Washington State Integrated Climate Change Response Strategy

Photo Credit: Spencer Reeder

Interim Recommendations from Topic Advisory Group 3 **Species, Habitats and Ecosystems** (TAG3)

February, 2011

Acknowledgments

- This Interim Report is a collaborative product, representing many hours of dedicated work by the members of TAG3. Members participated actively at full group meetings, and joined subgroups to craft strategies for specific ecological systems. The co-chairs would like to express our gratitude to each and every TAG member and all those who participated in the subgroups, not only for the enormous contribution in producing this report, but for making the process itself rewarding and enriching. The TAG3 co-chairs, Lynn Helbrecht, Anna Jackson and Pene Speaks guided the TAG in its work and coordinated development of the interim report.

Special Thanks to:

- Lara Whitely-Binder (Climate Impacts Group) for drafting the narrative and tables in Chapter II and in supporting the TAG's work throughout by providing appropriate reference material when needed.
- Dan Siemann and Erin Morgan (National Wildlife Foundation) for researching and preparing the four Science Summaries on Climate Impacts for specific ecological systems.
- Jennie Hoffman (EcoAdapat) for assistance in framing and drafting portions of the report.
- Chris Konrad, Cathy Baker, John Pierce, Pene Speaks for chairing subgroups.
- Kara Nelson of TNC for her assistance with framing and supporting the TAG3 process.

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I. INTRODUCTION

PURPOSE AND BACKGROUND

This document was prepared to inform the development of a statewide, integrated climate change response strategy, as required by state legislation passed in 2009. The Steering Committee guiding the development of that strategy formed four separate topic advisory groups (TAGs) to develop draft recommendations for different sectors; TAG3 was directed to consider impacts, key vulnerabilities and draft adaptation strategies for species, habitats and ecosystems across Washington. Approximately 30 individuals representing a range of organizations and perspectives participated in the TAG's work.

This report should be considered as interim. The recommendations presented represent the best thinking of the individuals participating in the TAG3 process at the time the report was drafted. While a number of experts were consulted during development, the limited time and resources available did not allow for extensive peer review of draft recommendations or iterative review and comment. Ultimately, development and implementation of an effective adaptation strategy will require more extensive participation by those charged with implementing and overseeing it. This will ensure that adaptation strategies reflect both scientific information and the management structure within which strategies will be carried out.

TAG3 GOALS AND ORGANIZATION

One of the first tasks of the TAG was to adopt two goals to guide its work: 1) Ensure the long-term viability of ecosystems in Washington, including ecosystem integrity, ecosystem services, and the ecological processes they depend on, and 2) Maintain biodiversity, with an awareness of the needs of climate-sensitive species.

The TAG also determined early in its process that since the specific ecological consequences from climate change will vary by ecosystems, adaptation strategies should also be evaluated separately for each major system. The TAG therefore elected to work in four separate subgroups; Marine/Coastal, Freshwater/Aquatic, Forests and Western Prairies, and Aridlands. Each group reviewed current scientific literature for observed and projected impacts from climate change and then identified a set of strategies and possible actions. Reports from each group are presented in Appendix A. The Science Summaries used to provide current and projected impacts were prepared by the National Wildlife Federation and are available in Appendix E, found in a separate document.

ADDRESSING CLIMATE IMPACTS TO SPECIES AND ECOSYSTEMS IS CRITICAL

Addressing impacts to species and ecosystems is a critical component of a comprehensive state adaptation strategy. Washington citizens rely on our many varied ecosystems for a wide range of benefits; for provisioning services such as clean water, fiber and food, for regulating services such as flood control and erosion control, pollination of crops, and cultural services such as outdoor recreation opportunities. Climate change puts our ecosystems, and the life supporting benefits they provide, at risk. Chapter II discusses in more depth the ecological consequences of projected climate impacts and how they may affect the delivery of ecosystem services to human communities, with examples of the economic costs which occur with the disruption of ecosystem services

KEY CONCEPTS[1]

There is no single best approach for developing adaptation strategies for species and ecosystems. Depending on any number of factors, conservation practitioners may opt for one of three basic conceptual approaches – resistance, resilience or response. TAG3 used each of these concepts (explained below) in developing the goals and priority strategies presented in this document.

- Resistance focuses on minimizing the impact of global climate change on a particular system, either by limiting local or regional climatic changes or minimizing the effect of changes that do occur. Examples from the built environment include using light-colored roofs to limit heating in cities or maintaining dikes and levees around low-lying cities to prevent flooding. Examples from the conservation world include maintaining or restoring riparian vegetation to reduce warming in cold water systems, or restoring wetlands to reduce drought and flooding.
- Resilience means that a population or system is able to bounce back to something like its previous state following disturbance or change, with ecological functions and processes still intact. Many of the recommended strategies to address the risks of catastrophic fire for both built and natural systems are focused on increasing the resilience of a system to recover from the disturbance.
- Response: There is some level of change beyond which a system becomes irrevocably altered. In these situations, management can focus on facilitating longer-term species or system responses to maintain desired resources or ecosystem services over time. A related concept is the idea of "preserving the canvas." The philosophy here is essentially one of facilitating natural responses to change rather than trying to maintain the status quo. Examples from the built environment include rolling easements and other mechanisms of managed retreat from sea level rise. Examples from the conservation world include maintaining ecosystem connectivity to support species range shifts or including likely future habitat in critical habitat designations.

[1] Additional definitions can be found in the glossary in Appendix D.

Another concept to consider in developing climate change adaptation strategies is the risk of maladaptation. Most adaptation actions require some sort of trade-off. When the negatives of an adaptation action or strategy outweigh the benefits, it becomes a maladaptation. Maladaptations may include: strategies that benefit one sector or community at the expense of others; strategies that decrease near-term harm but increase long-term vulnerability; strategies that result in increased greenhouse gas emissions or otherwise increase the rate or extent of global or regional change; economic actions or strategies that reduce incentives to adapt or set paths that limit choices available to future generations.

HOW THIS REPORT IS ORGANIZED

There are four chapters in the main body of the report: Chapter I introduces the report, Chapter II summarizes climate change impacts and consequences, and Chapter III includes recommended goals, priority strategies and near-term actions. Chapter IV introduces key issues which should be considered for further development in the context of the statewide integrated response strategy. The appendices provide further depth and background. Appendix A includes both narrative and tables describing adaptation strategies and actions for each of the four ecological systems. Appendix B is a summary of projected climate impacts for Washington, provided by the Climate Impacts Group. Appendix C includes information on prioritizing adaptation options, Appendix D is a glossary of key terms, and Appendix E contains the four science summaries which summarize climate impacts separately for each ecological system.

II ECOLOGICAL CONSEQUENCES OF CLIMATE CHANGE

Climate change has already led to demonstrable impacts to many species, habitats and ecosystems in Washington State. For example, sea levels have risen along our shores, threatening productive coastal ecosystems for our fish, shellfish, seabirds and other species. Summer temperatures in some rivers and streams already exceed temperature thresholds that are stressful or fatal for coldwater fish such as salmon and bull trout (Mantua et al. 2010). Temperatures are continuing to rise, and scientists estimate that, globally, approximately 20-30% of plant and animal species assessed to date could be at an increased risk of extinction if temperatures exceed 2.7°F to 4.5°F (IPCC 2007). These changes have the potential to fundamentally alter many ecosystems in the state, and dramatically affect the services and products they provide to human communities. The following section describes anticipated changes, the ecological impacts of those changes and some potential effects on ecosystem services.

Box 1. Examples of Ecosystem Services

Provisioning Services:

- Food production
- Fiber, timber, and fuel production
- Maintaining genetic resources

Regulating Services:

- Climate regulation (e.g., carbon storage, carbon sequestration; temperature regulation)
- Regulating river flows and groundwater levels
- Flood/storm protection
- Water filtration/water quality
- Preventing soil erosion
- Soil formation
- Habitat maintenance and regeneration
- Providing shade, shelter, refugia
- Insect/pest control
- Waste absorption and breakdown
- Maintaining the distribution, abundance, and effectiveness of pollinators

Supporting Services:

- Nutrient cycling (e.g., converting nitrogen, carbon, and phosphorus from unusable to usable forms)
- Maintaining soil fertility, health
- Water cycling

Cultural Services:

- Recreation Aesthetic value
- Education and research
- Maintaining tribal cultural practices

Adapted from UNEP 2006, Table 1.1; Ecosystem Services Project (2011); Batker et al. 2010, Table 1

ECONOMIC VALUE OF ECOSYSTEM SERVICES

Washington's diverse ecosystems, species, and habitats provide a complex range of goods and services, collectively referred to as "ecosystem services," that benefit Washington residents. These services include food production; fiber, timber, and fuel production; biodiversity; climate regulation (e.g., carbon storage, carbon sequestration; temperature regulation; storm protection; maintenance of soil fertility and health; water quality; spiritual and cultural sustenance, and recreation). A list of common ecosystem services is provided in Box 1. Although it is difficult to calculate the full economic value of many ecosystem services, the economic value associated with some aspects of ecosystem services have been calculated for Washington. For example:

- Habitat provided by marine and coastal ecosystems in Washington State sustain commercial and recreational fishing that directly and indirectly supported over 16,000 jobs and $540 million in personal income in 2006 (TCW Economics 2008).
- Washington's biodiversity supported hunting, fishing, and wildlife viewing activities that added nearly $3.1 billion to Washington's economy in 2006 (U.S. Department of the Interior 2006).

- Nitrogen removal by shellfish production in Oakland Bay (near Shelton, WA) provides approximately $77,000 and $650,000 in annual water quality treatment benefits for wastewater treatment facilities in the City of Shelton and the City of Olympia, respectively (Hudson 2010).
- One local study found that wetlands provide over $40,000 per acre of flood damage protection in Renton (Leschine, 1997). A recent pilot study for King County demonstrated that flood hazard reduction projects that widen the floodway of the Cedar River could avoid $468 to $22,333 per acre per year in damages to homes and county flood control facilities (Swedeen and Pittman, 2007).

A 2010 report on the annual value of ecosystem services in the Puget Sound watershed alone conservatively estimated the partial value of 14 ecosystem services at $9.7 billion to $83 billion annually (Batker et al. 2010). These services included gas and climate regulation, disturbance regulation (e.g., flood control), water supply, waste treatment, and habitat refugia.

HOW CLIMATE CHANGE DRIVERS MAY IMPACT ECOSYSTEMS AND THE SERVICES THEY PROVIDE

Provision of ecosystem services depends on preservation of key physical and ecological relationships within a system, much as the functioning of a car relies on a specific arrangement of car parts (Barclay et al. 2004). Climate change has the potential to impact many ecosystem services by affecting the key relationships that support those services. For example, coastal marshes act as important buffers against coastal erosion and infrastructure damage from storm surge. Sea level rise may “squeeze out” coastal marshes that do not have the ability to migrate inland in response to rising water levels (for example due to the presence of paved roads or other hard infrastructure), reducing and in some cases eliminating the natural protection they provide.

Research on Pacific Northwest climate change impacts by the University of Washington Climate Impacts Group (e.g., Climate Impacts Group 2009) and others have identified numerous climatic changes and associated impacts that are likely to have ecological consequences for Washington’s ecosystems, species, and habitats and impact the ecosystem services they provide. Projected physical changes include, but are not limited to those on the following bulleted list. Box 2 describes examples of how ecosystem services will be affected by these changes.

PROJECTED PHYSCIAL CHANGES:

- **Increasing air temperature.** Global climate models project increases in average annual Pacific Northwest temperature (with range) of +2.0°F (+1.1 to 3.4°F) by the 2020s, +3.2°F (+1.6 to 5.2°F) by the 2040s, and +5.3°F (+2.8 to 9.7°F) by the 2080s, relative to 1970-1999. Warming is expected across all seasons with the largest warming expected in the summer months. (Mote and Salathé 2010)
- **Changes in annual and seasonal precipitation.** Projected changes in annual precipitation, averaged over all models, are small (+1 to +2% for much of the 21st century) but some models project a stronger seasonal precipitation cycle with wetter autumns and winters and drier summers. (Mote and Salathé 2010)
- **Declining snowpack**. April 1 snowpack is projected to decline in mid and low elevation basins as warmer cool season (Oct-March) temperatures cause more winter precipitation to fall as rain rather than snow and earlier spring snowmelt. Average April 1 snowpack is projected to decline -37% (for the B1 greenhouse gas emissions scenario) or -44% (for the A1B scenario) by the 2040s, and -53% (B1) or -65% (A1B) by the 2080s, relative to the 1916-2006 historical average. (Elsner et al. 2010)
- **Changes in the timing of streamflow runoff, low flows, and flood risk.** Declining winter snowpack, shifts to more winter rain, and earlier spring snowmelt are projected to shift the timing of peak spring runoff earlier into the year and reduce summer streamflows in transient (rain/snow mix) and snow-dominant watersheds. Low elevation rain-dominant basins are also likely to see lower summer streamflows as a result of warmer summer temperatures, although groundwater contributions to base streamflow may help offset declines in late summer streamflow. Flood risk increases in some basins, particularly transient basins west of the Cascades, and decreases in other basins, including east-side snowmelt dominant watersheds. In all cases, results will vary by location and basin type. (Elsner et al. 2010; Mantua et al. 2010; Tohver and Hamlet 2010)

Box 2. Examples of Impacts on Ecosystem Services

- **Impacts on food production,** due for example, to losses in spawning and breeding grounds for fish.
- **Impacts on fiber, timber, and fuel production** due for example, to shifts in commercial timber species, and losses from increased disturbances, such as fire.
- **Reduced water quality**, due for example, from lower flows and increased sediment and pollutant loads.
- **Impacts on water supply for communities, agriculture, and wildlife** due for example, from declining snowpack, reduced groundwater recharge, reduced contributions to summer streamflow in certain rivers and streams.
- **Reduced erosion and flood protection,** particularly in unstable areas after disturbance, or in areas where sea level rise reduces coastal habitats that usually provide buffering capacity.
- **Impacts on recreation** and related economic activities, such as fishing and snow skiing.
- **Impacts on culturally significant species, practices, sites of importance to tribes.**

- **Impacts on soil moisture.** Warmer temperatures, declining snowpack, and related changes in hydrology are projected to cause modest reductions overall in July 1 soil moisture, with more significant decreases projected in the Cascades and Olympic Mountains. Some areas in south central Washington may see slight increases in July 1 soil moisture as a result of increasing winter and spring precipitation in some climate scenarios. (Elsner et al. 2010)
- **Increasing summer water temperature.** Warmer summer air temperatures are projected to increase summer stream temperatures, likely reducing the quality and extent of freshwater habitat for coldwater adapted species such as salmon. The duration of periods that cause thermal stress and migration barriers for salmon is projected to at least double (under the B1 greenhouse gas emissions scenario) and perhaps quadruple (for the A1B scenario) by the 2080s for many streams and lakes. As with other hydrologic impacts, results will vary by location. (Mantua et al. 2010)
- **Increased risk of forest fires and impacts from insects such as the mountain pine beetle.** Due to increased summer temperature and decreased summer precipitation, the area burned by fire regionally is projected to double by the 2040s and triple by the 2080s (relative to 1916-2006). The probability that more than two million acres will burn in a given year is projected to increase from 5% (observed) to 33% by the 2080s. Primarily east of the Cascades, mountain pine beetles will likely reach higher elevations and pine trees will likely be more vulnerable to attack by beetles. (Littell et al. 2010)
- **Increasing sea level.** Sea level is projected to increase in Washington State although specific projections vary by location depending on differences in vertical land movement, the influence of onshore winds, and other factors. For the three regions analyzed in Mote et al. 2008, the projected medium change (with range) in Washington sea level in 2100 is +2" (-9 to +35") for the Northwest Olympic Peninsula, +11" (+2 to 43") for the central and southern coast, and 13" (+6 to 50") for Puget Sound. (Mote et al. 2008)
- **Potential for more extremes, including precipitation, heat, and coastal storms.** More intense precipitation is projected, although the spatial pattern of this change and the changes in intensity are 1) highly variable, and 2) not statistically significant for much of the state (Salathé et al. 2010). For extreme heat, the average annual number of heat events, average heat event duration, and maximum heat event duration are expected to increase in all scenarios and all four regions (Seattle, Yakima, Spokane, and the Tri-Cities region) evaluated by Jackson et al. 2010. Projected intensification of mid-latitude[2] winter season storm tracks is likely to increase coastal storm intensity (i.e., precipitation and winds) (Ulbrich et al. 2008).
- **Increasing ocean acidification.** The pH in the North Pacific, which includes the coastal waters of Washington State, is projected to decrease 0.2 and 0.3 units with increases in the atmospheric concentration of CO_2 to 560 and 840 ppm, respectively. This projected decrease

[2] Mid-latitudes" are the areas lying between the tropics and the polar regions, or approximately 30° to 60° north or south of the equator.

in pH is equivalent to a 100-150% increase in the hydrogen ion concentration or “acidity” of the oceans. (Feely et al. 2009)

More details about these and other impacts are provided in the four “Science Summaries” prepared for each ecological system (see Appendix E), the climate impacts summary table in Appendix B, and the individual papers cited herein. Table 2.1 illustrates how projected climatic changes and associated impacts may produce ecological consequences that impact ecosystem services in Washington.

Climate change is not the only issues facing ecosystems, habitats, and species, however. Existing problems with pollution, habitat fragmentation, reduced genetic and species diversity, and competition from invasive and exotic species can reduce the adaptive capacity of ecosystems, habitats, and species. Human responses to climatic change and associated impacts may also affect ecosystems, habitats, and species in negative ways. For example, increased groundwater pumping in response to warmer temperatures and growing water demands could reduce groundwater contributions to summer streamflow, increasing the potential for warmer summer stream temperatures and increased thermal stress for coldwater adapted species. Water levels in wetland systems could also be impacted. Levees installed for flood protection may restrict channel migration, limiting the diversity of riparian habitat. Consequently, it is critical to consider how Washington’s ecosystems, habitats, and species can adapt to both the direct and indirect (e.g., human) impacts of climate change in the context of existing stressors.

TABLE 2.1: Projected Climate Change Impacts, Ecological Consequences, and Impacts on Ecosystem Services[3]

Ecosystem	Examples of Projected Physical and Chemical Changes	Examples of Potential Ecological Consequences (with primary drivers)[4]	Examples of Potential Impacts on Ecosystem Services
Marine & Coastal	1. **Sea level rise.** Projected increase in Puget Sound of +6” (range: 3-22”) by 2050 and +13” (range: 6-50”) by 2100. 2. **Ocean acidification.** Ocean pH is projected to decrease in the North Pacific and Puget Sound due to increased concentrations of CO_2 in the atmosphere. 3. **Increasing sea surface temperature.** Sea surface temperature is projected to increase +2.2°F for the 2040s. 4. **Increasing coastal storm intensity** projected (i.e., more intense precipitation and winds). 5. **Altered hydrology.** More winter rain, warming temperatures, and declining snowpack are projected to significantly increase Oct-March streamflow and reduce April-Sept streamflow. Flood risk increases in some basins, particularly west-side transient (rain/snow mix) basins. These changes will affect freshwater inflow to	• **Reduced and/or lost coastal habitats** (1-4) • **Changes in the distribution of coastal habitats** (1-5) • **Loss of spawning grounds, rearing grounds, and key foraging and resting sites** (1-5) • **Reduced and/or lost habitat connectivity** (1-4) • **Increased coastal erosion** (1,4) • **Increased coastal hypoxia** (3,5) • **Shifts in species migration and distribution,** e.g., salmon migration ranges may shift due to sea surface temperature changes (1-5) • **Changes in food webs,** e.g., shifts in phytoplankton diversity (1-5) • **Impacts to marine and coastal water quality** (2,3,5) • **Impacts on range and competitive ability of exotic and invasive species** (1-5)	• **Impacts on food production** due, for example, to losses in spawning and rearing grounds for fish, losses in aquaculture beds, and changes in marine food webs affecting species distribution • **Reduced flood, storm surge, and erosion protection,** particularly in areas where sea level rise reduces coastal habitats that typically provide buffering capacity • **Reduced water quality,** e.g., water temperature, sedimentation, dissolved oxygen • **Impacts on biodiversity,** including species and genetic diversity, due to shifting species composition, distribution, and abundance, changes in habitat suitability, disturbances, and invasive species. • **Impacts on culturally significant species, practices, sites, economic activities, etc.,** e.g., loss of species or access to coastal

[3] The four “Science Summaries” for each ecological system (see Appendix E) and the climate impacts summarized in Appendix B provided the references for this table.

[4] “Primary impact drivers” refers to any combination of projected climate impacts identified in the first column. Primary impact drivers are impacts that play a significant role in a specific ecological consequence but should not be interpreted as the *only* cause (or causes) of the identified ecological consequence. Also note that human responses to climate change impacts will have a role in determining the extent to which ecological consequences are realized. Human impacts are not included in this table.

Ecosystem	Examples of Projected Physical and Chemical Changes	Examples of Potential Ecological Consequences (with primary drivers)[4]	Examples of Potential Impacts on Ecosystem Services
Marine & Coastal	coastal waters.		sites that are significant to tribes; loss of community identities (and economies) tied to aquaculture or fishing • **Impacts on recreation** and related economic activities**,** e.g. shifts in/lost opportunities for fishing, wildlife viewing, or harvesting (e.g., shellfish) due to loss/shifts in coastal habitat, changes in species distribution.
Forests	1. **Increased air temperature.** Warming is projected by all models for all seasons through the 21st century, with the largest warming in the summer months. 2. **Changes in precipitation**. Average annual precipitation is projected to increase slightly with an enhanced seasonal cycle (drier summers and wetter falls and winters) likely. 3. **Reduced snowpack**. Projected decline in April 1 snowpack in the range of -37% or -44% by the 2040s (depending on the greenhouse gas emissions scenario) and -53% or -65% by the 2080s. 4. **Altered hydrology.** More winter rain, warming temperatures, and declining snowpack are projected to significantly increase Oct-March streamflow and reduce April-Sept streamflow. Flood risk increases	• **Changes in forest productivity**. Enhanced productivity at upper elevations as snowpack declines; decreasing productivity at lower elevations where decreasing water availability is a limiting factor (1,2,3,5,6) • **Impacts on species composition, distribution, and abundance,** particularly for species less able to move in response to habitat changes ; includes changes in elevational boundaries (1-6) • **Changes in the distribution of forest habitats**, e.g., projected declines in climatically suitable habitat for Douglas fir and pine species; exacerbated for alpine habitats, which have limited ability to move upslope in response to warming (1-6) • **Reduced and/or lost habitat connectivity** (1,2,3,4) • **Changes in phenology** (the timing of ecological	• **Impacts on fiber, timber, and fuel production** due, for example, to shifts in commercial timber species, losses from increased disturbances (e.g., insect outbreaks, forest fires), or drought • **Impacts on biodiversity**, including species and genetic diversity, due to shifting species composition, distribution, and abundance, changes in habitat suitability, disturbances, and invasive species • **Reduced water quality,** e.g., sediment loads • **Impacts on water supply benefits**, particularly surface and groundwater regulation and flow • **Impacts on climate regulation**, e.g., temperature regulation, carbon storage,

Ecosystem	Examples of Projected Physical and Chemical Changes	Examples of Potential Ecological Consequences (with primary drivers)[4]	Examples of Potential Impacts on Ecosystem Services
Forests	in some basins, particularly west-side transient (rain/snow mix) basins, and decreases in other basins, including east-side snowmelt dominant watersheds. 5. **Declining soil moisture**. Modest decreases in July 1 soil moisture are projected overall with the largest declines projected for the Cascades and Olympic Mountains. 6. **Altered groundwater.** Changes in groundwater possible although highly uncertain and with great spatial variation. Shallow aquifers are more likely to be affected than deep aquifers.	events) (1-4) • **Increased susceptibility to pests and diseases** (1-6) • **Impacts on the range of exotic and invasive species** (1-4) • **Changes in tree moisture** (1-5) • **Increased frequency and duration of fires and increase in area burned** (up to double or triple likelihood of severe fire by 2080s) (1-6) • **Increased risk of drought** (1-6)	carbon sequestration • **Impacts on nutrient cycling and soil health** necessary to support healthy forest ecosystems • **Reduced erosion and flood protection,** particularly in unstable areas after disturbance (e.g., forest fires, landslides) • **Impacts on culturally significant species, practices, sites, economic activities, etc.,** e.g., loss of species or access to sites that are significant to tribes, or loss of community identities (and economies) tied to forest-related activities • **Impacts on recreation** and related economic activities, e.g. hunting, fishing, hiking, wildlife viewing
Freshwater/ Aquatic	1. **Increased air temperature.** Warming is projected by all models for all seasons through the 21st century, with the largest warming in the summer months. 2. **Changes in precipitation**. Average annual precipitation is projected to increase slightly with an enhanced seasonal cycle (drier summers and wetter falls and winters) likely. 3. **Reduced snowpack.** Projected decline in April 1 snowpack in the range of -37% or -	• **Shifts in aquatic community composition, distribution, and abundance** (1-9) • **Changes in phenology** (the timing of ecological events) (1-9) • **Reduced and/or lost freshwater/aquatic habitat, wetlands, and floodplain connectivity** (1-9) • **Impacts on the range of exotic and invasive species** (aquatic vertebrates, invertebrates, fishes) (1-4,6,8,9)	• **Impacts on biodiversity**, including species and genetic diversity, due to shifting species composition, distribution, and abundance, changes in habitat suitability, disturbances, and invasive species • **Impacts on commercial, sport, and subsistence fisheries, shellfisheries, and harvesting** of other natural resources derived from freshwaters • **Reduced flood control and drainage**

Ecosystem	Examples of Projected Physical and Chemical Changes	Examples of Potential Ecological Consequences (with primary drivers)[4]	Examples of Potential Impacts on Ecosystem Services
Freshwater/ Aquatic	44% by the 2040s (depending on the greenhouse gas emissions scenario) and -53% or -65% by the 2080s. **4. Altered hydrology.** More winter rain, warming temperatures, and declining snowpack are projected to significantly increase Oct-March streamflow and reduce April-Sept streamflow. Flood risk increases in some basins, particularly west-side transient (rain/snow mix) basins, and decreases in other basins, including east-side snowmelt dominant watersheds. **5. Declining soil moisture**. Modest decreases in July 1 soil moisture projected overall with largest declines projected for the Cascades and Olympic Mountains. **6. Reduced glacial size and abundance.** Could lead to short-term increases in summer streamflow but will ultimately exacerbate decreasing summer streamflow conditions. **7. Altered groundwater.** Changes in groundwater possible although highly uncertain and with great spatial variation. Shallow aquifers more likely to be affected than deep aquifers. **8. Increased summer stream temperatures** and longer periods of warmer stream temperatures, although with significant	• **Increased mortality and displacement** of redds and juvenile fish associated with flooding and streambed changes (2-5) • **Impacts on stream and river channel dynamics**, including migration, incision, aggradation, bed texture, and mass wasting; includes upland channels and river mouths (2-4,6,9) • **Increasing sediment loads** (2,4,6) • **Increased salt water intrusion** into coastal rivers and streams, freshwater wetlands (4,9) • **Increasing thermal stress** during summer months for coldwater adapted fish species like salmon (1-8) • **Increased nutrient loading** (e.g. eutrophication) (1,2,4)	provided by flood plains, wetlands • **Impacts on water quality,** e.g., water temperature, sediment loads, dissolved oxygen, pollutant loading • **Impacts on water supply and filtration benefits** associated with wetlands, bogs, fens, etc., including groundwater recharge and reduced groundwater contributions to summer streamflow in rivers and streams near impacted wetlands. • **Reduced or loss of cold water refugia** for coldwater adapted fish species such as salmon • **Impacts on culturally significant species, practices, sites, economic activities, etc.,** e.g., loss of species or access to sites that are significant to tribes, or loss of community identities (and economies) tied to forest-related activities • **Impacts on recreation** and related economic activities, e.g. hunting, fishing, wildlife viewing, rafting

Ecosystem	Examples of Projected Physical and Chemical Changes	Examples of Potential Ecological Consequences (with primary drivers)[4]	Examples of Potential Impacts on Ecosystem Services
	spatial variation around the state. 9. **Sea level rise.** Projected increase in Puget Sound of +6" (range: 3-22") by 2050 and +13" (range: 6-50") by 2100.		
Aridlands	1. **Increased air temperature.** Warming is projected by all models for all seasons through the 21st century, with the largest warming in the summer months. Increased length of the frost-free period expected although impact on growing season length in eastern Washington will be limited by water availability. 2. **Changes in precipitation**. Average annual precipitation is projected to increase slightly with an enhanced seasonal cycle (drier summers and wetter falls and winters) likely. 3. **Altered hydrology.** More winter rain, warming temperatures, and declining snowpack are projected to significantly increase Oct-March streamflow and reduce April-Sept streamflow. Spring flood risk projected to decrease in east-side snowmelt dominant watersheds. 4. **Changes in soil moisture.** Projected changes in July 1 soil moisture in arid lands vary. Most areas in eastern Washington show modest decreases in July 1 soil moisture	• **Changes in arid lands productivity**, including reduced carbon sequestration, due to (for example) changes in soil carbon and nitrogen cycling, microbial biomass concentrations (1,2) • **Increased risk of drought** (1-5) • **Reduced and/or lost arid lands habitats** (1-5) • **Changes in the distribution of arid lands habitats** (1-5) • **Impacts on species composition, distribution, and abundance**, particularly in areas affected by disturbance (e.g., fire, overgrazing, erosion, insect or disease infestation) and for species less able to move in response to habitat changes ; includes changes in elevational boundaries (1-5) • **Changes in phenology** (the timing of ecological events) (1,2,3) • **Impacts on the range of exotic and invasive species**, e.g., cheatgrass, sagebrush moth, particularly in areas affected by disturbance (1-5) • **Increased risk of fire** (1-4) • **Increased erosion**, particularly in areas affected	• **Impacts on biodiversity**, including species and genetic diversity, due to shifting species composition, distribution, and abundance, changes in habitat suitability, disturbances, and invasive species • **Impacts on water quality,** e.g., water temperature, sediment loads • **Impacts on water supply benefits** associated with riparian areas, wetlands, springs, intermittent water courses, vernal pools. May include reduced water supply for livestock and wildlife, reduced groundwater recharge, reduced groundwater contributions to summer streamflow in rivers and streams near impacted areas. • **Impacts on nutrient cycling and soil health** necessary to support healthy arid land ecosystems • **Reduced erosion protection,** particularly in unstable areas after disturbance (e.g., fire, overgrazing, erosion, insect or disease

Ecosystem	Examples of Projected Physical and Chemical Changes	Examples of Potential Ecological Consequences (with primary drivers)[4]	Examples of Potential Impacts on Ecosystem Services
Aridlands	while some areas in south central Washington may see slight increases as a result of increasing winter and spring precipitation in some climate scenarios. 5. **Altered groundwater.** Changes in groundwater possible although highly uncertain and with great spatial variation. Shallow aquifers more likely to be affected than deep aquifers. 6. **Increased summer stream temperatures** and longer periods of warmer stream temperatures, particularly in eastern Washington (1-5)	by disturbance (2,3) • **Increasing thermal stress** during summer months for coldwater adapted fish species using riparian habitat in arid lands (1-5)	infestation) • **Reduction or loss of cold water refugia** for coldwater adapted fish species such as salmon using riparian habitat in arid lands. • **Impacts on culturally significant species, practices, sites, economic activities, etc.,** e.g., loss of species or access to sites that are significant to tribes, or loss of community identities (and economies) tied to activities connected to arid lands ecosystems • **Impacts on recreation** and related economic activities, e.g. hunting, fishing, hiking, wildlife viewing

III PRIORITY STRATEGIES AND ACTIONS

This chapter introduces a set of priority strategies and examples of recommended near-term actions to advance them. The strategies and actions were developed with the intent to sustain natural systems and the critical ecological services they provide for human health and well being.

STRATGIES IDENTIFIED FOR ECOLOGICAL SYSTEMS

TAG3 members reviewed climate change risks and evaluated possible actions separately for four major ecological systems: coastal and marine, freshwater, forests and prairies, and aridlands. Appendix A includes the full complement of the strategies and actions identified for each system, as well as considerations for implementation, including existing programs, new programs or policies needed, and institutional barriers. The goal was not a comprehensive review of all changes, vulnerabilities, and adaptation options within each system; rather, it was to ensure that our assessment considered at some level the full range of systems and species that are likely to be impacted in different ways. Once these strategies and actions were identified for each of the four major ecological systems, the TAG reviewed the collective list and looked for common themes and strategy recommendations that were important and applicable for all habitat types.

OVERARCHING GOALS AND NEAR TERM ACTIONS

TAG3 developed ten broad goals which apply programmatically across the state and cross all ecological systems. Drawing from the recommendations for each ecological system (Appendix A), we identified high priority strategies and near-term actions for each goal. Near-term is defined as 1-5 years. The criteria for determining a priority strategy or near-term action were qualitatively applied, and included consideration of the certainty and severity of the impact (urgency), the opportunity cost of delayed action, and whether or not other actions depended on its completion. For a more substantive discussion on criteria for determining priorities, please see Appendix C.

We tried to capture as many priority strategies as possible from each ecological system in the overarching goals, strategies and actions presented in this chapter. However, some strategies and actions that are unique to a particular habitat type may not be fully reflected. Please see the tables found in Appendix A for all of the strategies and actions developed for each of the four habitat areas considered.

Note that the goals, strategies and actions are numbered only to facilitate discussion and do not indicate relative priority. When possible, we have also provided a reference to the corresponding recommendation within a particular ecological system; more information on a given strategy can be found in the appropriate table in Appendix A.

The goals and strategies to achieve them are roughly divided into two sections. The first set focuses on actions to facilitate the ability of natural systems to provide ecological functions and services in the face of climate change. The second set is oriented towards building the necessary scientific and institutional readiness to support effective adaptation.

Facilitate the Resistance, Resilience and Response of Natural Systems

1. Provide for habitat connectivity across a range of environmental gradients
2. For each habitat type, protect and restore areas most likely to be resistant to climate change.
3. Increase ecosystem resilience to large-scale disturbances, including disease, invasive species, catastrophic fire, flooding, and drought.
4. Address stressors contributing to increased vulnerability to climate change.
5. Incorporate climate change projections into plans for protecting sensitive and vulnerable species.

Build Scientific and Institutional Readiness to Support Effective Adaptation

6. Fill critical information gaps and focus monitoring on climate change.
7. Build climate change into land use planning.
8. Develop applied tools to assist land managers.
9. Strengthen collaboration and partnerships.
10. Conduct outreach on the values provided by natural systems at risk from climate change.

DESCRIPTION OF PRIORITY STRATEGIES AND NEAR-TERM ACTIONS FOR EACH GOAL

The following actions are designed to facilitate the ability of natural systems to continue to provide ecological functions and services in the face of climate change, and build scientific and institutional readiness to support effective adaptation

GOAL #1: Provide for habitat connectivity across a range of environmental gradients

Habitat connectivity is expected to allow species and ecosystems to better withstand climate change by allowing them to follow changes in climate across the landscape and maintain critical ecological processes such as dispersal and gene flow. For example, sea level rise will directly displace coastal species; therefore, their persistence will require the ability to move inland to new habitats. In general, it is much costlier and more difficult to restore connectivity than to maintain existing connectivity, yet ongoing development rapidly removes this opportunity. Planning for habitat connectivity in the near term will be far more economical the sooner it is implemented.

Key Concept	Identifying important areas for habitat connectivity is expected to enhance species and ecosystem capacity to adapt by facilitating changes in range. Connectivity should be considered along gradients in elevation, latitude and temperature.
Priority Strategies	1. Identify and designate areas most suitable for core habitat and connectivity in light of a changing climate. 2. Protect and restore areas most suitable for current core habitat, likely future core habitat, and connections between them. 3. Protect and re-establish connectivity of rivers and their floodplains. 4. Adjust the size and boundaries of conservation areas (parks and natural areas) to accommodate anticipated shifts in habitat and species' ranges. 5. Adjust land use designations in important connectivity areas (for example, allowable density). 6. Facilitate inland migration of coastal habitats.
Near Term Actions	1. Secure adequately detailed elevation maps necessary to determine areas most sensitive to sea level rise and determine areas suitable for maintaining costal-inland connectivity. (Marine/Coastal 1.1.1) 2. Complete the habitat connectivity analyses under development by the Washington Habitat Connectivity Group, and work to integrate findings into land use planning activities (Forests 1.1.1) 3. Use regulatory and non-regulatory means to secure or limit inappropriate activity in high priority buffer areas and habitat connectivity corridors for both coastal and terrestrial systems (Marine/Coastal 1.1.1)

	4. Update flood maps in floodplain and riparian areas to account for potential climate change impacts. (Freshwater 1.3.1) 5. Protect and restore current sediment sources and transport processes throughout the littoral system (Marine/Coastal 1.1.2)

GOAL #2: Protect and restore areas most likely to be resistant to climate change, aiming for a full representation of habitat types.

Broadly speaking, climate refugia are areas where climatic change is likely to occur more slowly or to a lesser extent than other areas. The concept of refugia can be considered on different scales; for example, the moist temperate climate of the west side of the Cascades and the high mountains of the state will likely serve as refugia for some species at very broad spatial scales. However, in this instance we are using the concept on a more localized scale, for example, some refugia are created by physical landscape features, such as north-facing slopes, valleys or other low areas that serve as sinks for cold air, or streams fed by deep coldwater springs. Other refugia are supported by biological features, such as the ability of forests to maintain cooler, moister conditions. Once identified and protected, refugia can help facilitate the long-term survival of species or at least buy time for species to adapt to changing conditions. Restoration can also target the creation of refugia, for example by reforestation or the reintroduction of beavers.

The concept of climate refugia can be expanded to apply to sea level rise as well. The rate of sea level change within Washington State is highly variable—sea level is currently dropping around Neah Bay but rising faster than the global average in the South Sound—so areas with slower rates of sea level rise could be considered refugia. The rate of effective sea level rise can in some circumstances be slowed by restoring natural or enhanced rates of sediment input and accretion (e.g. through removing dams or restoring certain types of coastal marshes), and by limiting groundwater withdrawals.

Current thinking suggests that high quality habitats may help to provide refugia for species under stress from climate change. In this case, the concept of refuge is not specific to climatic change; rather it refers to places where stressors related to habitat loss or degradation are reduced and which ostensibly increase the ability of species to withstand or recover from stresses linked to climate change.

Key Concept	Where possible, restoration and protection programs should be carried out in ways that help to slow the rate of climatic change locally or regionally, and used to provide refugia for species likely to be under stress from climate change

Priority Strategies	1. Identify and protect high quality habitats that are minimally affected by (or resistant to) climate change and most likely to act as climate refugia, including maintaining and improving ecological function and integrity.
Near Term Actions	1. Develop criteria to identify areas most resistant to and resilient to climate change in different ecological systems. 2. Inventory and map important thermal refugia and snowmelt systems in priority freshwater systems (sub-basins within WRIAs) and prioritize for protection. (Freshwater 1.1.1) 3. Evaluate size and location of existing reserves and protected areas to address opportunities to protect important climate resilient habitats. (Forests 1.2.1; Aridlands 1.3.2)

GOAL #3: Increase ecosystem resilience to large scale disturbances, including disease, invasive species, catastrophic fire, flooding and drought

Climate change will likely affect species and ecosystems both through gradual, directional changes in climate conditions and through increased frequency and intensity of major disturbances such as wildfire, extreme weather events such as droughts or flood, species invasion, disease and parasite outbreaks. While reducing vulnerability to gradual changes typically relies more on supporting resistance to change or facilitating longer-term responses to change that maintain desired characteristics or functions, reducing vulnerability to large-scale disturbances more often focuses on supporting resilience, that is, the ability of a system to return to its former state after a disturbance.

Key Concept	Larger, well-functioning ecosystems better withstand large-scale disturbance than smaller ecosystems because of their greater likelihood of containing remaining resources such as remnant seed and vegetation sources or pockets of undisturbed animal populations. Diverse, functioning ecosystems allow easier dispersal of system elements to help recover impacted areas or colonize new areas, and in this way contribute to ecosystem resilience.
Priority Strategies	1. Promote structural and landscape diversity to minimize the impacts from catastrophic disturbances. 2. Redefine priorities for fire management in areas important to biodiversity; priorities should shift emphasis from fire prevention/suppression to proactive management designed to increase resilience to fire and decrease likelihood of severe fire. 3. Protect and restore habitat to support adequate water supply,

	moderate temperature, and mitigate flooding impacts, through reintroduction of beaver, wetland creation and other off-channel water storage basins, and by protecting cold-water springs.
Near Term Actions	1. Target habitat restoration programs towards increasing species and structural diversity and disturbance-resistant species. 2. Modify existing land management plans to promote (seral stage) diversity such as using prescribed fire and thinning in forest systems to promote structural complexity. (Forests 2.1.4) 3. Identify priority systems (sub-basins within WRIAs) for basin-wide climate adaptation planning; including habitat restoration, promoting conjunctive use of groundwater and surface water, and integrating riparian and floodplain management.

GOAL #4 Address stressors contributing to increased vulnerability to climate change

Reducing non-climate stressors such as unsustainable harvest, pollution or habitat fragmentation can help to increase overall ecosystem resistance and resilience to climate change. Human responses to climate change or other existing stressors may further interact to increase or decrease overall vulnerability. Possible interactions of non-climate stressors and increased vulnerability to climate change include the following:

- Overharvest: reduced population sizes from over-harvesting can limit the ability of a population to adapt evolutionarily to changing condition because of the reduction in genetic diversity. Smaller populations are also more at risk to local extinctions from catastrophic events such as floods or droughts.
- Habitat fragmentation: fragmentation reduces connectivity and thereby the ability of individuals and species to move across the landscape in response to changing conditions.
- Pollutants: the toxicity and bioavailability of many pollutants is affected by soil, air, or water temperature and chemistry, all of which are changing as a result of climate change. Also, some pollutants increase species' sensitivity to high temperature or other climate-related stressors.
- Invasive species: some invasive species directly increase the climate vulnerability of the ecosystems they invade (e.g. nutria have destroyed or degraded coastal wetlands in the areas of the U.S. where they have become established, and this degradation increases the vulnerability of the coastline to flooding, erosion, and the impacts of sea level rise). Climate change in some cases will increase the success of invaders, and in other cases potentially decrease their success and make eradication more feasible.

- Habitat loss: in addition to direct habitat loss as a result of climate change (e.g. coastal habitat lost to rising seas, freshwater habitat lost to increasing drought), restoration projects may become less successful if restoration practitioners fail to incorporate changing climatic conditions in their plans.

It should be noted that simply addressing existing stressors will not always be an effective adaptation strategy. In some cases this approach will work, but in others it will not (e.g. reducing harvest levels won't be the most effective strategy if the habitat is vulnerable to degradation) or increasing the size of a protected area may not be the most effective strategy if the land is highly vulnerable to sea level rise).

Key Concepts	• Reducing non-climate stressors such as unsustainable harvest, pollution or habitat fragmentation can help to increase overall ecosystem resilience to climate change. • Human responses to climate change or other existing stressors may further interact to increase or decrease overall vulnerability
Priority Strategies	1. Evaluate and prioritize efforts to address human activities that can exacerbate climate change impacts in vulnerable systems (for example, stormwater pollution which impairs water quality; habitat fragmentation from development pressure, fuel buildup from wildfire suppression). 2. Integrate climate change into invasive species management. This may include use of climate models to highlight areas where invasion by particular species may become more problematic or where eradication may be possible, as well as using existing tools and best practices.
Near Term Actions	1. Reduce non-climate stressors (such as stormwater and septic issues, non-point and point source pollution) that contribute to hypoxic conditions and exacerbate marine acidification. (Marine/Coastal 1.4.1) 2. Conduct vulnerability assessments to determine specific areas and/or species most vulnerable to climate change impacts and under threat from existing stressors. 3. Manage stormwater to protect and restore flow characteristics in light of expected climate change impacts. (Freshwater 2.2.2) 4. Manage water withdrawals to ensure adequate stream flows and lake levels to maintain freshwater systems. Potential tools such as acquiring water rights, using water banks, incentives, and regulatory, planning and policy tools. 5. Implement the Washington Invasive Species Strategic Plan .

GOAL #5: Incorporate climate change into plans for protecting sensitive and vulnerable species and the habitats they depend on

While protecting the most robust species and systems can be effective at retaining processes and functions of ecosystems, there are multiple reasons to focus on sensitive and vulnerable species and systems as well. These include preserving species and landscape diversity and protecting culturally or spiritually important species. Some even argue that it can be more strategic to focus on species whose survival is most dependent on human intervention, rather than those likely to survive regardless. Furthermore, some existing laws mandate the protection of sensitive and vulnerable species and systems; effectively fulfilling this mandate requires taking a climate-smart approach. For example, focusing only on current habitat is unlikely to be successful in the fact of climate change, given that core habitat for some threatened and endangered species is already shifting.

Key Concepts	Climate change will increase the stress on species that are already sensitive or vulnerable, and alter what is necessary for their recovery and protection.
Priority Strategies	1. Map, protect and restore likely future critical or important habitat for vulnerable and at risk species based on a range of climate projections. 2. Incorporate actual and anticipated climatic changes and associated impacts into species recovery and management plans.
Near Term Actions	1. Develop and maintain long-term, large-scale monitoring of early warning indicators of species responses, including range shifts, population status and changes in ecological systems functions and processes. 2. Complete the Pacific Northwest Climate Change Vulnerability assessment for species and habitats and integrate findings into species conservation plans. Identify areas within vulnerable species critical habitats that would remain relatively stable given future climate change because of their physical characteristics. 3. Modify protection and recovery plans to accommodate individual movements and migration as well as longer-term species range shifts associated with climate change and its effects. 4. Coordinate among agencies, tribes and organizations to identify and prioritize additional research needs to identify adaptation strategies for vulnerable species.

GOAL #6: Fill critical information gaps and focus monitoring programs on climate change and impacts

Although there are many uncertainties in planning for climate change, there are key knowledge gaps that we can fill that will help us to develop and implement climate-smart conservation and resource management. Means of filling data gaps include vulnerability assessments that enable prioritization of adaptation efforts, experiments, monitoring, and modeling efforts that further our understanding of how species and ecosystems respond to climate change. Sociological research could also fill information gaps related to developing adaptation options that integrate a range of community values.

Monitoring is important in several ways. First, it allows managers to track how climate change is progressing and how species and systems are responding to it. This information in turn allows us to refine and test the models we use for projecting future changes and responses. Monitoring can also be designed to test the assumptions underlying proposed management options and the effectiveness of the management actions in practice. Monitoring for climatic change and associated impacts can be carried out as a stand-alone effort or by integrating relevant variables into existing monitoring efforts. For example, California is investigating how it might incorporate climate change-relevant considerations into its statewide Marine Protected Area monitoring program.

Additional suggestions for developing appropriate monitoring programs include the following:

- Monitoring programs should be tied to specific management options, hypotheses, or questions. For example, rather than monitoring for precipitation changes using some standard or pre-existing set of precipitation-related parameters, monitor for changes in parameters that are directly linked to planning and management decisions (e.g., timing and volume of peak spring flooding for salmon biologists; size of 100-year flood and maximum rainfall in a 24-hour period for road and culvert engineers).
- Implement monitoring programs with sufficient coverage to track climate patterns and changes in those patterns on management-relevant scales, as well as track changes in related physical or chemical environmental parameters (e.g., marine pH, salinity, base stream flow, etc.).
- Implement monitoring programs that can identify changes in biota (plants and animals) and aquatic systems and relate those changes to climate conditions, weather events, and related physical or chemical parameters (e.g., ocean acidification).
- Implement monitoring programs designed specifically to test ecological assumptions underlying proposed adaptation actions (e.g., the assumption that pristine systems are more resistant or resilient to change).
- Implement monitoring programs designed specifically to test the effectiveness of adaptation actions.

Key Concepts	Monitoring programs are needed to: • Track climate patterns and changes on management-relevant scales. • Identify changes in biota (plants and animals) and aquatic systems and be able to relate those changes to climate conditions. • Test ecological assumptions underlying proposed adaptation actions. • Test the effectiveness of adaptation actions. • Inform management decisions.
Priority Strategies	1. Identify species and ecosystems within geographic areas most vulnerable to climate change 2. Identify key indicators for climate change response in species and ecosystems. 3. Design and implement monitoring programs that are sufficiently sophisticated and precise to identify species and vegetation changes and relate those changes to climate conditions. 4. Enhance existing monitoring of physical, chemical and biological properties of marine systems to identify and track climate change impacts. 5. Enhance statewide monitoring networks to document climate change impacts on freshwater systems. 6. Coordinate data collection needs, ensure data sharing and facilitate access to all relevant data among conservation partners (state and federal agencies, tribes and other organizations).
Near Term Actions	1. Update hydrologic information currently used in planning to better represent current conditions and enable adaptation to represent future scenarios for groundwater and hydrology. (Freshwater 1.2.1) 2. Develop and maintain large scale monitoring of key early warning indicators for species of interest such as timing of migration, changes of population patterns, size at first reproduction, etc. (Forests 2.8) 3. Identify map and monitor essential floodplain and riparian functions at risk from climate change, including updating flood maps, and tracking shifts in distributions of wetland and lake dependent species and vegetation. (Freshwater 1.3.1) 4. Conduct monitoring and research of marine acidification to understand local extent and impacts to food web and water quality. (Marine/Coastal 2.2) 5. Conduct a climate change vulnerability assessment for marine species. (Marine/Coastal 2.6)

GOAL #7 Incorporate climate change considerations into ocean and land use planning

The actions under this goal are designed to ensure that existing and future land and ocean use planning policies, guidance, technical assistance and incentive programs address climate change consequences and integrate adaptation strategies. This goal addresses one of the most immediate and relevant approaches for building our institutional capacity to adapt to climate change impacts on the ground.

"Land use plan" is intended here to be broadly defined and includes land management plans and policy documents such as local government comprehensive plans, conservation plans, grazing plans, Forest stewardship plans and habitat conservation plans. The concept of land use planning as used here also includes the regulatory mechanisms that drive land use planning at the local level, including the Growth Management Act, Shoreline Master Programs and rules to set in-stream flows. Ocean use planning includes establishment of marine reserves, regulation of marine harvest and recreation, and any future marine spatial planning efforts.

Key Concepts	Land and ocean use policy, planning, and implementation represent a big opportunity to institutionalize climate-smart approaches.
Priority Strategies	1. Ensure existing land and ocean management plans and regulatory processes incorporate climate change consequences and include adaptation strategies. 2. Integrate planning and decision making at watershed and statewide scales to identify, avoid, or resolve conflicts among adaptation strategies.
Near Term Actions	1. Develop mitigation requirements for habitat loss and degradation from development related to human response to climate change (e.g., additional water storage facilities). 2. Integrate findings from the Habitat Connectivity analysis and vulnerability studies into planning, policy and land management activities. (Forests 2.3.1) 3. Develop a state water plan that allows holistic planning of water resources and responses climate change. (Freshwater 2.2.1) 4. Evaluate Shoreline Master Programs to address current practices and institutional barriers that prevent inland migration of critical coastal habitats at risk from inundation. Options might include greater development setbacks, dynamic setbacks, and requiring planning that addresses future climate change impacts prior to allowing development projects to be built. (Marine/Coastal 2.1) 5. Build climate change into marine spatial planning from the start.

GOAL #8: Develop applied tools for decision makers and land managers

Climate change requires new ways of assessing information and determining the best tools or course of action for land managers and other decision makers. For instance hydrologic information based on past data may not be sufficient to determine what land restoration strategies are best for a particular location; changing soil moisture levels may need to be considered in determining what tree species are best for reforestation. Tools that effectively incorporate past and future changes in climate and associated variables into land and water management, as well as options for adapting land and water management to these changes, are critical to making good decisions affecting natural systems. Some existing land conservation and management tools can likely be adapted to incorporate climate change considerations but new ones may also be needed.

Key Concepts	Easy access to data and tools will help decision-makers adequately incorporate climate change considerations into management plans affecting natural systems.
Priority Strategies	1. Make information on climate change adaptation strategies and actions accessible and targeted towards the needs of land managers and other decision makers. 2. Develop tools and information to increase the contribution of working lands to ecological resilience. 3. Develop incentives and tools to encourage water conservation
Near Term Actions	1. Identify climate-smart management practices for cultivated and grazing lands. (Aridlands 2.4) 2. Incorporate climate change considerations into existing planning tools which evaluate the effects of alternative land-use policies (for example, INVEST, and models from the Natural Capital Project). 3. Expand landowner capacity to implement silvicultural practices that increase working forest resilience in the face of climate change impacts (for example, practices to increase forest structural diversity and species diversity such as thinning and species selection). Work with existing landowner assistance programs such as extension programs. (Forests 2.1.1) 4. Conduct pilot projects to develop decision analysis tools for land managers; for example, build on the USGS/NWS Methow Basin project for future runoff projections. 5. Develop tools (for example, transfer of development rights) to create incentives to reduce risk of conversion of working forests and to non-forest uses in areas most susceptible to climate change impacts. (Forests 2.2.1)

	6. Develop incentives for protection of essential habitats that will help mitigate losses from climate change impacts. 7. Develop incentives to allow for retreat of wetlands.

GOAL #9: Strengthen collaboration and partnerships

Climate influences human and natural systems in a multitude of ways—where and how infrastructure is developed, what industries succeed in a particular location, where and how species interact, and when different populations of plants or animals reproduce or migrate are just a few climate-sensitive elements of the world around us. Thus climatic change will bring changes in many systems and processes simultaneously. To minimize chaos and cost and to maximize the chance of success, agencies at all levels, private and public land managers, conservation organizations, tribes, and others must work collaboratively and on a landscape scale when addressing climate change. Communication and coordination can prevent time and money being invested in efforts that counteract each other (for example, restoring wetlands in an area that will be flooded by the construction of a new dam). Partnerships can also help to leverage support from federal or non-profit funders, prevent the duplication of effort when it comes to climate modeling, response modeling, or gathering and analyzing data, and facilitate development, transfer, and assimilation of effective adaptation approaches.

Key Concepts	Because changing climatic conditions will influence human and natural systems in intertwined ways across a range of scales, coordinated and collaborative adaptation efforts can increase the success and decrease the costs of such efforts. At the very least, good communication may limit adaptation efforts working at cross-purposes.
Priority Strategies	1. Coordinate at regional and statewide scales to develop, prioritize and implement specific adaptation strategies and actions, and resolve conflicts across jurisdictions and among different resource users. 2. Develop institutional mechanisms to enable and facilitate shared resources, joint projects and coordinated action between federal, state, local agencies, tribes, NGOs, tribes, private entities, universities, and landowners.
Near Term Actions	1. Develop climate change conservation partnerships for ecological systems or specific landscapes/basins to share information, leverage resources, identify shared priorities and facilitate implementation of climate change adaptation strategies.

	2. Support existing landscape scale conservation initiatives and integrate climate change consequences and responses (for example, Arid Lands Initiative, Landscape Conservation Cooperatives, Western Governors Association initiatives). 3. Develop a mechanism for shared accountability for implementing climate change adaptation.

GOAL #10: Conduct outreach and education on the values of ecosystem services at risk in the face of climate change

Education about the importance of maintaining and restoring healthy well-functioning natural systems is a critical climate adaptation strategy. Washington's diverse ecosystems, species, and habitats provide a complex range of goods and services, collectively referred to as "ecosystem services" that benefit Washington residents in numerous ways (see chapter II). Many of these services in fact become even more valuable in the face of climate change, helping to lessen associated impacts to human communities. Education targeted at all levels – K-20, policy makers, general public – is essential to ensure that the value of ecosystem services is fully recognized as we develop response strategies and take action to respond to climate change.

Key Concept	Education and outreach can help ensure that the value of ecosystems and the services they provide is considered in adapting to climate change.
Priority Strategies	1. Conduct outreach and education on the values provided by natural assets at risk from climate change. 2. Promote a climate literate citizenry. 3. Promote opportunities for citizens to engage in actions that will help minimize impacts from climate change (for example, habitat protection and restoration, citizen science programs, preventing invasive species, etc).
Near Term Actions	1. Provide case studies and real world examples of the economic and social benefits ecological systems provide; emphasizing the mitigating impacts of climate change on communities and human well being. 2. Initiate and support existing efforts to quantify value of ecological services and natural systems particularly those comparing the lifetime cost-effectiveness of nature-based versus engineered adaptation options (for example, the flood protection analysis performed by Earth Economics for the Chehalis River Basin Flood Authority).

	3. Integrate messages about the value of ecological services at risk from climate change into environmental education programs and curriculum. 4. Consider nature-based alternatives to more typically engineered adaptation options such as flood control, ensuring water quality and water quantity, erosion control, etc. 5. Facilitate development of programs to engage citizens in monitoring impacts of climate change on the landscape (for example, citizen science monitoring network and the National Phenology Network, nature center programs, etc.). 6. Make information about climate and climate change understandable and accessible to the general public.

IV OVERARCHING CONSIDERATIONS AND NEXT STEPS

In the course of its work, TAG3 raised a number of important issues and topics that it had insufficient time and opportunity to adequately develop. This section introduces or reiterates selected issues with the recommendation that they be further described, examined, and considered as the Statewide Integrated Response Strategy is developed and implemented.

1. INTEGRATE RECOMMENDATIONS INTO POLICIES AND PROCEDURES

Ultimately, implementation of any of the recommended strategies in this report depends on how approaches and strategies are "mainstreamed"; that is, integrated into existing policies, programs and guidance. Further work is needed to identify governance and policy tools that could help institutionalize adaptationmindset. In particular, effort is needed at the level of implementing agencies and bodies to ensure that climate change considerations are built into relevant processes. Examples include environmental assessment programs (for example, building climate criteria into SEPA), state funded grant programs to acquire or restore habitat or conservation land (for example, including criteria for climate resilience in acquisition proposals), and land use planning guidance and technical assistance programs (for example, providing assistance to local jurisdictions to build climatic changes and adaptation needs into critical areas ordinances).

One important next step is for the Steering Committee to include a recommendation in its final report that asks state agencies (and possibly local governments) to review and incorporate climate change considerations into existing programs, policies and funding mechanisms.

2. AVOID MALADAPTATION

As awareness about current and projected impacts from climate change grows, and as government jurisdictions begin to craft plans and approaches for responding to these impacts, the risk of unintended consequences of adaptation strategies increases. Most adaptation actions require some sort of trade-off; when the negatives of an adaptation action or strategy outweigh the benefits, it becomes a maladaptation. When an adaptation strategy becomes a maladaptation can be subjective or contextual, and what may seem successful to one group, at one time, or in one location may seem damaging to others or at other times and places. For example, subsidizing or providing extra water allocation to farmers growing water-intensive crops in areas experiencing increasingly dry summers may seem like a good adaptation strategy in the short term, but in the long term it increases their vulnerability by reducing incentives to shift to crops or agricultural strategies more suited to a dry location.

Similarly, subsidizing rebuilding costs for communities in coastal areas vulnerable to sea level rise may seem like an appropriate adaptation in the near term (it reduces the harm done by sea level rise to the community), but in the long term it encourages the community to remain in harm's way. Building seawalls or bulkheads to protect one property often increases the vulnerability of others by increasing erosion farther down the shoreline, and can even worsen erosion in front of the property it is designed to protect. Developing new water storage facilities as a response to more frequent or severe drought may increase the vulnerability of cold-water species to climate change by increasing water temperatures both up- and down-stream of the dam. The state's Climate Change Response strategy should be built on a framework that evaluates all consequences and tradeoffs before responses are selected and seek to design up front ecosystem-based approaches that benefit both natural and human systems.

3. PROMOTE ECOSYSTEM-BASED ADAPTATION

While some human responses to climate change will be detrimental to ecosystems, it is important to avoid creating a false dichotomy between adaptation actions that benefit natural systems versus actions that benefit people. For many climate impacts, it is desirable to develop "ecosystem-based adaptation" strategies that deliver benefits to people *and* natural systems. Ecosystem-based adaptation uses sustainable management, conservation, and restoration of ecosystems to provide services that help human communities adapt to the impacts of climate change.[5] Examples of ecosystem-based adaptation include: increasing the resilience of coastal communities by maintaining or restoring coastal wetlands to reduce coastal flooding and coastal erosion; and increasing the resilience of forest systems by implementing forest restoration and forest health treatments, thereby reducing the risk of catastrophic fire and damage to people and property.

By considering impacts to both human and ecological communities and concurrently considering a range of adaptation approaches for these two communities, adaptation strategies are more likely to succeed. Using ecosystem-based adaptation can also be more cost-effective than measures based on hard infrastructure and engineering, and it generates social, economic, and cultural co-benefits.[6] Many of the strategies we recommend in our report, while they will benefit ecosystems, will also benefit people. We encourage the Steering Committee to ensure that the Statewide Integrated Climate Response Strategy includes adaptation actions that are in the best interests of both human *and* natural communities.

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[5] *Connecting Biodiversity and Climate Change Mitigation and Adaptation (2008),* The Ad Hoc Technical Expert Group on Climate Change and Biodiversity (AHTEG) & Ecosystem Based Adaptation. http://www.cbd.int/doc/publications/cbd-ts-41-en.pdf

[6] Ibid

4. **INCREASE OPPORTUNITIES FOR MULTI-SECTOR, LANDSCAPE-LEVEL APPROACHES**
   Several recommendations in this report address the need and opportunity for collaboration at landscape scales and across jurisdictions. This is because actions in one location may drastically influence vulnerability to climate change in other locations. The rate of relative sea-level rise threatening a coastal community, for example, may be influenced by dams or diversions that can limit sediment influx to the coast or withdrawal of water from nearby aquifers that may cause subsidence. Thus coordination should be undertaken at a level determined by the systems and actions under consideration. This notion should be further developed and integrated into the Climate Change Response Strategy.

5. **CONSIDER IMPLEMENTATION PLANNING**
   TAG3 recommends that the Steering Committee include an implementation plan as part of the final report. The implementation plan should identify lead organizations or entities for advancing priority recommendations, and lay out specific actions and timeframes.

6. **PROVIDE ONGOING LEADERSHIP AND COMMITMENT**
   Finally, TAG3 recognizes the imperative that the state climate response strategy be a dynamic document; effective implementation will require continued leadership and commitment. The 5560 Steering Committee should evaluate mechanisms for ensuring ongoing leadership (such as a standing steering committee, a state level cabinet post on climate change, etc.) as well as providing guidance and support for active adaptive management that builds new science, tools and approaches.

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APPENDIX A: SPECIFIC ADAPTATION STRATEGIES FOR ECOLOGICAL SYSTEMS

INTRODUCTION AND FORMAT

The following section presents specific adaptation strategies for four separate ecological systems. Each subsection begins with a narrative description of the system and projected climate impacts and follows with a table listing the major adaptation objectives, strategies and actions identified by the subgroups working on this system. The tables include early ideas and considerations related to implementation, including existing programs, new programs or policies which might be needed, and institutional barriers that may need to be addressed prior to implementation.

The narrative for each ecological system also highlights a selected number of strategies considered more or less unique to that system. While many adaptation strategies for ecosystems and species are similar across habitat types, some are more exclusive or applicable to a single habitat type. Each of the following narratives thus highlight those strategies most applicable to the specific ecological systems for which they were developed.

Marine and Coastal systems in Washington [7]

Description and Distribution

Washington's coastline stretches through 3,100 miles of diverse terrain along the shores of the Pacific Ocean and Puget Sound. This area encompasses a variety of habitats including bays and estuaries, coastal dunes and beaches, rocky shores, and the continental shelf.

Projected Climate impacts and consequences on marine and coastal ecosystems:

- Coastal estuaries, tidal flats, beaches, dunes and other coastal habitats particularly vulnerable to many of the projected impacts from climate change. For example:
- Sea surface temperatures are projected to increase 2.2 degrees by 2030-2059, affecting salmon migration ranges, introducing increased stress and diseases for shellfish, sea urchins and some mammals.
- Conservative estimates project a sea level rise of 6-22" in Puget sound by 2050, with estimates for 2100 projected at 6-50". Sea level rise at the mid range of 23" would result in significant loss or reduction of coastal habitats -- 65% loss of estuarine beaches, 61% loss of tidal swamps, 44% loss of tidal flats. These changes will reduce the availability of refuge and spawning areas for finfish, shellfish, wildlife and shorebirds.
- Coastal erosion is expected to increase due to sea level rise and intensified storm activity, resulting in lost near shore habitat and lack of sediment accretion.

[7] The primary reference document for this section was "Climate Change Effects on Marine and Coastal Habitats in Washington State", prepared by the National Wildlife Federation and WDFW (Appendix E)

- A lack of dissolved oxygen in coastal waters, known as costal hypoxia is also expected to increase due to more upwelling, sea surface temperature rise and changes in the delivery of nutrients to coastal zones. Hypoxic conditions can result in fatal stresses for some organisms, such as rockfish, Dungeness crab, and decreases in reproductive success and growth rates for others. Coastal hypoxia is also believed to exacerbate ocean acidification.
- Ocean acidification, a decline in ocean pH, is already observed in Washington's coastal waters. Future projections depend on the concentrations of atmospheric CO_2 , but could be significantly increased. The reduced carbonate harms shell building species such as corals and shellfish, as well as some plankton. Shifts in phytoplankton diversity has potential implications for ocean food webs.
- Loss of snowpack and changes in freshwater inflow to Puget Sound and ocean systems will alter the hydrology of coastal systems; for example, increased winter flooding could bring in increased nutrients and pollutants and salinity patterns may be altered due to reductions in freshwater inflow.

MARINE/COASTAL	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Support resistance, resilience and response of natural systems in the face of climate change.			
OBJECTIVE 1.1: Facilitate inland migration of habitats; preserve and restore corridors.			
Strategy 1.1.1: Identify, designate and protect areas most suitable for natural habitat migration zones. Actions might include: • Secure better maps and modeling; know the rate of sea level rise at specific locations. • Conducting a vulnerability assessment to determine areas most sensitive to sea level rise, • Using regulatory, non-regulatory means to designate and secure natural buffer areas. • Develop non-regulatory incentive programs to protect migration corridors. • Acquire land or development rights. • Assess costs and remove incentives of maintaining at-risk development, • Use failure as an opportunity to remove or move structures and barriers versus building them back.	Designate priority habitats for protection under GMA -- critical areas ordinances and through state agency conservation designations. Build adaptation criteria into private, federal and state grant programs for protecting habitat. (for example Pacific Coast Joint Ventures (private), Washington Wildlife Recreation Program, Salmon Recovery Funding Board grants, ESRP (state) and USFWS coastal grant (federal) . Ensure climate change and the importance of preserving habitat migration zones is integrated into the Puget Sound Near Shore Estuary Restoration Program (PSNERP)	Integrate climate change adaptation priorities into federal and state funded agricultural easement program.	Better maps and characterization of sea level rise vulnerability for WA coast. Identification of high priority areas for inland habitat migration
Strategy 1.1.2: Restore priority habitat areas most suitable for natural habitat migration zones – current and future. Actions might include: • Identify priority areas for restoration,	Build adaptation criteria into private, federal and state grant programs for protecting habitat. (for example Pacific Coast Joint Ventures (private), Washington Wildlife Recreation Program, Salmon Recovery Funding	Address potential economic impacts to agricultural community from removing dikes. Conduct cost/benefit for	Identify areas to relocate land uses that require heroic protection. Resistance from development community.

MARINE/COASTAL	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
• Recover essential processes (fluvial, tidal connections, material transport). • Redesign and ultimately remove existing structures and barriers to inland migration for priority areas (for example, dikes, roads, seawalls, bulkheads).	Board grants, ESRP (state) and USFWS coastal grant (federal) . Habitat restoration programs focused on dike removal (Skagit and Nisqually deltas). Coastal erosion programs.	maintaining at risk properties (those vulnerable to sea level rise and storm surges).	Possible economic impacts to agricultural community from removing dikes.
OBJECTIVE 1.2: Maintain Shoreline Sediment Transfer Processes.			
Strategy 1.2.1: Protect current sediment sources and transport processes throughout the littoral system. Actions might include: • Prohibit armoring on feeder bluffs • Prohibit barriers in sediment transport in drift cells. • Protect connectivity b/w sediment sources and deposition areas. • Protect habitat structure that influences sediment processes (i.e., submerged aquatic vegetation (eelgrass beds, seafloor morphology) • Strengthen existing setback regulation in SMA and local programs.	Puget Sound Nearshore Ecosystem Restoration project (PSNERP) Build adaptation criteria into private, federal and state grant programs for protecting habitat. (for example Pacific Coast Joint Ventures (private), Washington Wildlife Recreation Program, Salmon Recovery Funding Board grants, ESRP (state) and USFWS coastal grant (federal) . Shoreline Management Act and the HPA permits are existing regulatory tools which can possibly be used to facilitate implementation.	Ensure that data on areas important for protection is in useable formats for planners and others.	Finer scale mapping of sediment sources in coastal areas. Costs to preserve sediment transport; eliminate barriers and preserve connectivity. Resistance from communities and others on development restrictions.
Strategy 1.2.2. Restore sediment sources and transport processes that provide ecosystem services.	Build adaptation criteria into private, federal and state grant programs for protecting habitat. (for example Pacific Coast Joint Ventures (private),	Programs to mitigate the short term impact from the restoration action.	Finer scale mapping of sediment sources in coastal areas.

MARINE/COASTAL	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Actions might include: • Prioritize areas most in need or most valuable for restoration. • Explore removal of dams and other barriers where feasible. • Explore small scale projects with significant benefit (for example, Stavis NRCA estuary restoration). • Consider beach nourishment where restoration is not possible.	Washington Wildlife Recreation Program, Salmon Recovery Funding Board grants, ESRP (state) and USFWS coastal grant (federal) . PSNERP: Prioritize areas most in need or most valuable for restoration		Resistance from communities and others on development restrictions.
Objective 1.3 Protect viable populations of native species			
Strategy 1.3.1: Identify and protect high quality habitats that are resilient to climate change or important to maintaining species diversity (genetic, dispersal, recruitment). Actions might include: • an inventory of coastal lands which provide high quality habitats and which are resilient to climate change and currently have inadequate protection.	Land acquisition programs (federal, state and NGO funded). Use regulatory mechanisms to designate and protect lands (for example (GMA – critical areas ordinances, Shoreline Management Program, HPA permits). Employ existing voluntary programs, , such as tax incentives for open space.		Costs – purchase and longterm maintenance of lands. Inventory of coastal lands which provide high quality habitats and which are resilient to climate change and currently have inadequate protection
Strategy 1.3.2: Increase the resiliency of species vulnerable to climate change by reducing current and preventing future stressors. Actions might include: • Prevent fragmentation of habitats,	PSNERP addresses priorities for protection and restoration of habitat. Oil Spill Task Force. Clean Water Act		Better understanding the role and impact of non native species. What do priority species need to maintain viability?

MARINE/COASTAL	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
• Improve water quality, • Address invasive species • Reduce risks from consumptive uses (including harvest pressure) • Recover processes influenced by human activities and that exacerbate climate change impacts.	Invasive Species Council and programs need to address climate change priorities.		
Objective 1.4: Preserve high water quality for humans and species.			
Strategy 1.4.1: Reduce non-climate stressors that contribute to hypoxic conditions and exacerbate marine acidification. For example, stormwater and septic issues, non-point and point source pollution.	Federal and State Water Pollution laws. Coastal Zone and Shoreline management laws. Local land use laws. Federal and state grant programs.	Enhance existing programs to address hypoxia and acidification.	
Build the Necessary Scientific and Institutional Readiness to Support Effective Adaptation			
Strategy 2.1: Address existing practices and institutional barriers that prevent inland habitat migration. Actions might include review and revision of policies, for example: • Requiring greater development set back and dynamic or adaptive setbacks such as rolling easements. • Preventing shoreline hardening through use of alternatives	Use regulatory tools to address institutional barriers to protecting priority areas for inland habitat migration -- (for example (GMA – critical areas ordinances, Shoreline Management Program, HPA permits).	Evaluate and consider implementation of tools such as rolling easements.	Address possible impacts due to increased risk of property damage from flooding? Better maps and characterization of SLR vulnerability for WA coast. Build a better science base to inform alternatives to hard armoring.

MARINE/COASTAL	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
• Build a better science base to inform alternatives to hard armoring. • Requiring planning that addresses future climate change impacts prior to allowing development projects to be built.			
Strategy 2.2: Conduct monitoring and research of marine acidification to understand local extent and impacts to food web and water quality	Existing marine monitoring programs should address acidification. Federal and state grants; dedicated state and federal funding	Expanded monitoring and research programs to understand extent and impacts from acidification.	Research on this subject is in the early stages – much is not known about impacts and potential adaptation. Perception that it is a federal program.
Strategy 2.3: Address the impacts of climate change related changes in freshwater inputs to marine and estuarine waters. Actions might include: • Adjust design standards for stormwater to better protect marine waters, include promoting low impact development. • Implement programs for managing instream flows to enhance resiliency of the marine and estuarine environment.	Government and academic researchers. Federal, State, and Tribal water quality and habitat programs. State and Federal grants and dedicated funding. Improvements to stormwater permits and state water management programs.		Lack of regulatory and management structure to address large-scale cumulative effects. Research, monitoring, and modeling needed to understand the effects of these changes.
Strategy 2.4: Incorporate sea level rise and increased storm events in prioritization, design and post project maintenance of toxic cleanup sites on shorelines. Actions might include: • Assess degree of threat and existing efforts.	Incorporate sea level rise into federal, State, and Tribal water quality and toxic cleanup programs.	Enhance existing programs to address climate impacts.	Lack of regulatory and management structure to address climate impacts. Research, monitoring, and modeling needed to understand these impacts.

MARINE/COASTAL	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Strategy 2.5: Enhance existing monitoring of physical, chemical and biological properties of the estuarine and marine water column and sediments to monitor climate change impacts. Actions might include: • Evaluate potential cumulative impacts with enhanced monitoring programs.	Existing marine monitoring and research programs could be expanded and enhanced. For example: • Support expanded monitoring for long term oceanographic data for nearshore waters in Puget Sound, Gray's Harbor and Willapa Bay. • Establish long term monitoring stations near the western extent of the Strait of Juan de Fuca to monitor characteristics of oceanic waters.		Establish a marine zooplankton monitoring program to characterize zooplankton populations and their vulnerability.
Strategy 2.6: Conduct a climate change vulnerability assessment for marine species. Actions might include: • Inventory who is doing what, conducting research to understand the productivity of food webs and species relationships among trophic levels. • Develop a management plan for maintaining most at risk species that includes actions to address climate change. •	Puget Sound Partnership Action Agenda – Science Panel.	Inventory "who is doing what". Need a partnership to implement – maybe between federal, state, tribes, academics, NGOs	Information about species distribution in marine environments. Research to understand impacts to productivity of food webs and relationships among trophic levels.

Forests and Western Prairies[8]

Description and Distribution

Forests cover close to half of Washington State. They make up the principal ecosystems and comprise the major landscapes of the Pacific Northwest. These forest systems are dominated by native conifers with interspersed areas of hardwoods where recent or frequent disturbance has allowed species such as alder, maple or cottonwood to temporarily flourish. The western and wetter eastern portions of the state have forests dominated by Douglas-fir (*Pseudotsuga menziesii)*, which is also the most commercially harvested species.

Thousands of acres of once mixed species stands also have been planted to Douglas-fir for commercial purposes. Other conifer species dominate stands with areas of western hemlock, western red cedar, Sitka spruce, or silver fir on the west side of the state and Ponderosa and lodgepole pine becoming more dominant on the east side of the state. The ecological services provided by the forested areas of the state include clean cold water, clean air, flood and temperature attenuation, and nutrient and soil development, not to mention the numerous wood and other products and resources upon which we depend.

Western Prairies

The grassland prairies of western Washington once covered tens of thousands of acres in the lowlands and islands of Puget Sound and south to the Columbia River. They developed on soils leftover from the retreating glaciers of the most recent "stade" of the past ice age which reached its peak 15,000 years ago. Today only about three percent of the original prairies remain. The prairie areas existing today are threatened by encroaching tree cover, due to the suppression of fire once used to as a management tool; continued development of residential areas and the desire to exploit the gravel deposits that underlay them. These areas provide significant ecological services for groundwater recharge due to the porosity of the soils on which they are found.

Projected Climate Impacts and Consequences

Climate change is likely to bring significant changes to Washington's forest and prairie ecosystems. Particularly, shifts in the frequency and type of precipitation, with decreased snowpack and warmer, wetter winters and summers that are longer with less rain and higher temperatures, will impact the plant associations and distribution of the forests and forest types. It is expected that an increase in the intensity and frequency of wildfires will be an outcome of

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[8] The primary reference document for this section was "Climate Change Effects on Forest, Alpine and Western Prairie Habitats in Washington State", prepared by the National Wildlife Federation and WDFW (Appendix E)

these shifts. Tree species also are likely to become more susceptible to pests and increased storm intensity will bring more threats from landslides and flooding.

- **Drier Summers**: For summer months, a majority of models projected decreases in precipitation, with the average declining 16% by the 2080s. Some models predicted reductions of as much as 20-40% in summer precipitation; these percentages translate to 3- 6 cm over the summer season (June/July/August).
- **Wetter winters:** In winter, a majority of models projected increases in precipitation, with an average value reaching +9% (about 3 cm) by the 2080s under the higher-emissions modeling scenario (A1B); this value is small relative to interannual variability. Although some of the models predicted modest reductions in fall or winter precipitation, others showed very large increases (up to 42%).

In general, forest species are predicted to shift their ranges northward and higher in elevation, with new vegetation communities developing over space and time. The predicted rates of climate change may push the climatic boundaries of forest types northward at a rate faster than the predicted rate of species migration, such that shifts could lag behind changes in climate. Increases in fire frequency could result in shifts in vegetation community composition toward more fire-tolerant species or otherwise alter plant communities that depend on a given fire regime to persist. In addition to altering forest structure, a change in fire frequency and duration could influence the susceptibility of forests to insect attacks (either more or less so, depending on change).

Projected changes in climate will have impacts on western Washington prairie ecosystems as well. Warmer springs and associated shifts in stream peak flows, longer and drier summers, and more intense rainfall events may affect species composition and competition between native and invasive species. While some of the impacts might be negative for vulnerable endemic species, there might also be opportunities created for oak-woodland restoration efforts as climatic conditions for oak growth and development improve. Longer summer drought may favor the continuation or expansion of prairie grasslands into areas where conifer encroachment has overtopped and changed the prairie landscape.

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Support resistance, resilience and response of natural systems in the face of climate change.			
OBJECTIVE 1.1: Maintain connectivity between core functioning forest habitats.			
Strategy 1.1.1: Identify important connectivity areas for plants and animals that are robust to climate change (areas that provide connectivity across climatic gradients, including elevational, latitudinal, and precipitation gradients.) Actions might include: • Complete ongoing climate change connectivity analysis at ecoregional level; • Conduct periodic update analysis to incorporate changing land use patterns and climate change science.	Washington Wildlife Habitat Connectivity Working Group (WWHCWG). – statewide analysis of habitat corridors project. The PNW Climate change Vulnerability Assessment for Species and Habitats.		Species movement requirements and habitat preferences are often highly uncertain
OBJECTIVE 1.2: Maintain ecological services provided by forest landscapes.			
Strategy 1.2.1: Adjust the size, boundaries and location of large conservation areas (e.g. parks, wilderness, NRCAs) to meet needs of biodiversity under climate change impacts. Actions might include: • Conduct study to evaluate options for changing preserve boundaries, identify new areas that are needed to provide core areas or important connectivity between cores; • Identify ecological conditions that are critical for species movements or migrations.	Agency Plans for species and habitats; DNR's Natural Heritage Plan, and WDFW Lands 20/20 Regional conservation initiatives, including Western Governors Association Pilot Projects, NW Forest Plan, and the WWHCWG. Federal and State grant programs for conservation. PNW Climate Vulnerability Assessment for Species and Habitats.		Studies to evaluate options for changing preserve boundaries in light of needs of biodiversity in a changing climate. Identify new areas that are needed to provide core areas or important connectivity between cores;

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Build necessary scientific and institutional readiness to support effective adaptation			
OBJECTIVE 2.1: Increase resilience to large scale disturbances caused by fire, flooding, insects and disease.			
Strategy 2.1.1: Expand landowner capacity to implement silvicultural practices (e.g., thinning, fuel management, underplanting) that increase forest structural diversity and enhance species diversity. Actions might include: • Increase outreach and information efforts. Expand WSU and County extension capacity to deliver forestry education programs and tools. • Fund Landowner Assistance program capacity, technical assistance, incentives and grant programs. • Diversify forest regional economy	Stewardship Forestry education. Cost share programs for landowners. Workshops hosted by a variety of NGOs and Universities Modify existing programs to accommodate climate change priorities.	Increased public education on the valued of forest structural diversity Increased markets for ecosystem services and carbon storage	Timber value impacts of variable density thinning Long-term impacts on carbon storage need to be better quantified
Strategy 2.1.2: Implement silvicultural practices that increase tree vigor and resistance to insects, pathogens, and adverse weather in areas of increased risk to climate change. Actions might include: • Increase capacity to inform and assist small private forest landowners. • Increase biomass or other marketing options for wood products. • Reduce hazardous fuels in fire prone ecosystems.	WSU and County Extension programs DNR Landowner Assistance, NRCS and Conservation Districts, Washington Forest Protection Association and Washington Farm Forestry Association.	Modify existing programs to increase forest landowner access to federal grants and other funding mechanisms. Develop new ecological services markets and/or incentives.	Expand laboratory evaluations and test out planning performance of native conifer families or alternative species. Short term impacts on species at risk poorly quantified/politically difficult

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Strategy 2.1.3: Develop drought and disease resistance forest ecosystem non-commercially important species. Actions might include: • Expand funding for high priority noncommercial and commercial species genetic research and testing.	USFS Research programs, BC Ministry of Forests, Universities. NW Seed Orchard Managers Association		Existing knowledge limited for some species
Strategy 2.1.4: Promote structural and landscape diversity to minimize likelihood of catastrophic disturbances. Actions might include: • Modify existing land management plans to increase seral stage diversity on landscapes. • Promote certification of lands which brings the requirement to coordinate planning on a landscape level	Forest Practices Rules Landowner management plans, Habitat Conservation Plans	Landscape level landowner agreements among multiple landowners, Encourage forest certification programs. Address apprehensions from private lands owners to coordinate planning with public land that has a different management goal	
Strategy 2.1.5: Redefine priorities for fire management in areas important to biodiversity and species at risk, shifting emphasis from fire prevention/suppression to proactive management designed to increase resilience and decrease likelihood of severe fire. Actions might include: • Increase fuel reduction strategic plan; • Increase fuel reduction treatments. • Public outreach. • Increase expertise and capacity in prescribed fire management.	DNR Wildfire Strategic Plan Washington Statewide Assessment and Strategy USFS National Fire Plan & Cohesive Strategy	Prioritize areas for emphasis on fuel reduction and suppression.	Pattern of ownership will remain an impediment to implementation

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
OJBECTIVE 2.2: Maintain ecological services provided by forest landscapes			
Strategy 2.2.1: Identify and implement action to increase landscape resilience by reducing risk of conversion to non-forest use in areas most susceptible to climate change impacts. Actions might include: • Purchase land or development rights in high priority areas. • Provide education and incentives to increase forest stewardship over time.	NW Environmental Forum Cascade Land Conservancy and other land trusts. Forest Legacy Programs (grant funding) "Ties to the Land" Forest conservation planning program (WSU, DNR).	Provide education and incentives to increase forest stewardship over time.	
Strategy 2.2.2: Outreach and education on values of ecological services provided by forest lands Actions might include: • Landowner/Public Opinion surveys	WSU and County Extension programs DNR Landowner Assistance, NRCS and Conservation Districts, Washington Forest Protection Association and Washington Farm Forestry Association	Develop outreach and educational materials on value of ecosystem services that can be shared among organizations	Quantifying contribution of forest ecosystem services; identifying those at risk from climate change.
Strategy 2.2.3: Protect specific habitat components that are rare, are hard to replace, or provide critical spatial and temporal habitat linkages in a time of rapid environmental change. Actions might include:	WSU and County Extension programs DNR Landowner Assistance, NRCS and Conservation Districts,	Prepare extension material and case studies that describe vulnerable elements and demonstrate protection techniques.	Identify elements at risk through the PNW Climate change Vulnerability Assessment for Species and Habitats.

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
• Identify elements through WDFW Vulnerability Assessment. • Prepare extension material and case studies that describe vulnerable elements and demonstrate protection techniques. • Provide special outreach to conservation area managers to communicate vulnerabilities. • Create incentives to landowners to implement conservation measures	NGOs and land trusts, State and Federal Grant programs. Forest Health and Heritage Programs.	Provide special outreach to conservation area managers to communicate vulnerabilities. Create incentives to landowners to implement conservation measures	
Strategy 2.2.4: Develop Decision support systems that make climate change science and conservation needs accessible to decision makers, landowners and managers, NGO's and other interested public Actions might include: 1. Expand capacity of DSS from pilot scope to statewide/ regional scope	WDFW – Priority Habitat and Species Database; online NOAA/USGS Pilot Project in Methow to develop climate change DSS for land use managers. DataBasin	Long-term, sustainable decision support system.	
Strategy 2.2.5: Flooding Disturbance Vulnerability Assessments Actions might include: • Outreach to planning groups • Targeted coordination with fisheries and near shore interest groups • Increased coordination on forest management with impacts on infrastructure, fish, water supply, transportation	USFS Research programs, BC Ministry of Forests, Universities USDA Forest Service, Pacific Northwest Region (Region 6) Protection Program Conservation Biology Institute data basin	Modify existing programs/laws to accommodate climate change priorities and risks Increased public education on the value of forest cover and scope of riparian influence	Relations are based on episodic events with limited public memory Private resistance to increasing riparian buffer capacity and redundancy

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Strategy 2.2.6: Conduct vulnerability assessment for different ecological systems and key species within forest habitats and implement findings in planning, policy and management actions. Actions might include: • Coordination of data use • Cooperative data collection • Development of new analysis methods	NatureServe Climate Change Vulnerability Index (NSVI) Climate Change Sensitivity Database (CCSD), a part of the Pacific Northwest Climate Change Vulnerability Assessment (Lawler and Case 2010), USDA Forest Service, Pacific Northwest Region (Region 6) Vulnerability Assessment underway.	Modify existing programs/laws to accommodate results of vulnerability assessment in terms of protecting elements most at risk.	Species movement requirements and habitat preferences are often highly uncertain
Strategy 2.2.7:: Implement monitoring programs that are sufficiently sophisticated and precise to identify vegetation changes and relate those changes to climate conditions or weather events. Actions might include: • Coordination of existing monitoring efforts • Provide monitoring planning specifically for change species change detection • Increased data sharing extended to non federal partners	Forest Service and National Park Service Pacific Northwest Research Station's Forest Inventory and Analysis (FIA) USDA 2010. North Coast and Cascades Network (Woodward et al. 2004) USDA Forest Service, Pacific Northwest Region (Region 6) Forest Health Protection Program	May require new interpretation of HCP requirements/ other existing agreements and regulations Focus is on federal land	Funding for monitoring programs under threat Existing temporary monitoring plots networks used for most forestry inventory might be insufficient
Strategy 2.2.8: Insect/Pest/Disease Outbreak Vulnerability Assessments Actions might include:	USDA Forest Service, Pacific Northwest Region (Region 6) Forest Health Protection Program Forest Service Pacific Northwest	May require new agreements and regulations	Coordination of existing monitoring efforts and data sharing as in the date basin project to no federal partners

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
• Coordination of existing monitoring efforts and data sharing as in the date basin project to no federal partners • Provide monitoring planning specifically for change species change detection	Research Station's Western Wildland Environmental Threat Assessment Center based in Oregon		
Strategy 2.2.9: Large scale Fire Vulnerability Assessments Actions might include: • Coordination of existing monitoring efforts and data sharing as in the date basin project to no federal partners	USDA Forest Service, Pacific Northwest Region (Region 6) Forest Health Protection Program Interior Columbia Basin Ecosystem Management Project	May require new agreements and regulations Existing temporary plots networks used for most forestry inventory might be insufficient	
OBJECTIVE 2.3: Maintain connectivity between core functioning forest habitats.			
Strategy 2.3.1: Integrate results of statewide connectivity analyses into planning and policy and land management activities. Actions might include: • Conduct local planning efforts, • Develop management recommendations, • Protect/conserve key connectivity areas	WDFW Priority Habitats and Species Database; Growth Management Act WWHCWG report on institutional opportunities to implement habitat connectivity planning.	Add capacity to existing FIA program	Landscape-level monitoring of species frequency and range is a substantial undertaking

FORESTS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
OBJECTIVE 2.4: Minimize the number of species at risk that are vulnerable to climate change impacts.			
Strategy 2.4.1: Incorporate actual and anticipated climate change impacts into species recovery or management plans Actions might include: • Determine genetic conservation needs for Species of Greatest Conservation Need. • Modify recovery plans to accommodate movements/migrations associated with changing habitats associated with climate change.	Habitat Conservation Plans; ESA recovery plans. Natural Heritage Plan	Need mechanism to encourage the retrofitting existing HCPs and landscape plans	Determine genetic conservation needs for Species of Greatest Conservation Need.

ADAPTATION STRATEGIES FOR WESTERN PRAIRIES

WESTERN PRAIRIES
Strategy 1.1 Increase resistance of prairie systems to invasion by non-native grasses Actions might include: • Invest in strategies that effectively remove invasive grasses from prairie systems • Conserve and restore habitat components (native bunchgrasses) or processes (fire, soil nutrients) that improve competitive advantage of native species • Invest in and implement multi-ownership programs for early detection and rapid response to non-native grasses
Strategy 1.2 Maintain sensitive native prairie species and promote species and landscape diversity Actions might include: • Invest in genetic research of drought and disease resistance provenances • Conserve and restore species diversity • Reduce existing stressors where applicable • Promote landscape diversity through management and restoration to provide refugia during summer drought
Strategy 1.3 Manage prairie/grassland ecosystems so that they are more resilient to fire Actions might include: • Implement multi-ownership landscape-level planning to prioritize areas for fire management. • Collaborate with other agencies and organizations to develop technology and markets that increase economic feasibility of fire treatments. • Engage in public outreach and education opportunities that increase public awareness and support for management that promotes fire management. • Promote adaptive approach to landscape scale prairie/grassland management, including robust monitoring programs to evaluate fire effects. • Restructure how state and federal fire prevention funding is managed, shifting the emphasis from fire prevention/suppression to proactive management designed to reduce fire risk • Increase the expertise, capacity, and resources of the Department of Natural Resources to increase the use prescribed fire to promote

prairie/grassland health and sustainability of fire-adapted grasslands on state and private lands • Convene a state-wide multi-stakeholder group (incl. WDOE, WDNR, USFS, USEPA, TNC, WDFW, etc.) to identify current and projected barriers to increasing the extent of prescribed burning in relation to state smoke management guidelines and national ambient air quality standards. • Conduct prescribed burning according to best management practices to achieve ecological and management goals aligned with fuel reduction and native habitat enhancement
Strategy 1.4 Maintain and restore a diversity of habitats with complex topography and functional habitat networks Actions might include: • Collect, store and propagate seed of rare and at-risk species • Identify, preserve and/or restore diversity of habitats to provide refugia for sensitive species • Identify core and connectivity areas that are resilient to climate change effects • Identify and prioritize areas for protection that provide connectivity across climatic gradients, including latitudinal and precipitation gradients • Explore mechanisms for adjusting the size, boundaries and location of protected reserves

Aridlands and Shrubstepe[9]

Description and Distribution

The aridlands of Washington primarily exist just beyond the east slopes of the Cascade Mountains. The area is described as relatively well-vegetated semi-desert scrub or shrub-steppe that occupies comparatively lower elevations in the basins, valleys, lower plateaus, foothills, and lower mountain slopes in this region. They are composed of a number of habitat types including sagebrush-steppe, grasslands and Palouse prairie that are punctuated or crisscrossed by perennial or seasonal streams, springs, vernal pools and other wetland types, and some dune fields. Aridland ecosystems in Washington receive precipitation largely during winter and spring when evaporation and transpiration are minimal; summer storms are generally high-intensity, short-lived events that contribute relatively little water to soils. Typical areas of native vegetation include landscapes dominated by sagebrush (*Artemesia spp.)*, bitterbrush (*Purshiana tridentata)* and other woody shrub species along with bunch grasses, such as Idaho fescue (*Festuca idahoensis)* or bluebunch wheatgrass (*Pseudoroegneria spicata)* and forbs adapted to dry climatic conditions.

The aridlands of Washington are dominated by large areas of land converted to a variety of agricultural uses such as wheat fields and row crops, fruit orchards, vineyards, and livestock feeds like alfalfa. Others areas are used extensively for livestock grazing. Towns and other population centers are generally small and widely dispersed. Public lands are broadly interspersed with private lands with some private land holdings including blocks of thousands of acres in a single ownership.

Projected Climate Impacts and Consequences

The effects of climate change in the Pacific Northwest are expected to include impacts to the dry-adapted ecosystems in eastern Washington. In broad terms, temperatures will increase both seasonally and year-over-year. Spring and summer seasons will likely see greater temperature increases and the annual number of frost free days will continue to increase. Projections for changes in precipitation include a small change in annual rainfall but some models predict a trend toward wetter winters and drier summers with winter precipitation increasingly coming in the form of rain instead of snow. The increasing levels of CO_2 in the atmosphere could also have effects on vegetation growth for both native plant populations and agricultural crops potentially increasing productivity.

Changes in soil, water and air temperatures coupled with changes in precipitation will undoubtedly have impacts on the native plant and animal populations that have adapted to past conditions in the state's aridlands. The consequences of climate change on aridlands species and

[9] The primary reference document for this section was "Climate Change Effects on Grassland and Aridland Habitats in Washington State", prepared by the National Wildlife Federation and WDFW (Appendix E)

ecosystems will likely include degradation and loss of plant and animal habitats, spatial shifts in habitats and species, increased frequency and intensity of wildfires, increased soil erosion and conditions favorable for invasive species and changes in plant and animal phenology resulting in potential disruption in life cycles. A compounding factor that also must be considered when analyzing impacts from climate change on natural systems is how humans will respond with changes to infrastructure, water use and agricultural practices. These impacts may be "indirect" but may magnify the effects of strictly climate-driven changes to the environment. To minimize the potential detrimental consequences of climate change on the native plant and animal populations of Washington's arid land environment, a number of strategies and actions should be adopted and implemented in order to protect and maintain the state's biodiversity.

Table 4.3

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
GOAL 1: Support resistance, resilience and response of natural systems in the face of climate change.			
OBJECTIVE 1.1: Minimize and mitigate for loss of habitat due to climate change			
Strategy 1.1.1: Protect habitat/areas most resilient to climate change and that contribute to core habitat and connectivity. Actions might include: • Prioritize and evaluate areas for protection ○ Develop criteria to identify areas most resilient to climate change and which contribute to core habitat and connectivity importance ○ Identify areas important to biodiversity and species retention • Protect prioritized areas ○ Consider what tools are best – acquisition, incentives, changes in regulation ○ identify best entity to implement protection	State and Federal grant programs for habitat acquisition (for example, WWRP, National Resource Conservation Service, USFWS). Regulatory Tools, such as Growth Management Act and the Priority Habitat and Species lists. Landscape level planning initiatives with potential to address climate change: Arid lands initiative, Western Governors Association projects, Landscape Conservation Cooperative, and the Washington Habitat Connectivity Working Group. Agency strategic plans for land and species protection, including the Natural Heritage Plan, The Comprehensive Wildlife Conservation Strategy, WDFW lands 20/20 and the Habitat and Recreation Lands Coordinating Group.	Modify existing grant program criteria to incorporate climate change.	More complete ecosystem/habitat inventory information, where resilient habitats exist, criteria for prioritizing areas for protection In general there is a lack of understanding of the value of aridlands and a lack of incentives for protecting lands. Bias toward individual wildlife species rather than plants and ecosystems. Lack of criteria for habitat protection within GMA

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
OBJECTIVE 1.2: **Maintain or increase the resilience of aridland ecosystems to climate change at both local and landscape levels**.			
Strategy 1.2.1: Maintain or improve ecological function/integrity of those high priority areas (see objective 1.1) Actions might include: • Evaluate the current ecological condition of important areas • Develop restoration goals based on changing conditions • Provide incentives for restoration on private lands ○ Retool CRMP to address ecological concerns	Federal and state grant programs for land management and restoration (USFWS, NRCS, WWRP) Ecological Integrity Assessments, currently underway through the Natural Heritage Program, WDFW and State Parks. Existing range condition methodologies	Broader adoption and implementation of Environmental Impact Assessments (or something similar) Need for common language and metrics for assessing ecological function /integrity/condition.	Research on the trajectory of change for ecosystems under climate change. What new aggregations of species can we expect?
Strategy 1.2.2: Increase the ability of plants and animals to move across the landscape. Actions might include: • Protect critical spatial and temporal linkages that accommodate climate-influenced patterns of change • Assess current connectivity and prioritize important linkage areas for conservation (may be accomplished through the Columbia Plateau project of the WHCWG). • Adopt policies to avoid development (energy, residential) in those areas. • Incorporate connectivity concerns into proposals for new transmission lines (direct impact, plus enabler for wind and solar development)	WHCWG statewide and Columbia Plateau analyses; Western Governors Association Pilot Projects; Arid Lands Initiative. Farm Bill programs (NRCS,FSA) Local jurisdiction comprehensive plans	Arid lands wide mitigation program (funds from development, conversion due to new or enhanced water storage projects; alternative energy development, transmission lines, etc.). Incentives targeting connectivity conservation as a climate change adaptation strategy	Need agreed-upon priorities for connectivity conservation for all species, ecosystems and habitats

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Strategy 1.2.3: Decrease threat from invasive species *and other non-climate stressors* Actions might include: • Improve invasive species management ○ Establish early detection protocols ○ Develop invasive species tracking tools and alerts for landowners ○ Encourage coordinated and strategic control – Weed Management Areas? ○ Support innovation in control methods ○ Increase funding for management and weed control ○ Improve reporting of new and known invasive species.	State and county weed board, Washington Invasive Species Council, Farm Bill programs (NRCS, FSA)	Develop a program to support invasive species management and monitoring costs when acquiring land Establish an early detection/rapid response program for new species Address inadequate funding for weed control and stewardship on public lands	Develop a shared accessible database of invasive species detections and effective treatments
OBJECTIVE 1.3: Maintain biodiversity by minimizing the number of species at risk			
Strategy 1.3.1: Maintain high value and vulnerable (rare and endemic) species in the face of threats from climate change. Actions might include • Identify and prioritize places that support 'high value' and 'vulnerable' species. • Protect prioritized places (including core habitats, connectivity needs, etc.) • Evaluate full range of conservation mechanisms for each prioritized place. • Identify organization(s)/agency(ies) best-suited for each conservation mechanism and for each place. • Apply appropriate tool(s) to priority places.	State and Federal Grant programs aimed at habitat protection, including WWRP, USFWS Regulatory tools, including GMA (priority habitats and species database), hunting and fishing laws, GMA and County comprehensive plans. Agency plans for species and habitat protection, including Natural Heritage plan and Comprehensive Wildlife Conservation Strategy		Need to aggressively apply tools to increase our understanding of impacts of climate change on individual species. Need to develop better trend data for at-risk and endemic species.

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
	Climate change vulnerability assessments currently underway through UW and at NatureServe.		
Strategy 1.3.2: Explore mechanisms for adjusting the size, boundaries and location of protected reserves Actions might include: • Conduct study to evaluate options for changing preserve boundaries, identify new areas that are needed to provide core areas or important connectivity between cores; • Identify ecological conditions that are critical for species movements or migrations	Agency planning documents addressing protected areas, including: Natural Heritage Plan, WDFW Lands 20/20, Northwest Forest Plan, Regional Conservation Planning Initiatives, including Arid Lands Initiative, Western Governors Association Pilot Projects, Existing protected areas managed by agencies, including WDFW wildlife refuges, DNR natural areas and State Parks,	Modify existing programs to incorporate climate change considerations.	Create tools to make results of the UW vulnerability assessment widely accessible to planners and land use managers.
Strategy 1.3.3: Protect specific habitat components that are rare or hard to replace Actions might include: • Identify and prioritize hard to replace habitat components. • Create a spatially explicit inventory/database • Identify/evaluate protection needs	Agency planning documents addressing protected areas, including: Natural Heritage Plan, WDFW Lands 20/20, Northwest Forest Plan, Species and Ecosystem databases, including Natural Heritage Program (DNR), Priority Habitat and Species Database (WDFW)		Need a better understanding of how climate change will impact small-patch habitats and of how small-patch habitats might either migrate or be constructed if necessary.
GOAL 2: Build necessary scientific and institutional readiness to support effective adaptation			

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Strategy 2.1: Establish a conservation partnership, to address climate change and other stressors, for the aridlands of Washington (including agricultural lands) that includes public and private stakeholders. Actions might include: • Support existing landscape conservation initiatives efforts to address climate change consequences and responses (for example ALI, LCC, WGA, etc.) • Evaluate and fill gaps in coordination to ensure current initiatives are able to adequately address climate change issues • Develop mechanism to share information and coordinate outcomes • Coordinate implementation of strategies across the full scope of arid lands • Develop institutional mechanisms to enable and facilitate shared resources, joint projects and coordinated action between federal, state, local agencies, NGOs, tribes, private entities and landowners. • Develop mechanism for shared accountability for conservation actions and effectiveness • Provide funding to coordinated projects, and empower main conservation initiative/s through management of that funding	Aridands Initiative Regional Conservation Planning Initiatives, including: Landscape Conservation Cooperatives, Western Governors Association Projects. Tools such as the BLM rapid ecosystem assessment	Aridlands version of the Puget Sound Partnership, Create better incentives for coordinating conservation efforts Modify existing planning process, to incorporate climate change consequences	
Strategy 2.2: Ensure existing land management plans and regulatory processes address climate change consequences and include adaptation strategies. Actions might include:	Local jurisdiction comprehensive plans; DNR Strategic Plan for Agriculture.	Arid lands wide mitigation framework (funds from development, conversion due to new or enhanced water storage projects; alternative energy	Resistance to changing objectives for land use. Concern about implementing conservation strategies on priate lands

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
• Determine how best to incorporate climate change adaptation strategies in existing land management plans. • Evaluate existing land management plans, and work with the appropriate planners and implementers to integrate CC adaptation strategies. ○ county planning ○ private land management plans ○ state and federal land management plans • Develop mitigation requirements for habitat loss from development directly related to human response to climate change ○ Develop a mitigation framework for development ○ Create standards applicable to energy, conversion, residential development. ○ Develop replacement or enhancement acreage equivalencies	Habitat Conservation Plans.	development, transmission lines, etc. Funds to agreed-upon priority areas that increase resilience).	
Strategy 2.3: Improve and better coordinate fire management, in light of increasing risk from climate change. Actions might include: ○ Coordinate fire management across jurisdictions, and focus on agreed-upon priorities. ○ Prioritize areas for fire management and protection • Increase public awareness and decrease human ignition sources ○ Expand public awareness campaigns ○ Increase enforcement of restrictions of high risk activities during fire season. • Reduce impact of fires that occur ○ Increase ability to implement effective post-fire rehabilitation through:	Existing agency fire management programs and resources for agency managed lands -- DNR, BLM, USFWS Local funding for fire districts	Program coordinating fire management resources and use. Funding programs for climate-smart fire management and enforcement of current restrictions Develop a wildland firefighter training and recruitment program? Develop agreed-upon priorities for fire management based on ecological role of fire.	Inadequate coordination of fire management activities across the whole landscape Perception of native systems not being "valuable resources" Inadequate enforcement of restrictions of high risk activities during fire season Inadequate funding and capacity to manage fire in native systems

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
○ Creating a native-seed-buyers cooperative, to stabilize demand and encourage stable seed supply ○ Developing a revolving fund for immediate availability of funding for rehab actions in priority areas. ○ Implementing minimum impact suppression techniques.		Increase ability to implement effective post-fire rehabilitation through: Creating a native-seed-buyers cooperative, to stabilize demand and encourage stable seed supply Developing a revolving fund for immediate for rehab actions in priority areas.	Research ecological role of fire under changing climates, in a fragmented context and with invasives such as cheatgrass.
Strategy 2.4: Increase the contribution of cultivated land to ecological resilience Actions might include: • Develop incentives for climate-smart management on private grazing lands - Flexibility in grazing leases on public lands effective - Grass banking or other "storage" of forage to deal with increased inter-annual variability - Market premium for sustainable grazing, to compensate decreased size of operation due to drought, variability - Incentives for development of climate-smart management plans. (May need a research component to determine how to incorporate climate change projections and uncertainty into grazing management.) • Identify agricultural practices on cultivated and grazing lands with most value for wildlife and connectivity, and provide incentives for their implementation	Farm Bill programs (NRCS, FSA), Sustainable Agriculture certification programs (Food Alliance)	Markets for sustainable and/or climate-smart agricultural practices Incentives focused on practices that increase ecological resilience Incentives targeting connectivity conservation as a climate change adaptation strategy Prescriptive leases	Synthesis and/or development of recommendations of best ag practices (cultivation and grazing) that best support connectivity conservation and mitigate climate change.

ARIDLANDS	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Strategy 2.5: Implement a genetic conservation program			
Strategy 2.6: Incorporate actual and anticipated climate changes in species recovery or species management plans			
Strategy 2.7: Address information gaps to allow better understanding of how climate change can impact aridlands habitats and species			
Strategy 2.8: Develop and maintain a long-term, large scale monitoring plan of key early warning indicators of species responses (including range shifts, population status) and changes in ecological systems functions and processes Actions might include: • Design/develop long term monitoring protocol • Create Citizen Science Monitoring Network (includes Agency, Higher Ed, K-12, Adult volunteers)) to implement monitoring plan	Biodiversity Scorecard Agency species monitoring programs, Various citizen science efforts,	Modify scorecard/dashboards to include climate change indicators. Develop new programmatic citizen science monitoring network to provide mechanism to collect large scale long-term data sets. Will require strong formal science partnership between, professionals, NGOs, local citizen groups.	Citizen Science Network can serve all ecosystems. Once network is in place it can be used for collection of data and analysis of additional questions beyond monitoring.
Strategy 2.9: Develop mechanism for feeding that information back to decision makers at all levels (from policy to individual landowners) to inform management and policy decisions			

Freshwater and Aquatic[10]

Description and Distribution

Washington State is blessed with abundant freshwater resources. The Cascade and Olympic Mountains influence the precipitation patterns from weather moving in from the Pacific Ocean along the state's western edge and store large quantities of water in the form of ice and snow. They also create precipitation "shadows" creating areas of low rainfall and arid conditions along and beyond their eastern slopes. This is most noticeable in the dry eastern portions of the state. The result is strongly divided climate regimes with the western part of the state having an abundance of lakes, streams, ponds and wetlands and generally cool damp conditions much of the year and the eastern part of state experiencing semi-desert conditions with more ephemeral ponds and streams with large river systems, like the Columbia, Snake or Okanogan Rivers providing much of the water resources for agriculture and other human uses.

Projected Climate Impacts and Consequences

The impacts of climate change are likely to create significant changes to the patterns and processes affecting Washington's freshwater ecosystems. Washington relies on cool season precipitation (October through March) and resulting snowpack to sustain warm season streamflows (April through September). Approximately 75% of the annual precipitation in the Cascades falls during the cool season. Small changes in air temperature can strongly affect the balance of precipitation falling as rain and snow, depending on a watershed's location, elevation, and aspect. Based on information found in WACCIA (CIG 2009), PAWG (2008) and Karl (2009), the major climate driven effects on Washington's hydrology appear to be:

- Reduced snowpack and altered runoff regimes
- Reduced summer streamflows
- Increased flooding
- Increased water temperature
- Increased water pollution
- Altered soil moisture
- Altered groundwater
- Reduced glacial size and abundance

These effects are already being seen, for instance, in changes to hydrology in the Puget Sound Basin. Snover et al. (2005) report that freshwater inflow to Puget Sound has changed over the period 1948-2003 in the following ways:

- A 13% decline in total inflow due to changes in precipitation
- A 12 day shift toward earlier onset of snowmelt
- An 18% decline in the portion of annual river flow entering Puget Sound during the
- summer
- An increase in the likelihood of both low and unusually high daily flow events.

[10] The primary reference document for this section was "Climate Change Effects on Freshwater, Aquatic and Riparian Habitats in Washington State", prepared by the National Wildlife Federation and WDFW (Appendix E)

Freshwater systems may also be affected by human response to climate change. Changes to infrastructure to address changes in water use, to manage stormwater runoff and to support agricultural practices may create “indirect” but significant impacts and may magnify the effects of strictly climate-driven changes to the environment. Those indirect impacts are not addressed with specific strategies in this section, however, they should be considered when developing strategies to address climate change impacts to other sectors.

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Support resistance, resilience and response of natural systems in the face of climate change.			
OBJECTIVE 1.1: Protect climate resilient and intact river, lake and wetland systems, especially from non-climate threats to maintain their resilience and biodiversity.			
Strategy 1.1.1: **Prioritize the most resilient systems (e.g., sub-basins within WRIAs) for protection** Actions might include: • Conducting a spatially explicit vulnerability assessment to identify risks to freshwater systems caused by climate change. • Inventory and map thermal refugia, snowmelt systems, connectivity and biodiversity. • Identify high priority systems based on resiliency, biodiversity and current function.	DNR uses ecological integrity assessment methodologies to identify areas of high priority for protection; DOE wetland rating system identifies priority wetlands based on function; Stream typing systems used by forest practices regulations and local jurisdiction identify riparian areas for protection based on fish habitat values	Existing protection policies focus on protecting areas most threatened or rare; focusing protection more on intact (robustness, resilience) systems would require criteria revisions of various evaluation/prioritization tools. State agencies may need a vehicle to develop and implement shared criteria. Prioritization could be funded through federal programs like EPA Puget Sound Protection/Restoration program Cross agency/program cooperation and developing shared goals/objectives for funding distribution.	. Need to develop criteria for “resilience” from climate change impacts as well non-climate threats Convincing policy makers most resilient (most intact) areas are highest priority for protections. Land acquisition and protection programs need policies that prioritize climate-resilient systems with high biodiversity value. Concern about using climate change as an “excuse” to lock up lands
Strategy 1.1.2: Protect ecological function and communities in high priority systems Actions might include: • Acquire land, water rights, and easements and easements for upper	Land acquisition by state and federal agencies, local jurisdictions, tribes, and non-governmental land trusts; Protection of areas by local jurisdictions through CAOs, Clean Water Act 404	Land acquisition and protection programs need policies that prioritize climate-resilient systems with high biodiversity value.	Salmon recovery, wetland protection, conservation of aquatic species that are among the most imperiled species

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
watershed forests and meadows that act as natural water and snow storage. • Provide incentives for property owners/managers. • Use current regulatory systems to reduce non-climate stressors and increase system resiliency**.** For example, review and amend CWA to address changing ecosystem conditions, Forest Practices, GMA, SEPA, SMA, HPA and providing support to local jurisdictions with strengthened critical areas. • Coordinate and fund planning and policies to protect high priority systems.	permitting Existing Funding Options: Clean Water State Revolving Funds (US EPA), Habitat Conservation and Restoration Grants (Recreation and Conservation Office), Cooperative Endangered Species Conservation Fund (USFWS)	Consider establishing watershed authorities to manage funds for restoration and protection. Authority could be funded by land use development fees based on percentage of area hardened.	
OBJECTIVE 1.2: Protect and restore streamflow and water levels for ecological function			
Strategy 1.2.1: Develop hydrologic information that better represents current conditions and can be adapted to represent future scenarios – for groundwater, hydroecology, hydrologic modeling. Actions might include: 1. Map groundwater recharge and discharge as critical areas. 2. Monitor water levels in shallow aquifers that support freshwater systems. 3. Determine system specific streamflow targets that support ecological function. 4. Develop statewide network of flow	GMA Critical Aquifer Recharge Areas (CARAs) or instream flows for water rights. Groundwater Assessment Program (GAP) maintains data on locations and data for groundwater withdrawals in the state and assesses each for vulnerability to degradation. Ecology TMDL studies often assess groundwater discharge into surface waters Ecology's River and Stream Water Quality Monitoring Program collects data on 62 long-term stations and 20 basin (rotating) stations.	Expand groundwater inventory of recharge and discharge areas as critical areas through Ecology GAP, TMDL, watershed plans, and local jurisdiction GMA and SMP. Increase River and Stream Water Quality Monitoring sites and IMWs to address basins most at risk from climate change. Explore options with watershed leads to set streamflow targets for ecological functions.	Address lack of site-specific knowledge about the timing, location, and degree of exchange between groundwater and surface water systems (dry-season seepage evaluation and instream piezometer surveys). Current CAOs address CARAs for drinking water protection; "base flows" in streams are considered but not adequately for include ecosystem services and ecological functions. There is currently no state-level

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
monitoring stations to research impacts of climate change on stream hydrology. 5. Develop synthetic rainfall, temperature time series to represent future conditions. 6. Apply hydrologic models to basin-scale analysis of stormwater retrofits in priority basins. 7. Ensure sufficient data is collected on water supply, use and discharge to allow comprehensive water budgets at the watershed scale.	**<u>3. Hydrologic modeling</u>** a. Hydrologic Analysis and Flow Control Design/BMPs; Stormwater hydrology models rely on hourly precipitation data for sizing stormwater control facilities. Low Impact Develop (LID) approaches are given credit	Assess WRIA documents to verify that climate change projections, ground-surface water, ecological instream flows are addressed. Revise regulatory statistical flows (such as critical low flows, design storms and flood frequencies) to account for climate change Increasing demand for additional groundwater from aquifers requires long-term monitoring of recharge areas and ground-surface water interaction at representative sites in selected basins. Explore options for funding WRIA grants after 2013 for salmon habitat restoration activities that also incorporate development of ground-surface water information in critical watersheds.	program to monitor and assess larger-scale ambient groundwater conditions. Ensure sufficient data are collected on water supply, use, and discharge to allow for comprehensive water budgets at watershed scale including forecasting
OJBECTIVE 3: Maintain and restore riparian, floodplain, wetland and lake functions.			
Strategy 1.3.1: Identify, map, and monitor essential functions at risk from climate change Actions might include: 1. For floodplain and riparian areas, update flood maps to account for potential climate change impacts,			

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
a. map historic and future floodplains and riparian zones, b. Monitor distribution of focal animal species, changes to vegetation, nutrient levels, c. Identify floodplain areas at increased risk of inundation, d. Identify channels at increased risk of bank erosion and channel migration – reconnect historical channels to reduce damage and provide compensating refugia. e. Identify in-stream bedload transport areas that pose increased susceptibility to direct habitat loss. f. Identify potential areas for long-term habitat enhancement to offset loss. 2. For wetlands, monitor shifts in distribution of wetland-dependent animal species and changes to vegetation. 3. For lakes, monitor shifts in distribution of lake-dependent, animal species and changes to vegetation.			
Strategy 1.3.2: Re-establish connectivity of rivers and floodplains Actions might include: 1. Acquiring flood easements, 2. Restore floodplain capacity by removing artificial constrictions such as levees, tide gates, and undersized culverts. 3. Support barrier and dam removal and	1) WWRP, ALEA, and LWCF Grants for Critical Habitat, Riparian Protection and Natural Areas and Farmland Preservation (RCO) 2) Fish Passage Barrier Removal Program – dedicated I-4 funds, Highway Construction Program (WSDOT / WDFW)	Existing Programs to include criteria that give priority to riparian and floodplain connectivity. Policies to address the timing of acquisition and spatial relation of properties for optimal riverine and habitat connectivity.	

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
river restoration where appropriate. 4. Increase groundwater infiltration by reducing nearby impervious areas. 5. Update floodway regulations to reflect climate change impacts. 6. Incorporate climate change considerations into long range and emergency planning.	3) Flood Damage Protection Grants (WSECY) 4) Floodplain Development Permits – (Local governments, based on National Flood Insurance Program) 5) Washington State Land Acquisition Coordination Board (RCO)		
Strategy 1.3.3: Increase resilience of lakes and wetlands to climate change impacts by maintaining and restoring functions. Actions might include: 1. Establishing buffers, 2. Controlling invasive species 3. Addressing water quality 4. Creating new wetlands to offset anticipated loss or degradation of refugia elsewhere, 5. Managing water levels to reduce fluctuations and to maintain water temperature & chemistry (identify and reduce water diversions, and reintroduce native species such as beaver.	• State water pollution laws and regulations • State water resources laws and regulations • Lake Management Districts • Lake Management Plans • SMA • Noxious weed laws and programs • Volunteer lake monitoring • Dam licensing	• Statewide lake monitoring program • Remote sensing methodologies for lakes • Data on lakes sufficient to support adaptation is limited. •	Monitoring and modeling would be resource intensive to provide statewide coverage of major lakes.
Build necessary scientific and institutional readiness to support effective adaptation			
OBJECTIVE 2.1: Protect and restore streamflow and water levels for ecological function			
Strategy 2.2.1: Manage water uses for adequate flows that maintain freshwater systems at risk from climate change.	• Water acquisition program • Water banks and trusts • State water resources laws and regulations	• Statewide rollout of water banking, trusts, and acquisition programs • Statewide rollout and update	• Improved water monitoring and forecasting (both water users and basin hydrology)

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
Actions might include: 1. Acquiring water rights to put back in streams, lakes, ponds. 2. Establish water banks and improve legal and fiscal frameworks to allow water transfers without increasing climate related stressors. 3. Consider incentives such as fee for water use, promoting conjunctive use of groundwater and surface water, encouraging water conservation, water banks. 4. Employ regulatory tools such as instream flow rules, industrial and agricultural conservation standards, and enforcement of existing regulatory programs. 5. Use planning and policy tools, such as integrating water resource management, stormwater management and land use planning.	• Federal dam licensing • Flow monitoring and modeling programs <u>FUNDING OPTIONS</u> • Water rights fee program • State general fund, grants and loans • Mitigation credit sales Watershed-based tax district	of instream flow rules • Statewide quantification and adjudication of water rights • Statewide enforcement of water resources laws • Improved regulation of groundwater withdrawals • Stricter water conservation standards • Build prioritization into state program implementation based on climate impacts • Inclusion of instream flow benefits into water infrastructure projects, such as ASR, dams, desalinization, etc.	• Integrated watershed, regional and State Water Plans that provide for holistic Integrated Water Resource Management • Insufficient data is available on water use (permitted, exempt, and illegal), stream flows, ground water use, and interactions between ground water and surface water. • Conduct studies, such as the potential for desalination as a water supply and developing integrated water supply and demand forecasting to inform targeted flow restoration efforts.
Strategy 2.2.2: Manage stormwater to protect and restore flow characteristics in light of expected climate change impacts. Actions might include: 1. Creating incentives for more efficient stormwater management, 2. Modifying stormwater regulations to adapt to uncertain future hydrologic conditions, 3. Acquiring land for priority stormwater	• State water pollution laws and regulations • State and federal NPDES stormwater permit programs • Watershed and riparian restoration programs • Stormwater Technical Resources Center (WSU/UW) • Eastern and Western WA Stormwater Manuals • Local government stormwater programs • Puget Sound Partnership LID program	• State and Federal LID performance standards and requirements • Adapt stormwater hydrologic models to changing climate conditions • Stormwater retrofit program for land, design, construction. • Incentive program for stormwater management • Improve Stormwater TMDL Clean up plans	• Understanding of relationship between surface flows, interflows, and deep groundwater. • Basin-scale stormwater hydrologic models • Climate risk analysis plans • Local hydrologic basin modeling data for retrofits •

FRESHWATER	Existing Programs/Tools	New Programs or Policies Needed	Institutional Barriers or Information Gaps
retrofits.		FUNDING OPTIONS • State and Federal grant programs • Dedicated State and Federal funding (e.g. permit fees, hazardous waste fees) • Local Stormwater Utility Fees • Flood District Fees Clean Water District Fees	

Table 4.4

APPENDIX B

Summary of Projected Changes in Major Drivers of Pacific Northwest Climate Change Impacts

Prepared by the University of Washington Climate Impacts Group

December 16, 2010

The information provided below is largely assembled from work completed for the 2009 Washington Climate Change Impacts Assessment. Other sources have been used where relevant but this summary should not be viewed as a comprehensive literature review of Pacific Northwest (PNW) climate change impacts. Confidence statements are strictly qualitative with the exception of IPCC text regarding rates of 20th century global sea level rise. Note that periods of months are abbreviated by each month's first letter, e.g., DJF = Dec, Jan, Feb.

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Temperature	Increasing temperatures expected through 21st century	Projected multi-model change in average annual temperature (with range) for specific benchmark periods: • 2020s: +2°F (1.1 to 3.4°F)** • 2040s: +3.2°F (1.6 to 5.2°F) • 2080s: +5.3°F (2.8 to 9.7°F) These changes are relative to the average annual temperature for 1970-1999. The projected *rate* of warming is an average of 0.5°F per decade (range: 0.2-1.0°F). ---------------------------- *** Mean values are the weighted (REA) average of all 39 scenarios. All range values are the lowest and highest of any individual global climate model and greenhouse gas emissions scenario coupling (e.g., the PCM1 model run with the B1*	Projected warming by the end of this century is much larger than the regional warming observed during the 20th century (+1.5°F), even for the lowest scenarios.	Warming expected across all seasons with the largest warming in the summer months (JJA) Mean change (with range) in winter (DJF) temperature for specific benchmark periods, relative to 1970-1999: • 2020s: +2.1°F (0.7 to 3.6°F)** • 2040s: +3.2°F (1.0 to 5.1°F) • 2080s: +5.4°F (1.3 to 9.1°F) Mean change (with range) in summer (JJA) temperature for specific benchmark periods, relative to 1970-1999: • 2020s: +2.7°F (1.0 to 5.3°F)** • 2040s: +4.1°F (1.5 to 7.9°F) • 2080s: +6.8°F (2.6 to 12.5°F)	High confidence that the PNW will warm as a result of increasing greenhouse gas emissions. All models project warming in all scenarios (39 scenarios total) and the projected change in temperature is statistically significant.	Mote and Salathé 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		emissions scenario).				
Precipitation *(extreme precipitation addressed in separate field)*	A small increase in average annual precipitation is projected (based on the multimodel average, Mote and Salathé 2010), although model-to-model differences in projected precipitation are large (see "Confidence"). Potentially large seasonal changes are expected.	Projected change in average annual precipitation (with range) for specific benchmark periods: • 2020s: +1% (-9 to 12%)** • 2040s: +2% (-11 to +12%) • 2080s: +4% (-10 to +20%) These changes are relative to the average annual temperature for 1970-1999. ---------------------------- *** Mean values are the weighted (REA) average of all 39 scenarios. All range values are the lowest and highest of any individual global climate model and greenhouse gas emissions scenario coupling (e.g., the PCM1 model run with the B1 emissions scenario).*	Projected increase in average annual precipitation is small relative to the range of natural variability observed during the 20th century and the model-to-model differences in projected changes for the 21st century	*Summer:* Majority of global climate models (68-90% depending on the decade and emissions scenario) project decreases in summer (JJA) precipitation. Mean change (with range) in JJA precipitation for specific benchmark periods, relative to 1970-1999: • 2020s: -6% (-30% to +12%) ** • 2040s: -8% (-30% to +17%) • 2080s: -13% (-38% to +14%) *Winter:* Majority of global climate models (50-80% depending on the decade and emissions scenario) increases in winter (DJF) precipitation. Mean change (with range) in DJF precipitation for specific	Low confidence. The uncertainty in future precipitation changes is large given the wide range of natural variability in the PNW and uncertainties regarding if and how dominant modes of natural variability may be affected by climate change. Additional uncertainties are derived from the challenges of modeling precipitation globally. Model to model differences are quite large, with some models projecting decreases in winter and annual total precipitation and	Mote and Salathé 2010; Salathé et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
				benchmark periods, relative to 1970-1999: • 2020s: +2% (-14% to +23%)** • 2040s: +3% (-13% to +27%) • 2080s: +8% (-11% to +42%)	others producing large increases. Expect that the region will continue to see years that are wetter than average and drier than average even as that average changes over the long term.	

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Extreme precipitation	Precipitation intensity may increase but the spatial pattern of this change and changes in intensity is highly variable across the state.	State-wide *(Salathé et al. 2010)*: More intense precipitation projected by two regional climate model simulations but the distribution is highly variable; substantial changes (increases of 5-10% in precipitation intensity) are simulated over the North Cascades and northeastern Washington. Across most of the state, increases are not significant. For sub-regions *(Rosenberg et al. 2010)*: Projected increases in the magnitude (i.e., the amount of precipitation) of 24-hour storm events in the Seattle-Tacoma area over the next 50 years are 14.1%-28.7%, depending upon the data employed. Increases for Vancouver and Spokane are not statistically significant and therefore cannot be distinguished from natural variability.	Projected increases in the magnitude of 24-hour storm events for the period 2020-2050 for the Seattle-Tacoma area (14.1 to 28.7%) is comparable to the observed increases for 24-hour storms over the past 50 years (24.7%) *(Rosenberg et al. 2009).*	The ECHAM5 simulation produces significant increases in precipitation intensity during winter months (Dec-Feb), although with some spatial variability. The CCSM3 simulation also produces more intense precipitation during winter months despite reductions in total winter and spring precipitation *(Salathé et al. 2010)*	Low confidence. Anthropogenic changes in extreme precipitation difficult to detect given wide range of natural precip variability in the PNW. Computational requirements limit the analysis of sub-regional impacts within WA to two scenarios, reducing the robustness of possible results. Simulated changes are statistically significant only over northern Washington.	Salathé et al. 2010 Rosenberg et al. 2009 Rosenberg et al. 2010
Extreme heat	More extreme heat events expected	Generally projecting increases in extreme heat events for the 2040s, particularly in south central WA and the western WA lowlands *(Salathé et al. 2010).*** Changes in specific regions vary with time period (2025, 2045, and 2085), scenario (low, moderate, high), and region (Seattle, Spokane, Tri-Cities, Yakima) but all four regions and all scenarios show increases in the mean annual number of heat events, mean event duration, and maximum event duration *(Jackson et al. 2010, Table 4).* ---------------------------- *** Definitions of extreme heat varied between the two studies cited here. Salathé et al. 2010 defined a heat*	Projected increases in number and duration of events is significantly larger than the number and duration of events between 1980-2006 (specific values vary with location, warming scenario, and time period). In western Washington, the frequency of exceeding the 90th percentile daytime temperature (Tmax) increases from 30 days per year in the current climate (1970-	n/a (relevant to summer only)	Medium confidence. There is less confidence in sub-regional changes in extreme heat events due to the limited number of scenarios used to evaluate changes in extreme heat events in Jackson et al. 2010 (9 scenarios) and Salathé et al. 2010 (2 scenarios), although confidence in warmer summer temperatures overall is high (see previous entry for temperature).	Salathé et al. 2010 Jackson et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		wave as an episode of three or more days where the daily heat index (humidex) value exceeds 90°F. Jackson et al. 2010 defined heat events as one or more consecutive days where the humidex was above the 99th percentile.	1999) to 50 days per year in the 2040s (2030-2059).			
Snowpack (SWE)	Decline in spring (April 1) snowpack expected	The multi-model means for projected changes in mean April 1 SWE for the B1 and A1B greenhouse gas emissions scenarios are: • 2020s: -27% (B1), -29% (A1B) • 2040s: -37% (B1), -44% (A1B) • 2080s: -53% (B1), -65% (A1B) All changes are relative to 1916-2006. Individual model results will vary from the multi-model average.	Projected declines for the 2040s and 2080s are greater than the snowpack decline observed in the 20th century (based on a linear trend from 1916-2006).	n/a (relevant to cool season [Oct-Mar] only)	High confidence that snowpack will decline even though specific projections will change over time. Projected changes in temperature, for which there is high confidence, have the most significant influence on SWE (relative to precipitation).	Elsner et al. 2010
Streamflow	Expected seasonal changes include increases in winter streamflow, earlier shifts in the timing of peak streamflow in snow dominant and rain/snow mix (transient) basins, and decreases in summer streamflow. Increasing risk of extreme high and low flows also expected. In all cases, results will vary by location and basin type.	The multi-model averages for projected changes in mean annual runoff for Washington state for the B1 and A1B greenhouse gas emissions scenarios are: • 2020s: +2% (B1), 0% (A1B) • 2040s: +2% (B1), +3% (A1B) • 2080s: +4% (B1), +6% (A1B) All changes relative to 1916-2006; numbers rounded to nearest whole value *(Elsner et al. 2010)* The risk of lower low flows (e.g., lower 7Q10** flows) increases in all basin types to varying degrees. The decrease in 7Q10 flows is greater in rain dominant and transient basins relative to snow-dominant basins, which generally see less snowpack decline and (as a result) less of a decline in summer streamflow than	During the period from 1947-2003 runoff occurred earlier in spring throughout snowmelt influenced watersheds in the western U.S. *(Hamlet et al. 2007)*.	Projected changes in mean cool season (Oct-Mar) runoff for WA state: • 2020s: +13% (B1), +11% (A1B) • 2040s: +16% (B1), +21% (A1B) • 2080s: +26%(B1), +35% (A1B) Projected changes in mean warm season (Apr-Sept) runoff for WA state: • 2020s: -16% (B1), -19% (A1B) • 2040s: -22% (B1), -29% (A1B) • 2080s: -33%(B1), -43% (A1B) All changes relative to 1916-2006; numbers rounded to nearest whole value. *(Elsner et al. 2010)*	*Regarding changes in total annual runoff:* There is high confidence in the direction of projected change in total annual runoff but low confidence in the specific amount of projected change due to the large uncertainties that exist for changes in winter (Oct-Mar) precipitation. The large uncertainties in winter precipitation are due primarily to uncertainty about the timing of, and any changes in, dominant models of natural decadal variability that influence precipitation	Elsner et al. 2010 Hamlet et al. 2007 Mantua et al. 2010 Tohver and Hamlet 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		transient basins. *(Mantua et al. 2010; Tohver and Hamlet 2010)* Changes in flood risk vary by basin type. Spatial patterns for the 20-year and 100-year flood ratio (future/historical) indicate slight or no increases in flood risk for snowmelt dominant basins due to declining spring snowpack. There is a progressively higher flood risk through the 21st century for transient basins, although changes in risk in individual transient basins will vary. Projections of flood risk for rain dominant basins do not indicate any significant change under future conditions, although increases in winter precipitation in some scenarios nominally increase the risk of flooding in winter. *(Tohver and Hamlet 2010, in draft)* ---------------------------- *** 7Q10 flows are the lowest stream flow for seven consecutive days that would be expected to occur once in ten years.*			patterns in the PNW (e.g. the Pacific Decadal Oscillation) as well as changes in precipitation caused by climate change. *Regarding streamflow timing shifts:* There is high confidence that peak streamflow will shift earlier in the season in transient and snow-dominant systems due to projected warming and loss of April 1 SWE. There is less confidence in the specific size of the shift in any specific basin given uncertainties about changes winter precipitation *(see previous comment)*. *Regarding summer streamflows:* Overall, there is high confidence that summer streamflow will decline due to projected decreases in snowpack (relevant to snow dominant and transient basins) and increasing summer temperatures (relevant to all basin types). There is medium confidence that late summer streamflow will decline given 1) the sensitivity of late	

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
					summer streamflow to uncertain precipitation changes, and 2) uncertainties about if and how groundwater contributions in any given basin may affect late summer flows. For all changes in streamflow, confidence in *specific* projected values is low due to high uncertainty about changes in precipitation and decadal variability.	
Sea level rise	Varying amounts of sea level rise (or decline) projected in Washington due to regional variations in land movement and coastal winds.	Projected global change (2090-2099) according to the IPCC: 7-23", relative to 1980-99 average *(Solomon et al. 2007)*** 2050: Projected medium change in Washington sea level (with range) *(Mote et al. 2008)*: • NW Olympic Pen: 0" (-5-14") • Central & So. Coast: 5" (1-18") • Puget Sound: 6" (3-22") 2100: Projected medium change in WA sea level (with range) *(Mote et al. 2008)*: • NW Olympic Peninsula: 2" (-9-35") • Central & So. Coast: 11" (2-43") • Puget Sound: 13" (6-50") ---------------------------- ** *Since 2008, numerous peer-reviewed studies have offered alternate estimates of global sea level rise. The basis for these updates are*	Relative change in Washington varies by location. Globally, the average rate of sea level rise during the 21st century very likely‡ (>90%) exceeds the 1961-2003 average rate (0.07 ± 0.02 in/year) *(Solomon et al. 2007)* --------------------------- ‡ *= as defined by the IPCC's treatment of uncertainties (Solomon et al. 2007, Box TS1)*	Wind-driven enhancement of PNW sea level is common during winter months (even more so during El Niño events). On the whole, analysis of more than 30 scenarios found minimal changes in average wintertime northward winds in the PNW. However, several models produced strong increases. These potential increases contribute to the upper estimates for WA sea level rise. *(Mote et al. 2008)*	High confidence that sea level will rise globally. Confidence in the amount of change at any specific location in Washington varies depending on the amount of uncertainty associated with the global and local/regional factors affecting rates of sea level rise. Regionally, there is high confidence that the NW Olympic Peninsula is experiencing uplift at >2 mm/yr. There is less confidence about rates of uplift along the central and southern WA coast due to	Mote et al. 2008 Solomon et al. 2007

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		known deficiencies in the IPCC's 2007 approach to calculating of global sea level rise, including assumptions of a near-zero net contribution from the Greenland and Antarctic ice sheets to 21st century sea level rise. A comparison of several studies in Rahmstorf 2010 (Figure 1) shows projections in the range of 1.5ft to over 6ft. Overall, recent studies appear to be converging on projected increases in the range of 2-4ft (e.g., Vermeer and Rahmstorf (2009), Pfeffer et al. 2008, Grinsted et al. 2009, Jevrejeva et al. 2010).			sparse data, but available data generally indicate uplift in range of 0-2mm/yr. There is high uncertainty about subsidence, and rates of subsidence where it exists, in the Puget Sound region. Although annual rates of current and future uplift and subsidence (a.k.a. "VLM") are well-established at large geographic scales, determining rates at specific locations requires additional analysis and/or monitoring. Uncertainties around future rates are unknown and would be affected by the occurrence of a subduction zone earthquake.	

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Wave Heights	Increase in "significant wave height" ** expected in the near term (through 2020s) based on research showing that a future warmer climate may contain fewer overall extra-tropical cyclones but an increased frequency of very intense extra-tropical cyclones (which may affect the extreme wave climate). ------------------ *** "Significant wave height" is defined as the average of the highest 1/3 of the measured wave heights within a (typically) 20 minute period*	Based on extrapolation of historical data[‡] and assumptions that the historical trends continue into the future, the 25, 50, and 100 year significant wave height events are projected to increase approximately 0.07m/yr (2.8 in/yr) through 2020s. ---------------------------- *‡ the five highest significant wave heights measured at Washington NDBC Buoy #46005 (at the WA/OR border)*	Projected changes through 2020 are comparable to the observed increase in the average of the five highest significant wave heights for the mid 1970s-2007 (0.07m/yr, or 2.6 in/yr). *More on past changes:* Over the last 30 years, the rate of increase for more extreme wave heights has been greater than the rate of increase in average winter wave height. For the WA/OR outer coast (mid 1970s-2007): • The average of all winter significant wave heights increased at a rate of 0.023m/yr (0.9 in/yr) • Annual maximum significant wave height increased 0.095m/yr (3.7 in/yr).	These findings relate to the winter season (Oct-March), which is the dominant season of strong storms	*Regarding general trend:* There is low confidence that significant wave height will increase given the dependence of this increase on a limited number of studies showing potential increases in the intensity of the extra-tropical cyclones that can affect the extreme wave climate. *Regarding specific projected increases in wave height:* There is low confidence in the calculated trend for 25, 50, and 100 year significant wave height events given that this calculation is based on extrapolation of historic data and assumptions of continued historical trends rather than physical modeling.	Ruggiero et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
Sea surface temperature (SST)	Warmer SST expected	Increase of +2.2°F projected for the 2040s (2030-59) for coastal ocean between 46°N and 49°N. Changes are relative to 1970-99 average.	Projected change is substantially outside the range of 20th century variability.	*No information currently available*	Medium to low confidence in the degree of warming expected for the summertime upwelling season. Global climate models do not resolve the coastal zone and coastal upwelling process very well, and uncertainty associated with summertime upwelling winds also brings uncertainty to coastal SSTs in summer.	Mote and Salathé 2010
Coastal upwelling	Little change in coastal upwelling expected	The multimodel average mean change in winds that drive coastal upwelling is minimal	Comparable to what has been observed in the 20th century	Little change in seasonal patterns.	Low confidence given the fact that this hasn't been evaluated with dynamical downscaling of many climate model scenarios at this point.	Mote and Salathé 2010
Ocean acidification	Continuing acidification expected in coastal Washington and Puget Sound waters	The global surface ocean is projected to see a 0.2 - 0.3 drop in pH by the end of the 21st century (in addition to observed decline of 0.1 units since 1750) (Feely et al. 2010). pH in the North Pacific, which includes the coastal waters of Washington State, is projected to decrease 0.2 and 0.3 units with increases in the atmospheric concentration of CO2 to 560 and 840 ppm, respectively (Feely et al. 2009). pH in Puget Sound is projected to decrease, with ocean acidification accounting for an increasingly large part of that decline. Feely et al. 2010 estimated that ocean acidification accounts for 24-49% of the pH	Projected global changes are larger than the decrease of 0.1 units since 1750, and greater than the trend in last 20 years (0.02 units/decade). The observed decrease of 0.1 units since 1750 is equivalent to an overall increase in the hydrogen ion concentration or "acidity" of about 26%.	The contribution of ocean acidification to Dissolved Inorganic Carbon (DIC) concentrations within the Puget Sound basin can vary seasonally. Ocean acidification has a smaller contribution to the subsurface increase in DIC concentrations in the summer (e.g., 24%) compared to winter (e.g., 49%) relative to other processes (Feely et al. 2010).	For global changes, confidence that oceans will become more acidic is high. Results from large-scale ocean CO_2 surveys and time-series studies over the past two decades show that ocean acidification is a predictable consequence of rising atmospheric CO_2 that is independent of the uncertainties and outcomes of climate change (Feely et al. 2009).	Feely et al. 2009 Feely et al. 2010

Climate Variable	General Change Expected	Specific Change Expected	Size of Projected Change Compared to Recent Changes	Information About Seasonal Patterns of Change	Confidence	Sources
		decrease in the deep waters of the Hood Canal sub-basin of Puget Sound relative to estimated pre-industrial values. Over time, ocean acidification from a doubling of atmospheric CO2 could account for 49-82% of the pH decrease in Puget Sound subsurface waters.			For Puget Sound, estimates of the contribution of ocean acidification to future pH decreases in Puget Sound have very high uncertainty since other changes that may occur over the intervening time were not taken into account when calculating that estimate (a percentage) (Feely et al. 2010).	

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APPENDIX C: Criteria for Prioritizing Adaptation Actions

Note: Thanks to Lara Whitely-Binder and Dan Siemann for guiding the TAG in developing this criteria.

The following criteria were developed by TAG 3 for selecting and, where relevant, prioritizing adaptation objectives, strategies, and actions. The TAG used these criteria as general guidelines rather than in any kind of strict or quantitative fashion. TAG3 recommends that as implementation is advanced for natural resource climate adaptation strategies, these guidelines continue to be refined.

These criteria were selected because they were helpful in assessing:

- The degree to which a climate change impact needs to be addressed in the state's current adaptation planning effort (*Urgency*);
- If the objective, strategy, or action reflects key characteristics associated with increased climate resiliency, e.g., objectives, strategies, or actions that help reduce vulnerability to climate change while being able to adapt to the changing nature of projected climate change (*Robustness, Flexibility/Reversibility*);
- If, where, and how the benefits of the objective, strategy, or action are likely to be realized (*Risk of Unintended Consequences, Geographic Distribution of Benefits, Secondary Benefits, No/Low Regrets*);
- Considerations for implementing the objective, strategy, or action (*Time Frame for Implementation, Capacity, Window of Opportunity, Geographic Distribution of Benefits, Secondary Benefits, No/Low Regrets);* and, ultimately,
- Whether the objectives, strategies, and actions meet the goals and guiding principles of the TAG (*all of the criteria*).

The criteria are divided into two categories: 1) criteria that broadly evaluate the adaptive nature and relevance of an objective, strategy, or action ("general criteria"); and 2) criteria that relate more specifically to implementation considerations ("implementation criteria"). More information on each of the criteria is provided below and summarized in Tables 1 and 2.

General Criteria (Table 1)

1. ***Urgency*** – The urgency metric asks whether it is important to implement the objective, strategy, or action now as opposed to waiting. The need for urgency may be due to the fact that:
   - the impact (e.g., habitat loss) is occurring now, regardless of whether the presumed cause is climate change or some other driver (e.g., development or growing dominance of an invasive species);
   - it may take time to get all the necessary pieces in place to implement an action (e.g., legislative authorities, funding, and relevant technical data);
   - a specific action is necessary to accomplish other priority objectives, strategies, or actions; and/or

- the opportunity cost of not acting in the near-term is high (e.g., opportunities to preserve critical habitat may be lost while waiting to for sea level to rise a certain amount before taking action)

2. ***Robustness*** – asks whether the objective, strategy, or action is likely to be effective for a broad range of plausible future climate change projections rather than a single or narrow range of projections. Note that a limited range of robustness does not necessarily eliminate a specific objective, strategy, or action; a limited range of robustness may acceptable if, for example, the objective, strategy, or action is flexible and/or easily reversible or the projected impact being addressed by the objective, strategy, or action has potentially significant consequences (i.e., the urgency is high).

3. ***Flexibility/Reversibility*** – asks whether the objective, strategy, or action can be easily adjusted or reversed if future research or other factors indicate that climate impacts are likely to occur in ways not previously anticipated.

4. ***Risk of Unintended Consequences*** – asks whether the objective, strategy, or action could lead to unintended consequences. The potential for unintended consequences may be acceptable if the objective, strategy, or action is flexible or reversible. Risk tolerance will also be a factor in deciding whether the potential for unintended consequences is significant enough to warrant a different choice.

Implementation Criteria (Table 2)

5. ***Time Frame for Implementation*** – this metric is specific to actions and refers to the point in time that the action is considered "up-and-running". Work on securing the things required to implement an action (e.g., changes in law, funding, staffing, partnership building etc) could be happening in the interim period.

6. ***Capacity*** – asks whether current capacity for implementing an objective, strategy, or action is sufficient. Capacity may be determined by many factors, including the availability of funding, staff, and relevant information; access to necessary technical resources; and existing program requirements or limitations.

7. ***Window of Opportunity*** – refers to a unique (and presumably limited) opportunity for implementing an objective, strategy, or action. The window may include an upcoming revision of a strategic plan, law, or policy; allocation of a new funding source; enhancement of on-going initiatives, or other unique opportunities for integrating a recommended objective, strategy, or action into programs or other planning frameworks.

8. ***Geographic Distribution of Benefits*** - asks whether the objective, strategy, or action benefits to a small or large range and/or number of critical ecological functions11 or uniquely valuable species. Having a limited range of benefits does not necessarily reduce the value of that objective, strategy, or action since a place-specific ecological function or uniquely valuable species is important in its own right. The metric is simply a reflection of how broadly the objective, strategy, or action applies.

9. ***Secondary Benefits -*** asks whether the objective, strategy, or action provides benefits to other program or community goals beyond the primary goal of helping critical ecological functions or uniquely valuable species adapt to climate change. For example, "Re-establish connectivity of rivers and floodplains" (Freshwater/Aquatic Strategy) has the primary goal of improving habitat for aquatic and terrestrial species but also provides secondary benefits that include reducing flood risk and improving water quality. The absence of secondary benefits does not negate the value of the objective, strategy, or action, but could be a factor when prioritizing for implementation.

10. ***No/Low Regrets*** – asks whether an objective, strategy, or action is likely to provide adaptation or other benefits if climate change impacts occur in ways not previously anticipated. Although similar to "Secondary Benefits", this metric recognizes that both no/low regrets and high regrets objectives, strategies, and actions can provide secondary benefits. Consequently, "No/Low Regrets" is listed as a separate criterion that may be particularly useful when deciding which subset of objectives, strategies, and actions will be implemented in the near term.

Table 1: General Criteria

Note: "Action" should be interpreted as "objective, strategy, or action" depending on what is being evaluated.

CRITERIA	Low	Medium	High
Urgency	Low	Medium	High
Robustness	The action is effective for a narrow range of plausible future climate scenarios	(this cell left intentionally blank)	The action is effective for a wide range of future climate scenarios
Flexibility/ Reversibility	The action cannot be easily adjusted and/or reversed	The action is somewhat adjustable and/or reversible	The action can be easily adjusted and/or reversed
Risk of Unintended Consequences	The action has a high known risk of causing negative unintended consequences	The action has some known risk of causing negative unintended consequences	The action has little to no known risk of causing negative unintended consequences

Table 2: Implementation Criteria

Table note: "Action" should be interpreted as "objective, strategy, or action" with the exception of "Time Frame for Implementation", which applies specifically to actions.

CRITERIA	Low	Medium	High
Time Frame for Implementation	The action is not likely to be implemented for 5 or more years	The action is likely to be implemented in 3-5 years	The action can be implemented in 1-3 years
Capacity	Current capacity insufficient and gaps cannot be easily addressed.	Gaps exist in one or more areas but can be addressed.	Current capacity is largely sufficient.
Window of Opportunity	There is currently no window of opportunity for implementing the action	A window of opportunity can be created for implementing the action	A window of opportunity exists for implementing the action
Geographic Distribution of Benefits	The action benefits a very small geographic range and/or number of species (e.g. site specific)	The action benefits a sizeable geographic range and/or number of species (e.g., regional)	The action benefits a very wide geographic range and/or number of species (e.g., statewide)
Secondary Benefits	The action has no additional benefit(s) beyond the initial goal of helping critical ecological functions or uniquely valuable species adapt to climate change.	(this cell left intentionally blank)	The action provides additional benefit(s) beyond the initial goal of helping critical ecological functions or uniquely valuable species adapt to climate change.
No/Low Regrets	The action has no adaptation benefit(s) if climate change impacts occur in ways not previously anticipated	(this cell left intentionally blank)	The action provides adaptation benefit(s) even if climate change impacts occur in ways not previously anticipated

Note that some metrics presented here are binary in nature and therefore do not have a "medium" description. For example, it is easier (absent the use of models for testing) to qualitatively assess if an objective, strategy, or action is robust for a small vs. large range of future climate scenarios than to try to determine robustness for a small, medium, and large range of scenarios. Similarly, trying to distinguish between a medium versus high level of benefit would be hard to do in a meaningful way. Consequently, the Secondary Benefits and No/Low Regrets criteria simply ask if benefits are, or are not, expected.

APPENDIX D: GLOSSARY OF CLIMATE CHANGE ADAPTATION CONCEPTS AND TERMS[12]

Note that this glossary defines these terms specifically in the context of climate change and that many have different or broader meanings in other contexts.

Adaptation – Adjustment in natural or human systems in response to actual or expected climatic changes and associated effects that minimizes harm or takes advantage of beneficial opportunities.

Adaptive Capacity – The ability of a system to adjust to climatic changes and associated effects (including social, economic, and ecological), to moderate potential damages, to take advantage of opportunities, and to cope with the consequences.[i]

Climate Change – Any long-term change in average climate conditions in a place or region, whether due to natural causes or as a result of human activity.

(Climate) Impacts Assessment – The practice of identifying and evaluating the detrimental and beneficial consequences of climate change on natural and human systems.

Climate Variability – Variations in the mean state of the climate and other statistics (such as standard deviations, the occurrence of extremes, etc.) on all temporal and spatial scales beyond that of individual weather events, such as the occurrence of a particularly wet or dry year.

Co-benefits – Benefits that go beyond the primary intended benefits of a particular policy, or benefits of policies designed to address multiple concerns simultaneously. For example, restoring wetlands to minimize flood risk has the co-benefit of increasing waterfowl habitat. Reducing greenhouse gas emissions from driving has the co-benefit of improving air quality.

Impact (of climate change)– Any consequence of climate change on a system, species, etc., including effects on structure, composition, or function.

Maladaptation - An action or strategy that increases rather than decreases vulnerability to climate change or its effects.

Mitigation – In the climate change community, a human intervention to reduce the sources or improve the uptake (sinks) of greenhouse gases. In the disaster community, human intervention to minimize harm.

No-regrets policy – A policy that would generate net social benefits regardless of climate change or the effectiveness of the policy in achieving its primary goal.

Refugium (pl. refugia) - An area where climatic change is relatively less rapid or extreme (e.g., due to physical landscape features, such as north-facing slopes, valleys or other low areas that

[12] Definitions adapted from the California Climate Adaptation Strategy, 2009, and also provided by TAG3 members.

serve as sinks for cold air, or streams fed by deep coldwater springs). Refugia can serve as strongholds for species that can no longer survive elsewhere.

Resilience – The ability of a population or system to bounce back to something like its previous state following disturbance or change. Resilience can also applied to managing ecosystems and species to make them more able to recover from disturbance.

Resistance – The ability of a population or system to remain relatively unaffected by climatic change and associated effects. Resistance can also be applied to managing ecosystems and species to make them more able to resist the effects of global climate change.

Response – In the context of adaptation, the longer-term shifts in ecosystems or species as a result of climate change or its effects, for example changes in a species' geographic range or in the species and systems that make up an ecosystem. Response can also be applied to managing species or system responses to maintain desired resources or ecosystem services over time. The philosophy is essentially one of facilitating natural responses to change rather than trying to maintain the status quo.

Risk (climate-related) – The possibility of interaction of physically defined hazards with the exposed systems; the combination of the likelihood of an event and its consequences – i.e., the probability of climate hazard occurring multiplied the consequences a given system may experience.

System – A human community or an ecosystem; a social, economic, cultural, or natural complex; a group of interacting natural resources, species, infrastructure, or other assets.

Vulnerability – In the most general sense, susceptibility to harm or change. More specifically, the degree to which a system is exposed to, sensitive to, and unable to cope with the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, as well as of non-climatic characteristics of the system, including its sensitivity, and its coping and adaptive capacity.

Vulnerability Assessment – A practice that identifies who and what is sensitive to change, how much change they are exposed to, and how able a given system is to respond to the changes that occur (including variability and extremes). A vulnerability assessment considers the intrinsic and extrinsic factors that govern the exposure and sensitivity of species, communities, or ecosystems to change, and the ability of the species or system to successfully adapt (evolutionarily, behaviorally, physiologically, socially, economically, and so on).

APPENDIX E: Science Summaries for four ecological systems

(NOT INCLUDED IN THIS DOCUMENT)