage resources and to develop our collective capacity to develop meaningful adaptation strategies.

VII. Concluding Thoughts

Washington Department of Fish & Wildlife

In this era climate-smart conservation of Washington's treasured fish and wildlife species and the ecological systems they support is paramount. Indeed, Washington is seizing an opportunity to be proactive in its conservation actions by working towards desired future ecological conditions that will support people and wildlife alike. The impacts from climate change are already evident across the state and region, and scientists tell us that we can continue to expect climate to impact our natural systems in increasingly profound ways. Both NWF and WDFW recognize that, in order to ensure that our important conservation investments will endure for future generations we must continue to enhance our scientific understanding of the threat that climate change poses to species and ecological systems and fully integrate climate considerations into our conservation policies and actions. The projects and initiatives described in this report represent significant progress in building our collective capacity to do so. But the challenge is enormous, and the necessary science, tools, and management approaches are still emerging and evolving. As we move forward, we must build on the groundwork set in place through the collaborative efforts described in this report and continue to advance our knowledge and practical experience with effective and applied climate-smart conservation across the state and region.

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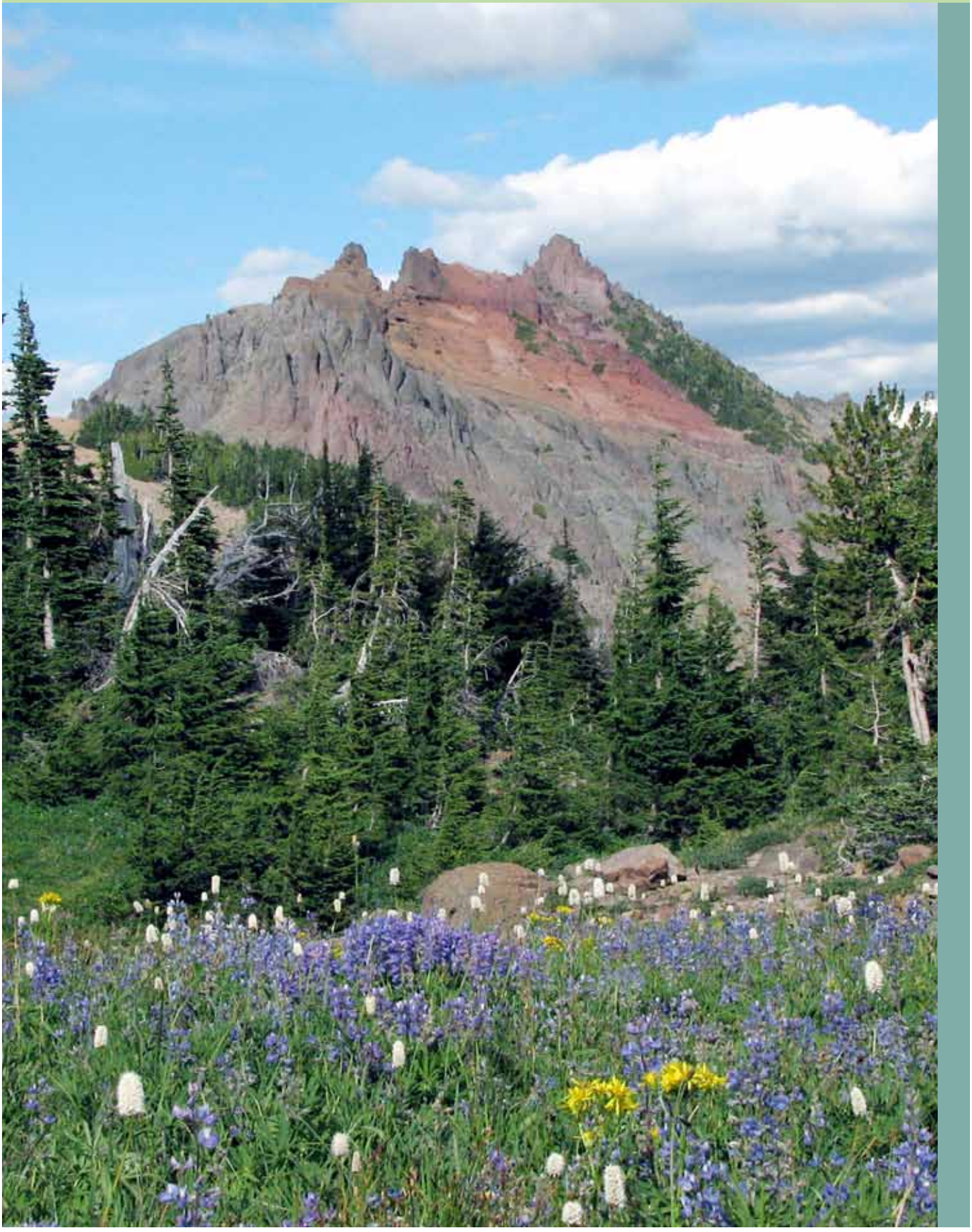

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