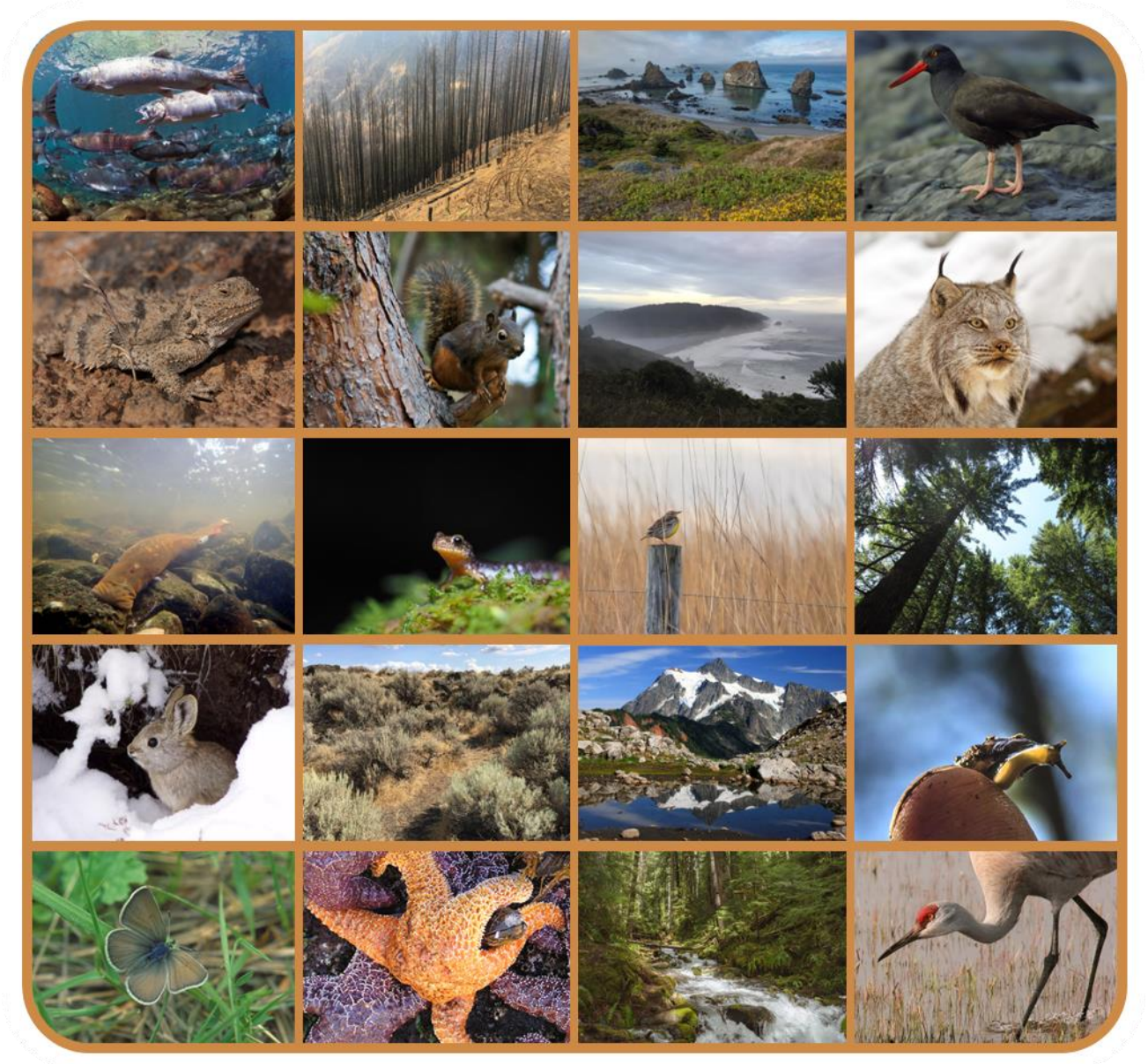
NORTHWEST
Climate Adaptation
Science Center

Science Agenda for 2025-2030



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Glossary

Several of the following terms can be challenging to define given their broad use by various communities and institutions. We provide these definitions in the context of the NW CASC Science Agenda and recognize that there are alternatives and nuances that may not be captured here.

Actionable Science: Scientific information or products useful to and usable by end-users and others interested in applying science and/or Indigenous Knowledges in direct support of a resource-management decision, action, or plan (Bamzai-Dodson et al. 2021).

Adaptive Capacity: The ability of a species or population to cope with or adjust to changing conditions, either by persisting in place (acclimating to new conditions *in situ*) or shifting in space to track more suitable conditions across the landscape (Thurman et al. 2020).

Climate Adaptation: The process of responding to current impacts of climate change and/or planning for the range of plausible future climate conditions to moderate ecological impacts or take advantage of beneficial opportunities.

Co-production: The process of creating new knowledge through collaboration between scientists and those who use science to make policy and management decisions, with the intention of making the science usable (or actionable) in practice. In a co-produced research process, researchers and decision-makers work together throughout the lifecycle of a project to identify a research question, design the research process, and share the results.

Co-stewardship: Refers to collaborative or cooperative arrangements between U.S. Department of the Interior bureaus and offices and Tribes and Alaska Natives related to shared interests in managing, conserving, and preserving federal lands and waters. This approach aims to integrate traditional ecological knowledge with modern conservation practices to enhance ecosystem health and resilience (US DOI 2023a, Stagner 2024).

Decision Support: Methods, tools, and other knowledge resources that facilitate the understanding and selection of climate adaptation options for planning and management (Schwartz et al. 2018).

Ecosystem Transformation: Significant changes in the natural environment resulting in the emergence of a new ecosystem (i.e., a self-organizing, self-sustaining, social–ecological system) that deviates from prior ecosystem composition, structure, and function (Lynch et al. 2021).

Federal Trust Responsibility: The legal obligation of the federal government, including all departments and agencies, to ensure the protection of Native American Tribes and Tribal lands, assets, resources, treaty, and reserved rights. Given the fiduciary obligation, agency officials must advocate for the Tribe, act in good faith towards the Tribe, and seek to make Tribal resources under the agency's control productive and profitable (Cherokee Nation v. Georgia, 30 U.S. 1, 16 [1831], Seminole Nation v. United States, 316 U.S. 286, 296-97 [1942], United States v. Jicarilla Apache Nation, 131 S. Ct. 2313, 2324-25 [2011], Secretarial Order 3335).

First Foods: Regionally specific foods, fibers, medicines, and technologies that Indigenous Peoples have relied on and have a reciprocal relationship with since time immemorial. Access to First Foods, medicines, and harvesting practices is central to the health of Indigenous Peoples – physically, mentally, and spiritually (STACC 2021).

Human Dimensions of Climate Adaptation: An interdisciplinary approach to understanding how individual or community knowledge, values, behaviors, and other social factors influence management of specific natural resources and decision-making around climate adaptation. This document uses human dimensions in a broad sense to refer to the application of a variety of social science fields to the challenge of climate adaptation (see Bennett et al 2017).

Indigenous Knowledges: A body of observations, oral and written knowledge, innovations, technologies, practices, and beliefs developed by American Indians and Alaska Natives through interaction and experience with the environment. It is applied to phenomena across biological, physical, social, cultural, and spiritual systems. Indigenous Knowledges can be developed over millennia, continues to develop, and includes understanding based on evidence acquired through direct contact with the environment and long-term experiences, as well as extensive observations, lessons, and skills passed from generation to generation. Indigenous Knowledges is developed, held, and stewarded by Indigenous Peoples and is often intrinsic within Indigenous legal traditions, including customary law or traditional governance structures and decision-making processes. Other terms such as Traditional Knowledge(s), Traditional Ecological Knowledge, Genetic Resources associated with Traditional Knowledge, Traditional Cultural Expression, Tribal Ecological Knowledge, Native Science, Indigenous Applied Science, Indigenous Science, and others, are sometimes used to describe this knowledge system (US DOI 2023b).

Resist-Accept-Direct (RAD): A menu of options that encompasses the full decision space for managing transforming systems ranging from *resisting* change, to *accepting* change, to *directing* the trajectory of change (Lynch et al. 2021; also see Thompson et al. 2021, Schuurman et al. 2022).

Tribal Sovereignty: The inherent authority of American Indians and Alaska Natives to govern themselves; any decisions that could impact their property or citizens must be made with their

participation and consent (NCSL 2013). The powers lawfully vested in a Native American Tribe are not, in general, delegated powers granted by express acts of Congress but are inherent powers of a limited sovereignty which has never been extinguished. What is not expressly limited [by Congress] remains within the domain of Tribal sovereignty (General Principles of Federal Indian Law | Tribal Governance (uaf.edu).

I. Introduction

The Northwest Climate Adaptation Science Center (NW CASC) was established to help safeguard the natural and cultural resources of Idaho, Oregon, and Washington by working with partners to produce accessible and actionable science on climate change impacts and adaptation. The NW CASC is one of nine regional Climate Adaptation Science Centers (CASCs) under the direction of the Department of the Interior (DOI) United States Geological Survey (USGS). Through multi-year cooperative agreements, CASCs operate as partnerships between the USGS and a consortium of university and non-university partners to ensure access to broad and deep scientific expertise, production of research products tailored to partner needs, and sharing of funds, resources, and facilities. The NW CASC is hosted by the University of Washington on behalf of a consortium that includes the Affiliated Tribes of Northwest Indians, Boise State University, Northwest Indian College, Oregon State University, Portland State University, University of Montana, Washington State University, and Western Washington University (Figure 1).

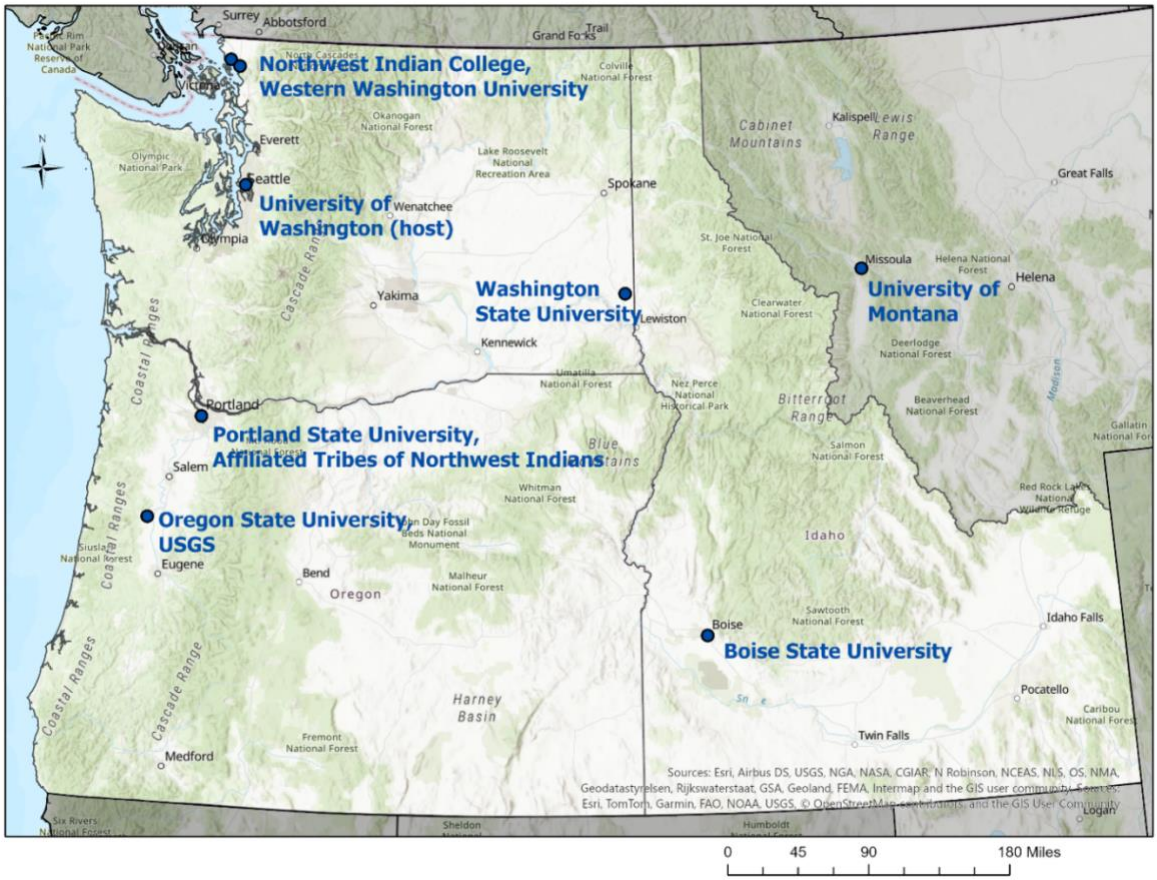

Figure 1. The Northwest Climate Adaptation Science Center geographic footprint and locations of university and non-university consortium members.

The NW CASC works closely with DOI bureaus, including the Bureau of Indian Affairs, Bureau of Land Management, Bureau of Reclamation, National Park Service, and U.S. Fish and Wildlife Service. We also partner with other federal, state, and local government agencies, universities and research institutes, Northwest Tribes and inter-tribal organizations, and non-governmental organizations across the region. These partners identify regional climate adaptation priorities and provide institutional, cultural, and scientific expertise that guides the NW CASC's work and informed the development of the NW CASC Science Agenda for 2025-2030.

The NW CASC science investments are guided by this Science Agenda, which identifies priority species and ecosystems, management challenges, research stages, and desired products and outcomes for our region. The Science Agenda also outlines our approach of supporting actionable, co-produced science to develop, synthesize, and share climate adaptation knowledge and tools. The NW CASC builds climate adaptation knowledge and capacity using several approaches:

- Annual project solicitations and directed funding for NW CASC consortium and USGS scientists
- NW CASC Deep Dives
- NW CASC Research Fellowship Program
- NW CASC Faculty Fellowship Program
- Northwest Regional Invasive Species and Climate Change Network
- Cross-CASC climate adaptation efforts
- Workshops, trainings, and technical services

The NW CASC Advisory Committee, which includes representatives of state, federal, and Tribal resource management agencies located in the Northwest (Appendix A), was instrumental in the development of this Science Agenda (Appendix B). The Advisory Committee meets regularly to identify climate-related management priorities, articulate science needs, and ensure that NW CASC-funded initiatives are useful, relevant, and of value to regional managers of cultural and natural resources. This Science Agenda has been designed as a "living document" that can be updated as climate adaptation science and practice advance.

II. Science Agenda Overview

NW CASC Mission

Deliver science to help fish, wildlife, water, land, and people adapt to changing climate.

Guiding Principles

The Science Agenda rests on seven guiding principles that influenced its development and will steer its implementation (Figure 2). These principles are based on the USGS Guiding Principles and reflect the NW CASC's purpose, foundational values, and operating principles.

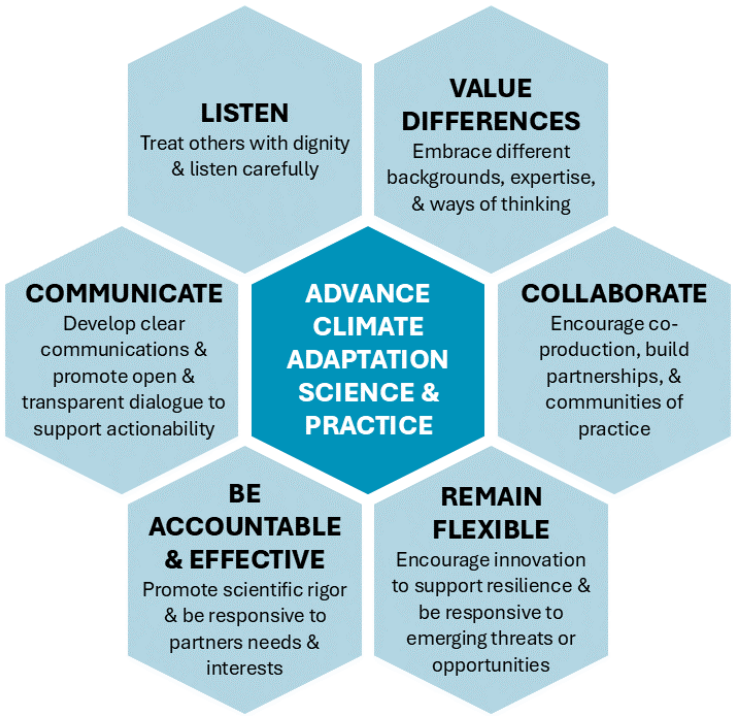

Figure 2. The Northwest Climate Adaptation Science Center 2025-2030 Science Agenda Guiding Principles.

Science Agenda Framework

The NW CASC Science Agenda describes a range of topics, approaches, and best practices for strategically addressing climate change impacts and adaptation challenges in the Northwest. The Science Agenda Framework (Figure 3) offers a high-level overview of the priority species and ecosystems, resource management challenges, research stages, and desired products and outcomes for our region, as well as important cross-cutting considerations. The framework was designed to be a flexible blueprint with various "entry points" for resource managers and researchers. Although the steps of this cycle are presented in a linear fashion, we recognize that—depending on the state of knowledge on a particular adaptation topic—one may enter the framework at various points, emphasize various aspects of this framework, or even use an alternative sequence of framework components.

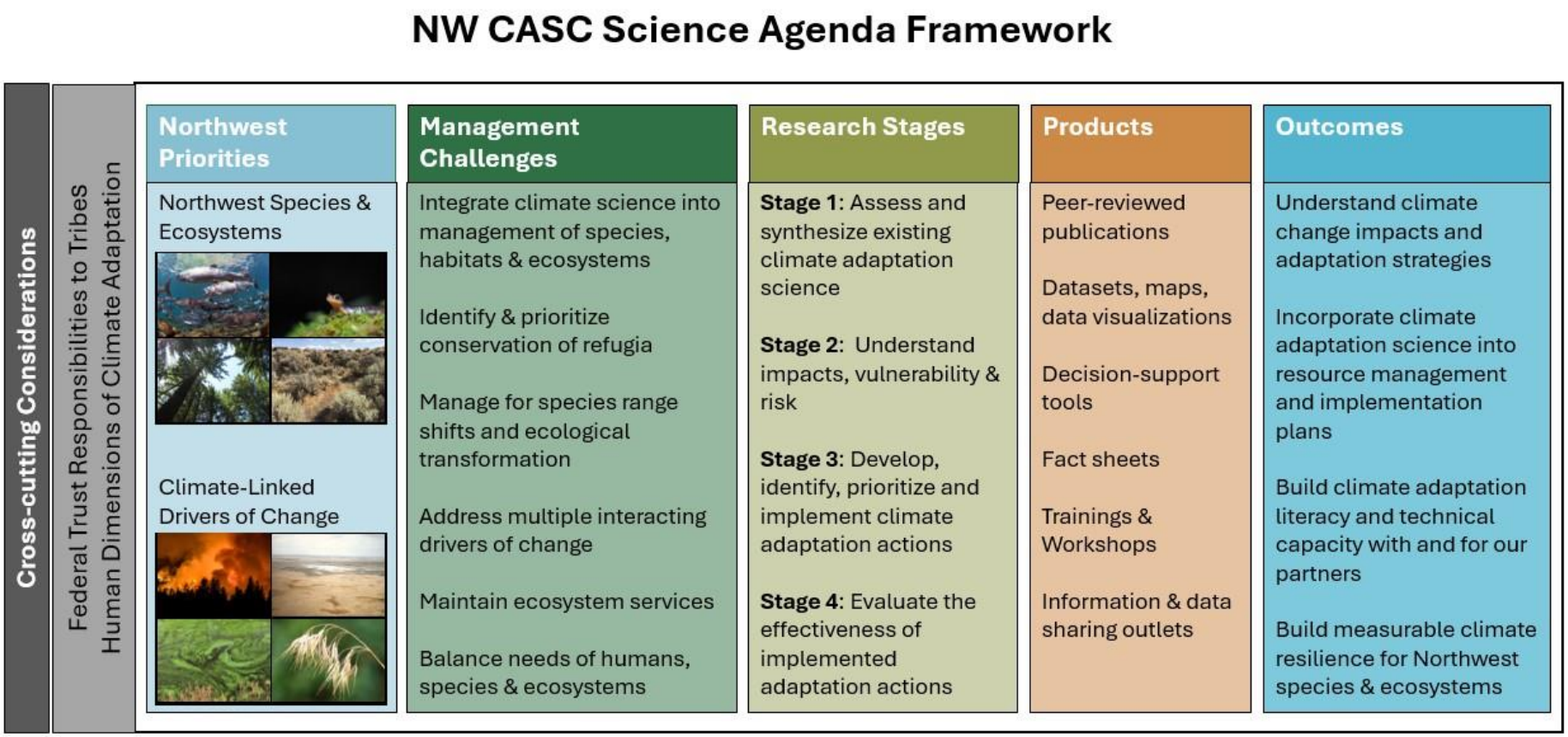

Figure 3. The Northwest Climate Adaptation Science Center 2025-2030 Science Agenda Framework.

Cross-Cutting Considerations

The Science Agenda framework contains two cross-cutting considerations: Federal Trust Responsibilities to Tribes and Human Dimensions of Climate Adaptation. **Although not every project will address these considerations explicitly, our goal is to integrate these considerations throughout our portfolio of funded research.** Each is its unique body of knowledge, and each encompasses some avenues of study that would fall outside of the mission scope of the NW CASC. However, all have points of intersection with the work we do and for legal, and scientific reasons merit consideration during project development.

Federal Trust Responsibility to Tribes

Indigenous Peoples have strong relationships with the lands and waters of the Pacific Northwest. They rely on the natural environment to sustain their families, communities, traditional ways of life, cultural identities, and governments. As Europeans settled in North America, many Indigenous Peoples were forced to cede large tracts of their homelands or forced from homelands completely, disrupting their connection to their lands and resources. (Farrell et al. 2021, Affiliated Tribes of Northwest Indians website)

Climate change further magnifies challenges affecting Indigenous Peoples and their resources, rights, and cultures. Increased drought, wildfires, ocean acidification, and sea level rise are profoundly impacting the relationship that Indigenous Peoples have with lands and waters. (Affiliated Tribes of Northwest Indians Website: Climate Change)

The NW CASC seeks to provide support for Tribal climate adaptation science and planning that promotes Tribal resilience. Our goal is to move beyond supporting the occasional project involving Tribes to a more holistic approach of seeking opportunities to partner and promote climate resilience for Tribes when and where relevant across our science portfolio. Likewise, we want to develop science that addresses the climate adaptation challenges of individual Tribes, recognizing that Tribes across the Northwest region have different priorities and are at different stages of planning with respect to climate adaptation.

Furthermore, we seek to support science related to co-stewardship of land and foster new connections for co-stewardship, including supporting Tribal data stewardship and sovereignty. We recognize that many Tribal Nations and Indigenous communities are on the leading edge of climate adaptation planning and mitigation efforts through application of Indigenous Knowledges. Tribal Nations and Indigenous communities have improved the health and resilience of their communities and ecosystems in important and lasting ways through their knowledge of land stewardship and implementation of climate adaptation strategies. Recent partnerships between Tribes and federal land management agencies have also demonstrated that, in “braiding” Western Science and Indigenous Knowledges many co-benefits can be realized (Eisenberg et al. 2024). We provide guidance for both Tribal scientists seeking to work with the NW CASC as well as non-Tribal scientists interested in working with Tribes or on Tribal lands in Section III.

The federal Indian trust responsibility is a legally enforceable fiduciary obligation of the United States government to honor, uphold, and protect Tribal treaty and reserved rights, resources, assets, and land. The United States also has a duty to carry out the mandates of federal law and special

commitments with respect to American Indian and Alaska Native Tribes and villages (BIA 2017). The United States "has charged itself with moral obligations of the highest responsibility and trust toward Indian Tribes" (Seminole Nation v. United States, 1942).

The USGS has a federal trust responsibility to American Indian and Alaska Native Tribal governments (FCNL 2016) and has recognized the importance of Indigenous Knowledges and living in harmony with nature as compliments to the USGS mission to better understand the Earth (USGS No Date). This responsibility includes the protection of Indian trust lands and Indian rights to use those lands, the protection of Tribal sovereignty and rights of self-governance, and the provision of basic social, medical, and educational services for Tribal citizens. The NW CASC strives to build awareness of Tribal science needs, provide support for research that enhances climate adaptation of Tribes and Indigenous Peoples in the Northwest, and upholds government-to-government relationships with Tribal Nations. The 2025-2030 Tribal & Indigenous Peoples Engagement Strategy (citation – currently in draft) was developed to guide the NW CASC in achieving these goals.

Federal Trust Responsibilities to Tribes – NW CASC Commitments

- *Contribute to a climate adaptation community of practice that understands the treaty and trust obligations the federal government has to Tribal Nations and recognizes the reserved rights of federally recognized Tribes to use and access cultural resources.*
- *Encourage ongoing and sustained relationship building and knowledge sharing among Tribal and non-Tribal resource managers, practitioners, scientists, and communities with a focus on shared goals and mutual benefits.*
- *Listen to Tribal members to understand their climate information needs and support research that fulfills federal obligations to Tribal Nations (e.g., expand baseline data collection, climate vulnerability assessments, and monitoring of First Foods, land, air, and water).*
- *Support research that respectfully engages with Tribes, promotes Tribal climate adaptation leadership, protects Indigenous Knowledge and data sovereignty, and alleviates the burdens of time, resources, emotional labor, and funding on Tribal partners through fair compensation.*
- *Expand, seek, and increase our knowledge, opportunities, and training of Tribal rights, sovereignty, self-determination, and Tribal climate priorities in the Northwest.*
- *Support Tribes in their roles and responsibilities towards sustainability of First Foods in the face of climate change.*

Human Dimensions of Climate Adaptation

Human behavior, values, power dynamics, and knowledge influence government, academic, industry, individual, and community decision-making, planning, implementation, comprehension, and acceptance of science and management actions. This means in many cases that climate adaptation science cannot fully explain drivers or outcomes without considering these types of human dimensions. Similarly, we recognize the need to better understand the human dimensions for our science to be impactful and actionable, as these factors influence who uses information, how and why. Social science and interdisciplinary projects that incorporate strong social science dimensions are also

important for understanding what affects the efficacy of climate adaptation actions. As a result, human dimensions of climate adaptation are a cross-cutting consideration that may be important to projects across management challenges, research stages, and the multitude of Northwest ecosystems and species.

The NWCASC seeks to support a range of human dimension inquiries. Some projects will rely on social science methods as one part of a larger interdisciplinary project. Other projects may focus on social, economic, cultural, institutional, or behavioral aspects that are important to climate adaptation in the region as causes, outcomes, or feedbacks with other parts of the ecological system. We are also interested in improving processes by which scientists in the region conduct actionable science and co-produce research with partners. As appropriate, we will fund projects that investigate the practice of scientific inquiry. Knowledge gained from these inquiries can provide a more nuanced understanding of barriers, opportunities, and cause and effect in climate adaptation, as well as help us better communicate our science, target our trainings, and assist in broadening the use and effectiveness of climate adaptation science.

We provide guidance for scientists seeking to incorporate human dimensions into their projects in Section III.

Human Dimensions of Climate Adaptation – NW CASC Commitments

- *Support the study of a range of* social, economic, cultural, institutional, or behavioral aspects *in climate adaptation, both as interdisciplinary components of larger projects (e.g., indicators of a climate-adapted ecosystem) and as objectives in themselves (e.g., effects of historical management actions on climate adaptation of contemporary ecosystems).*
- *Expand our understanding of ecological and environmental decision-making spaces (e.g., the values, knowledge, and social dynamics that shape human behavior/decisions, barriers to or opportunities for climate adaptation within these spaces).*
- *Support science that represents new challenges or novel areas of inquiry for human dimensions researchers, such as studies that seek to assess feedbacks between human behavior and changing ecological conditions or processes.*

Northwest Priority Ecosystems & Species

The NW CASC's mission is to help species, ecosystems, lands, waters, and people adapt to a changing climate. State, Tribal, and federal natural resource management agencies are all stewards of these resources across the Northwest, and each plays a different but complementary role in resource management. Unless preempted by federal authority (e.g., Endangered Species Act [ESA], Marine Mammal Protection Act, Migratory Bird Treaty Act), states possess primary authority and responsibility for protection and management of fish and wildlife. However, species occurring in some areas, such as National Parks or National Wildlife Refuges, are typically managed by the relevant federal land management agency. Further, many Tribes also retain the right to manage species within their reservation boundaries and retain rights to hunt, fish, and harvest in off-reservation areas. Ultimately, coordination and cooperation among federal, state, and Tribal agencies is necessary for successful conservation and management of fish, wildlife, plants, and their habitats.

Priority Ecosystems

The ecosystems of the Northwest range from moist maritime forest to arid shrub-steppe and from high elevation talus slopes to hardwood riparian forest. Climate change impacts (Appendix C) vary across these systems and are presenting new challenges for resource managers. NW CASC Advisory Committee members identified six major ecosystem classes and specific habitats or subclasses considered to be current management priorities for their respective agencies and Tribes, including:

<table>
<tr>
<td>  </td>
<td>Aquatic
Streams and rivers
Lakes and ponds
Riparian areas
Forested wetlands
Vernal pools
Cold water refugia</td>
<td>  </td>
<td>Coastal
Marine coastlines and nearshore habitats
Rocky intertidal zones
Estuaries
Sandy coastlines</td>
</tr>
<tr>
<td>  </td>
<td>Alpine & Sub-Alpine
High montane forests
High montane mesic meadows
Lower montane forests</td>
<td>  </td>
<td>Grasslands
Willamette Valley prairies
Western Washington prairies
Palouse Prairie</td>
</tr>
<tr>
<td>  </td>
<td>Forests & Woodlands
Temperate rain forests dominated by Douglas fir & Western hemlock
Mixed conifer forests
Drier ponderosa and lodgepole pine
Aspen
Oak woodlands
Juniper woodlands
Whitebark pine</td>
<td>  </td>
<td>Sagebrush Steppe
Perennial bunchgrasses
Large, intact areas of dry shrubland
Mesic areas in shrublands (e.g., vernal pools, playas, saline lakes
Sand dunes
Greasewood flats
Salt desert scrub</td>
</tr>
</table>

Figure 4. Northwest priority ecosystems identified by the NW CASC Advisory Committee.

While urban areas are not a primary focus of the NW CASC, green infrastructure and green spaces provide benefits to some Northwest priority species (e.g., monarch butterfly, other pollinators), and maintaining and improving these benefits in a changing climate is also a priority.

Priority Species

As noted above, responsibility for managing fish and wildlife in the United States is divided between the federal government, states, and Tribal partners. Resource managers participating on the NW CASC Advisory Committee identified some of their agency's priority management species. We also look to documents published by our partners identifying declining species, species of conservation concern, and federal and state listed species. The ESA provides federal guidelines for the protection of endangered and threatened species. However, state agencies are chief stewards for the wildlife within their borders and often possess scientific data and valuable expertise on the status and distribution of endangered, threatened, and candidate species of wildlife and plants.

State fish and wildlife agencies in the NW CASC region have developed State Wildlife Action Plans (SWAPs) to strategically conserve and manage the individual states' most at-risk fish, wildlife, and plants (identified as Species of Greatest Conservation Need) and the habitats on which they depend. Guidance on voluntary conservation actions needed for these species and habitats emphasizes prevention of future listings of these species under the ESA. For more information on species and habitats of conservation concern in the NW CASC region, see the Idaho SWAP, Oregon SWAP, Washington SWAP, state lists of threatened and endangered species in Oregon or Washington, and the federally listed species by state.

Climate-Linked Drivers of Ecological Change

Natural and cultural resources in our region are often impacted by multiple interacting stressors and drivers of ecological change. NW CASC partners and advisors indicated that understanding and addressing the following climate-linked drivers of change, as well as interactions among those drivers and compounding threats, are high priorities for implementing effective climate adaptation actions. For a more extensive review of climate change effects and trends in the Northwest see Appendix C. Resource managers participating on the NW CASC Advisory Committee identified five key drivers of change and additional stressors that they considered to be of paramount concern to their respective agencies (Figure 5).

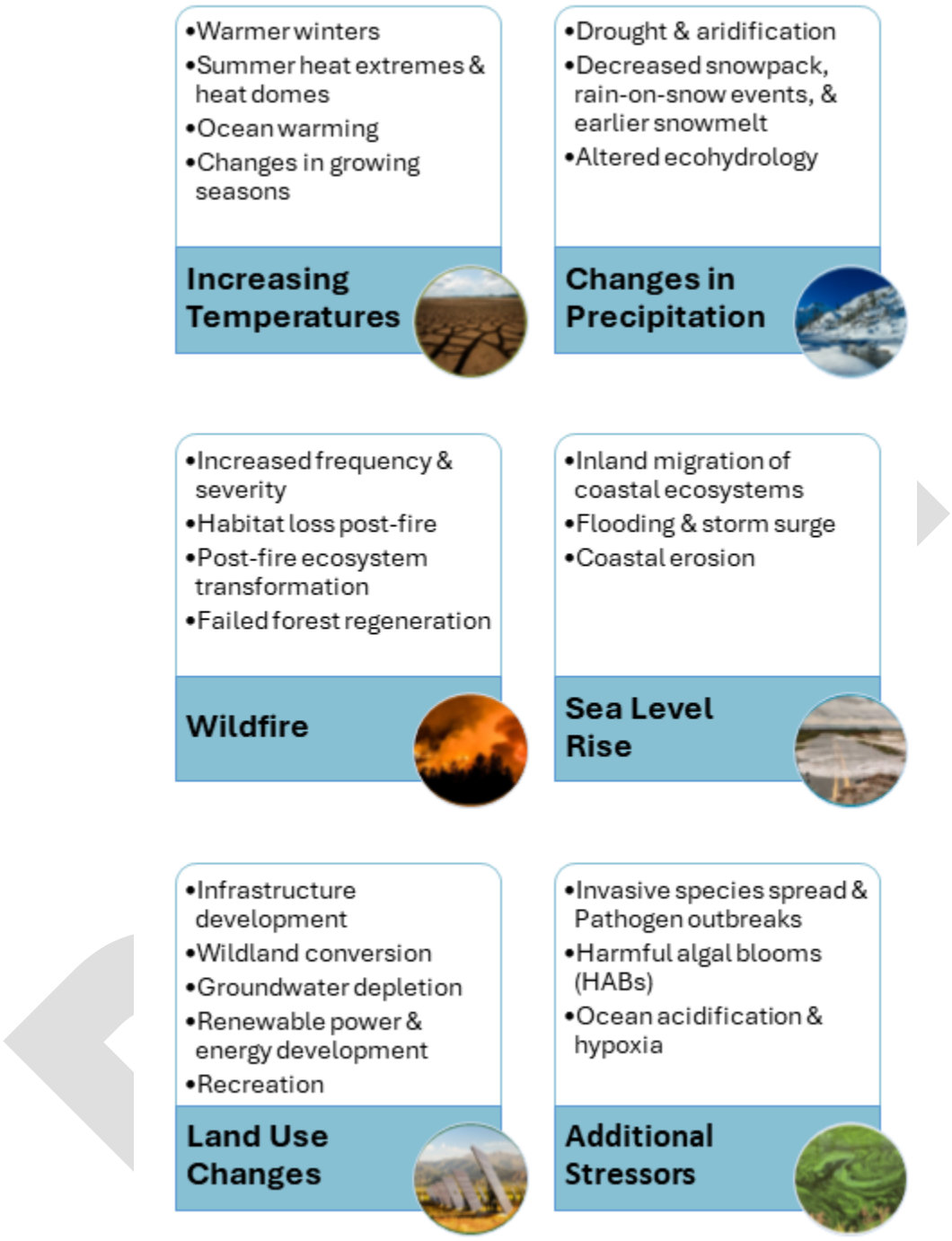

Figure 5. Examples of high priority, climate-linked drivers of change identified by resource managers in the Northwest.

Increasing temperatures

As temperatures in the Northwest increase, managers are facing challenges ranging from loss of glaciers and earlier snowmelt to increased summer heat waves and warming ocean temperatures. Increasing temperatures are affecting water availability, stream permanence, loss of habitat for snow-dependent species, and changes in growing seasons that can lead to mismatches in phenology (e.g., flowers and pollinators) resulting in negative impacts to species in the Northwest.

Changes in precipitation

Precipitation under future climate scenarios is expected to continue to have large interannual variability. Timing and amounts of precipitation are also projected to change, with more extreme storms and longer dry spells. Reduced winter snowpack, reduced summer stream flows, and increased evapotranspiration (USGCRP 2023) will compound the effects of increasing temperatures on water availability. Loss of water resources and changes in water availability affect fisheries, forestry, agriculture, and recreation across the region. Frequency of extreme precipitation events is projected to increase, with increased flooding risks in fall and winter.

Wildfire

In the western United States, climate conditions have grown hotter and drier during the last several decades. Larger, more frequent and severe wildfires and longer fire seasons are impacting forests, grasslands, and sagebrush-steppe, resulting in forest regeneration failures and post-fire ecosystem transformations. Secondary climate-related factors, such as invasive bark beetles, have made many forests more susceptible to high severity fire.

Sea level rise

Under all future climate scenarios, sea level is projected to increase across the Northwest, although net sea level changes will vary by location. Wave height and tidal surge are also projected to increase. Relative to the 1991–2009 average, sea levels in the Northwest are projected to rise 0.6 to 1.0 feet by 2050 for the Intermediate and High emissions scenarios, respectively placing physical structures and communities at risk. Inland migration of coastal species and habitats is anticipated with rising sea levels (USGCRP 2023).

Land use changes

Land use change, particularly transformations from natural systems to human-dominated systems, are stressors that can interact with and compound the effects of climate change. Infrastructure development, wildland conversion, renewable energy/power development and operations, and mineral development are all activities that resource managers need to address to restore and maintain healthy ecosystems in the face of climate change.

Additional stressors

Environmental stressors are processes or activities that impair the ability of species to meet their life history needs or affect the ability of ecosystems and communities to function. Species or individuals may become more susceptible to disease while ecosystems can become more vulnerable to invasive species and wide-ranging pathogens. Northwest managers have identified tree diseases, bark beetles, and harmful algal blooms as pathogens of concern. Invasive species, including both nonnative (introduced) and range-expanding native species, are a concern in aquatic and terrestrial systems.

Northwest Priority Ecosystems & Species

Ecosystem transformation, altered phenology, emerging infectious diseases, range shifts, declining forage for ungulates, ocean acidification, hypoxia (aquatic systems), and unintended consequences of management are additional environmental stressors of concern in these systems. Human activities including recreation, overgrazing, and water removal for agriculture can also be compounding stressors in the Northwest. The NW CASC recognizes that new stressors may emerge over the lifetime of this Science Agenda, and we encourage partners to share Emerging Priorities with the NW CASC.

Topics Outside the Scope of the NW CASC

NW CASC science seeks to develop knowledge that helps fish, wildlife, water, land, and people adapt to a changing climate. However, our work focuses primarily on climate adaptation approaches for managing natural resources and the services these resources provide to human communities. The following topics are currently not areas of focus for the NW CASC:

- Off-shore marine systems (e.g., deep-water oceanic species and habitats). *Example: Impacts of climate change on marine species distribution.*
- Infrastructure and green building (without an ecosystem or species focus). *Example: Development and evaluation of climate resilient roads, bridges, water supply systems.*
- Agriculture without a priority ecosystem or species focus. *Example: Evaluating crop production in a changing climate.*
- Domesticated animal husbandry and other agricultural practices related to breeding and raising livestock. *Example: Development of grazing strategies to minimize impacts of reduced water availability on beef production*.
- Aquacultural or maricultural practices unrelated to improving climate resiliency of native Northwest species or species considered to be First Foods of Northwest Tribes and Tribal Nations. *Example: Development of practices to reduce heat stress impacts on commercially farmed oysters.*
- Impacts of climate change on outdoor recreation industries (e.g., fishing, skiing, snowmobiling). *Example: Assessing impacts of reduced winter snow on ski resort viability in the Cascades mountains.*

Management Challenges

Resource managers are seeking solutions to a range of climate adaptation challenges that are increasingly impacting natural and cultural resource management goals across the Northwest. NW CASC partners identified six key challenges (Table 1) to effectively address climate change in resource management and decision-making. Addressing these challenges is fundamental to developing effective climate adaptation actions for the priority ecosystems and species in our region. We discuss approaches for addressing these management challenges in the Research Stages section below.

Table 1. Climate-related resource management challenges and example topics identified by NW CASC Advisory Committee members, Science Advisors, and other resource management partners through facilitated working group discussions.

Management Challenges	Example Research Topics
Integration of climate science into management of species, habitats, and ecosystems	• Develop science that supports USFWS Species Status Assessments • Develop science that supports State Wildlife Action Plans for ID, OR, and WA • Develop climate solutions and plan adaptation actions • Review and synthesize adaptation advances and provide decision support
Identification and prioritization of climate refugia	• Identify, prioritize, or create areas of cold or cooler water • Identify important sites that may act as refugia for Northwest priority species • Identify and manage for areas resilient to wildfire • Identify, prioritize, or create snow refugia and microhabitats resistant to early snowmelt
Managing for ecological transformation and species range shifts	• Understand factors influencing potential species range shifts • Identify, prioritize, and facilitate management of migration corridors • Test best approach(es) for managing ecological changes (e.g., RAD) • Assess effectiveness and feasibility of assisted migration
Addressing multiple interacting drivers of change	• Evaluate impacts of multiple drivers (including climate change) on shifts in food webs and ecological processes • Determine influence on, and effects of, invasive species and diseases under future climate scenarios • Assess the compounded impacts of population growth, human migration, climate change, and resource management actions on Northwest ecosystems and Tribal resources • Evaluate the potential for current management plans to maintain species' persistence or ecosystem function under projected climate and land use changes
Maintaining ecosystem services	• Understand how ecosystem services are valued (and quantified) in various socio-ecological settings • Identify climate change impacts on species, ecosystems, and ecological processes that maintain ecosystem services • Study exposure, sensitivity, and adaptive capacity for areas experiencing coastal squeeze from sea level rise • Determine seasonal variability of water quantity and quality and identify climate adaptation solutions for flood control, water storage, and drought
Balancing needs of humans, species, and ecosystems	• Understand resiliency of people and ecosystems within the context of climate adaptation • Evaluate impacts of extreme climate events such as heat domes on surrounding ecosystems and how communities respond • Identify, implement, and evaluate climate adaptation strategies that support communities and locations vulnerable to climate change • Assess the ecological and economic impacts of climate adaptation solutions

Our state of knowledge on each of the management challenges varies across ecosystems and species. Thus, we outline four entry points for researchers to tailor their science to specific climate adaptation information needs for a given management challenge and priority ecosystem or species.

Climate adaptation is a process that builds on and leverages the principles of adaptive management (Figure 6; Stein et al. 2014). This process lays the groundwork for identifying entry points for researchers to inform resource management and climate adaptation practices. Although the steps of this cycle are presented in a unidirectional fashion, we recognize that—depending on the state of knowledge on a particular adaptation topic—one may enter the cycle at various points, emphasize various aspects of this cycle, or even use an alternative sequence. There will often be more iterative steps than are reflected by the relatively few "back loops" shown in this simplified diagram. We identified four key stages of the climate adaptation cycle that can serve as in-roads for researchers to support specific phases of the adaptation planning process. These research stages will provide the structure for the NW CASC project portfolio and define the types of science projects we will fund and conduct over the next five years.

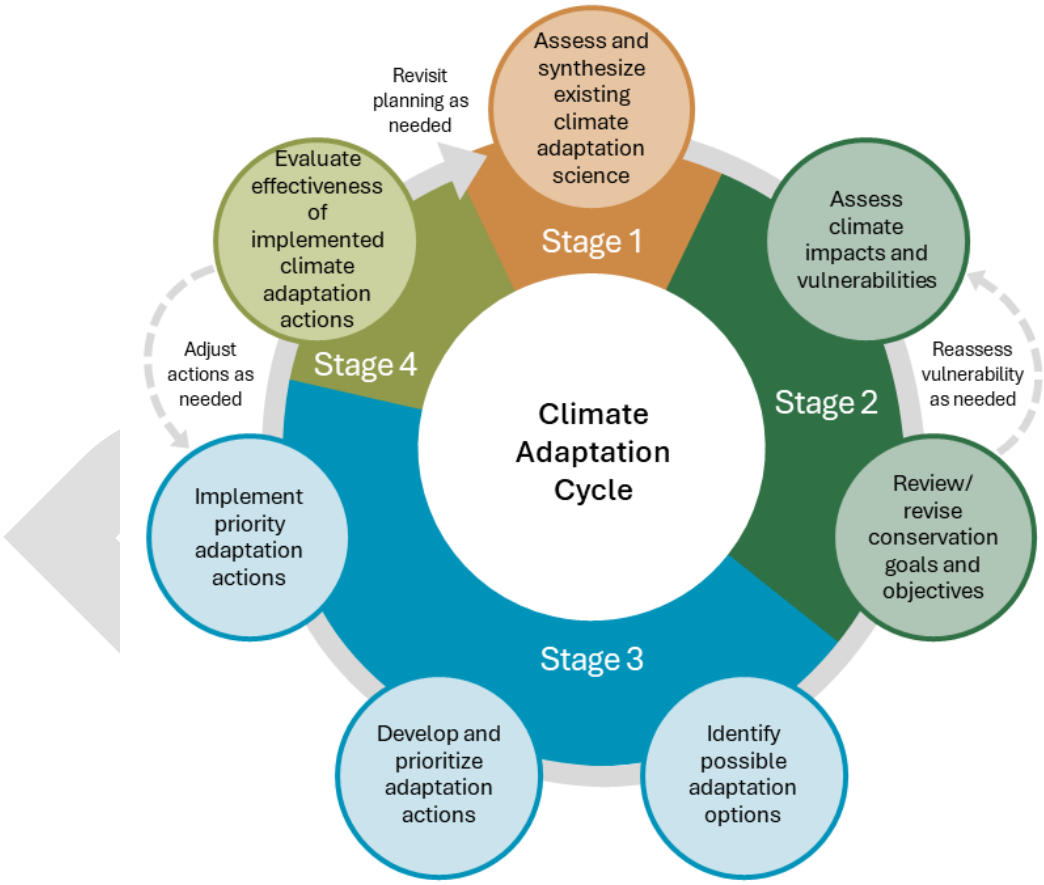

Figure 6. The four NW CASC Research Stages that coincide with key phases of the climate adaptation planning process. Each Research Stage can serve as an entry point for researchers to support information needs described in the Management Challenges section (adapted from the Climate-Smart Conservation Cycle; Stein et al. 2014)

Research Stages

Stage 1: Assess and Synthesize Existing Climate Adaptation Science

This research stage will focus on generating knowledge syntheses and using existing science to inform goal setting during the climate adaptation planning process. Clearly defining the purpose and scope of any adaptation effort is essential for designing an efficient and effective process and for selecting an appropriate course of action. As is the case with conservation planning more broadly, adaptation planning must also be scaled to available resources, which includes scientific information. Resource managers have identified that syntheses and interpretations of current knowledge about topics including climate projections, climate impacts, species and ecosystem vulnerability, species' range shifts, ecosystem transformation, and climate refugia are needed for effectively developing and evaluating climate adaptation actions. *Example: Synthesize actionable information on the relative vulnerability of headwater streams and headwater stream-associated amphibians to climate change and other anthropogenic stressors to better equip managers to implement effective adaptation and conservation projects.*

Stage 2: Understand Impacts, Vulnerability, & Risk

Understanding the likely effect of climatic changes on the species and ecosystems of interest is crucial for designing effective adaptation strategies. Although our understanding of climate impacts and adaptation actions has grown considerably over the past decade, new knowledge is often needed to understand the consequences of climate change and climate adaptation actions to maintain resilient ecosystems in the Northwest. Understanding relative impacts, vulnerabilities, and risks supports a manager's ability to identify *which* species or ecosystems are likely to be most strongly affected by projected changes and understand *why* these resources are likely to be vulnerable, including the interaction between climate change and other existing stressors (Glick et al. 2011, Foden et al. 2019). This second research stage is not meant to track species or ecosystem declines but rather aims to fill information gaps that will guide adaptation action. *Example: Develop tools to better understand complex relationships between broad-scale macroclimate data and the finer scale micro/meso-climates experienced by species to inform management decisions and conservation actions.*

Stage 3: Develop, Identify, Prioritize, & Implement Climate Adaptation Actions

This research stage involves using existing and new science to develop climate adaptation actions, prioritize which actions are best suited for particular applications, and how actions are most appropriately implemented (e.g., applications of the Resist-Accept-Direct framework for managing for ecosystem transformation). Outputs from this research stage should clearly inform coherent adaptation plans, including possible performance and evaluation metrics within subsequent monitoring. Also included in this research stage are opportunities to identify key barriers to implementing adaptation projects and opportunities for overcoming those hurdles and successfully moving to project implementation. These opportunities can be a place where human dimensions factors are especially relevant to investigate. Successful approaches to adaptation will vary widely and depend on many local and context-specific factors. Fundamental to this research stage is an emphasis on mainstreaming adaptation planning into existing efforts, engaging partners early on and regularly, demonstrating success, and keeping sight of transformative changes. *Example: Much of the sagebrush biome has been characterized as "degraded" in the Sagebrush Conservation Design (Doherty et al. 2022) and other conservation strategy documents. Managers have therefore identified a need to develop and*

implement adaptation actions that will minimize fire risk and support ecosystem function with benefits to wildlife and/or livestock, in these areas that are unlikely to return to a historical baseline.

Stage 4: Evaluate Effectiveness of Implemented Climate Adaptation Actions

Climate adaptation is necessarily an iterative process. Monitoring efforts can help ensure that adaptation strategies and actions are having the desired effect, as well as help discern when and where changes in tactics might be needed. Tracking ecological change is especially important considering significant climate-related uncertainties. Critical to this research stage is consideration of *what* aspects of the ecosystem or species to monitor (e.g., key vulnerabilities or indicators), *where* to monitor, *when* to monitor, and, possibly, even who participates in the monitoring, data analysis, and reporting. The goal of this research stage is to identify any management-relevant ecological changes in response to adaptation actions and to inform necessary adjustments in adaptation strategies, goals, and/or actions. *Example: Analyze the impacts of dam removals, including relationships among management strategies, ecological response, and infrastructure.*

The Science Agenda framework defines Northwest priorities, management challenges, and research stages for NW CASC climate adaptation science. Table 2 provides examples of science projects that could address each management challenge across the range of priority ecosystems. Cross-cutting considerations are also identified within the table. These examples are provided to illustrate how specific research projects fit within the framework, but do not represent the breadth of possible research topics that can be incorporated into the framework. We provide additional project development guidance for researchers in Section III.

Table 2. Examples of projects that would address NW CASC Science Agenda management challenges in specific priority ecosystems (priority ecosystems are shown in parentheses). The examples illustrate how potential projects would fit into the Science Agenda framework but do not represent an exhaustive list of projects that would be considered for NW CASC funding. Example projects that also address cross-cutting considerations (Federal Trust Responsibilities to Tribes & Human Dimensions of Climate Adaptation are shown in italics with gray shading).

Management Challenges	Research Stages			
	Stage 1: Assess & synthesize existing climate adaptation science	**Stage 2:** Understand climate impacts, vulnerability, & risk	**Stage 3:** Develop, identify, prioritize, & implement climate adaptation actions	**Stage 4:** Evaluate effectiveness of implemented climate adaptation actions
Integrate climate science into management of species, habitats, and ecosystems	Document impacts of drought on status and trends of endemic invertebrates in riparian systems to inform Species Status Assessments (SSAs). **(Aquatic)**	*Survey climate change impacts on soil health in sagebrush steppe and prairie ecosystems where many culturally important plants are located* **(Sagebrush)**	*Engage with Tribal, state, and local health organizations to develop best practices for water management following climate disasters* **(Multiple Ecosystems)**	*Evaluate effects of historical management actions on climate adaptive capacity of contemporary ecosystems* **(Multiple Ecosystems)**

Research Stages

Identify and prioritize climate change refugia	Synthesize science on riparian climate refugia (stream temperature, flow, ground water availability) to support salmon management plans (**Aquatic**)	Evaluate climate change risks to higher elevation meadows and parklands **(Grassland, Alpine)**	Identify strategies for retaining late successional forest while allowing for thinning and wildfire resilience **(Forest & Woodlands)**	Evaluate whether identification and conservation of snow refugia improves outcomes for alpine species of greatest conservation need (**Alpine**)
Manage for ecological transformation and/or range shifts	Synthesize knowledge on tree seed climate suitability to support DOI and USDA climate-informed reforestation efforts (**Forest & Woodland**)	Identify locations and types of barriers to inland movement of species and ecosystems resulting from sea level rise **(Coastal)**	Evaluate best approaches for assisted migration to maintain functional perennial grasses in arid ecosystems **(Grassland)**	Assess how ecological processes are affected by assisted migration of tree species through climate adapted reforestation practices **(Forest & Woodland)**
Address multiple interacting drivers of change	Understand how increasing temperature, ocean acidification, and hypoxia combined with changes in human recreation will impact nesting seabirds **(Coastal)**	Identify tipping points for ecological disasters such as rapid emergence and spread of invasive species or diseases **(Multiple Ecosystems)**	*Identify best practices to protect, conserve, and restore First Foods and uphold Indigenous food sovereignty* **(Multiple Ecosystems)**	Evaluate current management plans and adaptation strategies for maintaining persistent woodlands in potential end-of-century climate futures **(Forest & Woodlands)**
Maintain ecosystem services	*Synthesize urban and rural setting case studies that quantify ecosystem services of green infrastructure* **(Multiple Ecosystems)**	Assess climate change impacts on native pollinator conservation **(Multiple Ecosystems)**	Identify approaches for protecting ecosystem services provided by tidal marshes from sea-level rise impacts **(Coastal)**	Evaluate effectiveness of beaver dam analogs for enhancing wetland persistence and improving water quality and storage (**Aquatic**)
Balance needs of humans, species, ecosystems	*Understand socio-ecological resiliency within the context of climate adaptation* **(Multiple Ecosystems)**	*Identify the extent and distribution of socio-ecological impacts of urban heat-islands* **(Multiple Ecosystems)**	*Develop climate adaptation strategies to address fire in wildland-urban interfaces* **(Multiple Ecosystems)**	*Assess the ecological and economic impacts of adaptation solutions to address invasive species* **(Multiple Ecosystems)**

Products

The products needed to address each management challenge and research stage will vary and may include multiple types of products. Resource managers across the region identified the following products as highly valuable for informing their work:

- Peer-reviewed journal publications
- Datasets, maps, and data visualizations
- Co-produced decision-support tools
- Fact sheets
- Trainings and workshops
- Information and data sharing outlets (e.g., communities of practice)

Coordination between researchers and end-users over the life of a science project will help ensure that products developed are informative and directly applicable to implementing climate adaptation actions.

Outcomes

The Science Agenda Framework identifies four desired outcomes for the NW CASC's portfolio of work:

- Understand climate change impacts to natural and cultural resources and associated climate adaptation strategies.
- Develop resources to enable managers to incorporate climate adaptation science and practice into resource management and implementation plans.
- Build climate adaptation literacy and technical capacity with and for our partners.
- Build measurable climate resilience for Northwest ecosystems and species.

Some of these outcomes can be achieved in the short-term (i.e., over the next five years), while others—such as building measurable climate resilience for Northwest ecosystems and species—reflect outcomes that will likely persist in perpetuity. Progress towards the desired outcomes will be monitored using approaches detailed in the Evaluation section of this agenda.

Emerging Priorities

Emerging Priorities

This Science Agenda may be updated periodically with new information provided by our partners. New versions will be indicated using version numbers and updates will be made in both the PDF and online version of the Science Agenda.

We seek to identify emerging priorities in real time to better track climate adaptation needs of our partners across the region. If your agency or organization would like to add new or emerging management challenges, focal systems, or desired products, please fill out this online form to share your emerging climate adaptation priorities and challenges

III. Guide to Developing Actionable Climate Adaptation Projects

The NW CASC funds science projects through several mechanisms including directed funding and project solicitations. In addition to funding science projects, the NW CASC will also implement this Science Agenda through our Research Fellowship Program, Faculty Fellowship Program, NW CASC Deep Dives, and training activities. Project solicitations are typically developed on an every-other-year schedule.

Eligibility: As noted in the Introduction, NW CASC funds projects by scientists and managers affiliated with NW CASC Consortium institutions, USGS Science Centers, USGS Cooperative Fish and Wildlife Research Units, as well as other federal and state staff.

Because our goal is to fund science that supports co-production and climate adaptation knowledge that is directly applicable to the immediate needs of natural- and cultural- resource managers in the region, we have provided some general guidance and best practices for both researchers and managers to develop project ideas and proposals with strong partner engagement. We also provide recommendations and guidance for addressing the cross-cutting themes that underlie NW CASC science.

What is Partner Engagement and Why Do It?

Partner engagement is a key component of NW CASC science. Our reasons for emphasizing engagement include:

- Engagement between researchers and science end-users is critical to build relationships and establish trust which is essential for successful integration of science into management actions and planning (Bamzai-Dodson et al. 2021).
- Engaging partners and end users is key to ensuring that scientific outputs and findings are *useful, usable, and used.*
- To be acceptable and actionable, scientific information and products must be seen as *salient* (relevant to the decision choices), *credible* (scientifically plausible and technically accurate), and *legitimate* (created through a fair and unbiased process) (Cash et al. 2003).

In addition to collaboration with resource managers, partner engagement may also involve participation of local communities and Indigenous Peoples.

Spectrum of Engagement

The NW CASC recognizes the level and types of engagement that enable outcomes to be useful, usable, and used will vary by project.

Partner engagement approaches used to conduct actionable climate adaptation research fall along a spectrum of engagement intensity with distinct endpoints (Bamzai-Dodson et al. 2021). Four common

engagement approaches are described below. Building a habit of assessing which strategy to use on the front end of a project can result in better outcomes.

- **Inform**: Research involves minimal interaction with partners and is focused on one-way communication of quality information, such as publications, presentations, or fact sheets, from researcher to end user.
- **Consult**: Research includes collecting targeted input from partners through avenues, such as surveys or other forms of expert elicitation.
- **Participate**: Researchers maintain an active partnership (sustained, two-way interaction) with partners that allows them limited decision-making capabilities (e.g., through a formal or informal advisory committee).
- **Empower**: Researchers delegate or entrust partners with significant decision-making power such that they become coequal team members (e.g., scenario planning processes).

NW CASC places a high priority on projects where researchers and partners Consult, Participate, and Empower rather than simply Inform partners who may be interested in their results.

Integrating Cross-cutting Considerations into Climate Adaptation Research

Developing effective partnerships requires development of trust among partners and often requires a substantial investment of time. In addition to providing unique avenues for climate adaptation research, our cross-cutting considerations (Federal Trust Responsibilities to Tribes & Human Dimensions of Climate Adaptation) depend heavily on partner engagement to be effectively implemented. The cross-cutting considerations identified by NW CASC can be integrated throughout the climate adaptation science project lifecycle, though we recognize that much of this work occurs during the research design and planning phase. We also provide recommendations and guidance for integrating all cross-cutting considerations into research planning, execution, dissemination, and evaluation below.

Recommended Practices for Integrating Cross-cutting Considerations

We recommend that all researchers interested in developing projects for NW CASC support ask the following questions when designing their research.

Research Design Considerations	Guiding Questions
Federal treaty and trust obligations to Tribal Nations	In which Tribal territories is my study area located and what are the federal treaty or trust responsibilities to these Tribes? * Does my project fall under federal treaty or trust responsibilities to Tribes or require review under NEPA and/or Section 106 of the National Historic Preservation Act?

Research partners	Should this research include Tribal partners (e.g., falls under treaty or trust responsibilities, aligns with climate priorities of local Tribes, research proximity to Tribal lands, research expertise)? * Who can I partner with that is already playing a key role in the components of human dimensions of climate adaptation that are relevant to my study system or location (e.g., community leaders, social scientists, NGOs, public health)? Have I established agreements with partners on confidentiality, where data will be housed, research products, participation, and strategies for communication? *
Socio-ecological analyses	How can I integrate local knowledges and community values into analyses of climate change impacts, adaptation solutions, or decision-support products? What economic, policy, or governance analyses could be used to identify barriers to and opportunities for climate adaptation within my study system?
Research dissemination	What deliverables can I produce to address both focal systems of interest to resource management agencies and relevant cross-cutting considerations topics? How can I engage and share research with communities (e.g., adult or youth educational opportunities, collaboration with trusted community leaders)? What agency/organizational deadlines need to be met for deliverables to be incorporated into management plans?
Research evaluation	What key metrics can I track throughout the project to assess partner engagement, usability of science products, perceived benefits or impacts, and capacity building? What accountability mechanisms can I implement to ensure partner, community, and end user needs are met?

* Resources and additional information provided in the following section, “Engaging and partnering with Tribes, Indigenous peoples, and Tribal-serving non-governmental organizations”.

Engaging and Partnering with Tribes, Indigenous Peoples, and Tribal-serving Non-governmental Organizations

Non-Tribal researchers who are interested in developing research proposals for projects that engage or partner with Tribal governments, Indigenous Peoples, or Tribal-serving organizations should ask themselves these additional questions prior to and during development of project proposals.

Additional Considerations	**Guiding Questions**
Relationship building	Have I taken the time to build relationships and trust with intended Tribal partners before developing a research proposal? Have I taken the time to educate myself on Tribal concerns and prior engagement? What strategies can I use to facilitate meaningful and informed participation that allows for multi-directional and intergenerational knowledge sharing among research partners and the community?

	Are there opportunities to provide training or technical support so Tribes, Indigenous Peoples, or Tribal-serving organizations can expand this work to sensitive areas? How do I plan to continue building these relationships after this project concludes?
Respectful engagement	Which Tribal staff members will be PIs or co-PIs on this project? How can I design research that supports Tribal leadership and alleviates the burden of time, resources, and funding on Tribal partners and communities? What strategies can be used to allow research concepts, design, and products to develop according to Tribal needs/questions? Have I included funding for Tribal honoraria, time, and travel in the research budget?
Data sovereignty	Am I familiar with standards in INDIGENOUS KNOWLEDGES and data sovereignty such as the CARE Principles for Indigenous Data Governance (Carroll et al. 2020) and the FAIR Principles for scientific data (Carroll et al. 2021; Wilkinson et al. 2016)? Have all partners thoroughly discussed and established agreements on data sovereignty, confidentiality of sensitive information, and how research and Indigenous Knowledges will be communicated/shared (within the project lifespan as well as in the future)? Does this work require permits from the Tribe beyond research permits or Institutional Review Boards (e.g., Cultural Resource Clearance, Water Use Permit)?

We provide several resources below to provide guidance to non-Tribal and Tribal PIs for developing co-produced climate adaptation research projects.

Topic	**Resource**	**Description**
Tribal territories, land cessions, and treaties	Tribal GIS Base Map (National Tribal Geographic Information Support Center)	ArcGIS Tribal headquarters and Census Bureau-Tribal lands viewer (search by Tribe)
	Native Land Map (Native Land Digital)	Interactive map of Indigenous territories, treaties, and languages
	Tribal Connections (U.S. Forest Service)	ArcGIS federal and Indian lands and land cessions viewer (search by location or cession number)
	Tribal Treaties Database (Oklahoma State University)	Database of Tribal treaties, agreements, and other historical records with intuitive search function
	Indian Land Cessions in the United States (Library of Congress; Royce and Thomas 1899)	Collection of scanned descriptions, maps, and tables of land cessions from 1784-1894
	Indigenous Digital Archive Treaties Explorer and American Indian Treaties Catalog (U.S. National Archives)	Digitized Ratified Tribal Treaties
Engagement with Tribal communities and individuals	Procedures for the Inclusion and Application of Indigenous Knowledge in the Actions of the Department (Department of the Interior)	Handbook for DOI employees that engage with Indigenous Knowledges and Indigenous Knowledge holders

	Guidelines for Researchers: A Guide to Establishing Effective Mutually Beneficial Research Partnerships with American Indian Tribes, Families, and Individuals (University of Arizona; Gachupin and Slowtalker 2023)	Guidance document for researchers who are interested in partnering with Tribes
	Research is Ceremony: Indigenous Research Methods (Wilson 2009)	Book about Indigenous research paradigms and practices
	"Top Ten Considerations When Engaging with American Indian Tribes" (Cultural Heritage Partners)	Key considerations when developing a Tribal engagement strategy
	"Incorporating Indigenous Knowledges into Federal Research and Management" (National CASC)	Webinar series on Indigenous Knowledges engagement including federal guidance, Tribal policies, case studies, and best practices
	"Collaborating with Indigenous Communities to Address Climate Change" (apolitical)	Mini online course for public servants, policymakers, and those working closely with or funded by government
	"Indian Country 101 & 102: Tribal Engagement Training" (Conservation Training)	Publicly available online Tribal engagement training series for natural resource practitioners and anyone interested in learning more about Tribal engagement
	"COVID-19 and Climate Change: Understanding Place, History, and Indigenous Sovereignty in Emergency Response" (University of Colorado Boulder; Sapóoq'is Wíit'as et al. 2022)	Publicly available online teaching modules on Indigenous community experiences of climate change (and COVID-19)
Tribal research review and Tribal governance	How to Build and Sustain a Tribal Institutional Review Board (University of Arizona; Gachupin and Molina 2019a)	Guidance document for Tribal communities on building a Tribal research review board or IRB and registering a Federal Wide Assurance or IRB
	How to Review Research to Benefit Tribal Communities (University of Arizona; Gachupin and Molina 2019b)	Guidance document for both Tribal communities and researchers on the Tribal research review process
	CARE Principles for Indigenous Data Governance (Global Indigenous Data Alliance)	Summary, presentations, and publications about the CARE Principles (also links to resources on FAIR Guiding Principles for scientific data management and stewardship)
	Free Prior and Informed Consent Manual for Project Practitioners (United Nations Food and Agriculture Organization)	Manual for project practitioners on the fundamentals and implementation of Free Prior and Informed Consent
	Indigenous Governance Database (Native Nations Institute, University of Arizona)	Database of resources on Tribal sovereignty, governance, leadership, and Tribal community sustainability

IV. Implementation & Evaluation of the Science Agenda

Implementation

The Science Agenda will be implemented through annual project solicitations open to researchers at NW CASC consortium institutions and USGS science centers. Discretionary funds, technical assistance, and training and workshop development is also periodically available; interested managers and researchers should contact the NW CASC directly to discuss potential opportunities.

Implementation of the Science Agenda will depend heavily on annual Federal appropriations for the CASC Network and the Administration's priorities. We also consider guidance provided by the USGS Ecosystems Mission Area and National CASC, and we partner with other regional CASCs on large-scale projects and initiatives whenever possible.

Evaluation

We will use a three-pronged approach to evaluate our Science Agenda implementation, which includes impact evaluation, process evaluation, and project evaluation (Meadow 2023).

1. **Impact Evaluation** – How is the NW CASC making a difference to resource managers and other stakeholders in the region?

   This evaluation component focuses on the ways in which NW CASC science and products are informing resource management decisions by considering a range of outcomes and impacts including the awareness, knowledge, opinions, and skills gained by the various communities that participate in the NW CASC climate adaptation science activities, as well as the direct contributions of NW CASC science to resource management plans, policies, or other formal decisions. Sources of information for Impact Evaluation may include funded project annual and final reports, science publications and tools, and interviews or surveys of participants in NW CASC science activities. Overarching questions to be addressed in the Impact Evaluation include:

   - Did NW CASC science services and products address specifically stated management challenges?
   - Did the engagement between information producers and users occur early, often, and throughout the duration of the project?
   - How are NW CASC-supported science products being used by resource managers and decision makers in the region?
   - Who was impacted by the NW CASC's science activities?
   - Do different modes of science delivery have different levels of impact?
   - Was science product delivery appropriately timed to meet information use needs?
   - Are there changes to resource condition that make them more resilient to climate change?

2. **Process Evaluation** – Is the Science Agenda being implemented in the ways agreed to by the Advisory Committee and NW CASC and has the NW CASC been accountable to its partners?

This module is intended to analyze whether the Science Agenda is being implemented as intended and according to its original design. In other words, we are interested in knowing the level of consistency between the Science Agenda as a planning document and the resulting scientific activities and products that define our science portfolio. This evaluation approach allows for an analysis of strengths and weaknesses, identification of barriers or unexpected opportunities, and real-time examination of how the Science Agenda could be better implemented. Overarching questions in this component will include:

- Were AC members satisfied with their level of engagement and input into developing the Science Agenda?
- How have the management challenges identified in the Science Agenda been addressed in a given fiscal year? What is the range and type of scientific activities? Why have some key science opportunities not yet been addressed?
- Did other entities contribute to implementation of the Science Agenda?
- Is NW CASC facilitating partnerships among regional agencies, organizations, and Tribes?
- Who were the recipients or co-producers of NW CASC science services and products (e.g., federal, state, and Tribal resource management agencies)?
- How was funding allocated annually and over the life of the agenda by management challenge and research stage?

3. **Project Evaluation** – Are projects funded by the NW CASC being undertaken and completed in ways that use financial support effectively to achieve the best possible outcomes for scientists, partners, and end users?

   This Science Agenda will be implemented through funding of individual projects, Deep Dives, and trainings. These activities are inextricably tied to the impacts the NW CASC has in the region. As a result, there will be significant overlap between the Impact Evaluation and the Project Evaluation modules. However, the Project Evaluation also includes questions of accountability for use of funds, which are required by the funding agency, USGS. We will continue to track accountability information, but also integrate additional Impacts questions into the reporting process. Overarching metrics in this component will include:

   - Accountability information as required by the funding agency (USGS)
   - Summary of project findings and any unexpected findings
   - Outputs generated by the project and stakeholder satisfaction with that output (i.e., credibility and salience)
   - Explanation of how and when the researchers collaborated with intended end-users (e.g., were partners and end users satisfied with their level of engagement?)
   - Was the project successful in producing and communicating information that was used by resource managers and/or decision-makers?

While related and complementary, these three modules are distinct in their objectives, metrics, and assessment tools. We will use these approaches to provide useful feedback to a variety of audiences including organizational administrators, Congress, science producers, science users, partners, and staff.

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VI. Appendixes

Appendix A. Northwest Climate Adaptation Science Center Advisory Committee

NW CASC Advisory Committee Members
State Agencies
Idaho Department of Fish & Game
Oregon Department of Fish & Wildlife
Oregon Department of Transportation
Washington Department of Fish & Wildlife
Tribes and Inter-Tribal Organizations
Affiliated Tribes of Northwest Indians
Columbia River Inter-Tribal Fish Commission
Cow Creek Band of Umpqua Tribe of Indians
Northwest Indian Fisheries Commission
Suquamish Tribe
Tulalip Tribes
Federal Agencies – U.S. Department of the Interior
Bureau of Indian Affairs
Bureau of Land Management
Bureau of Reclamation
National Park Service
U.S. Fish & Wildlife Service, R1
U.S. Fish & Wildlife Service, R6
U.S. Fish & Wildlife Service, R8
U.S. Geological Survey
Other Federal Agencies
Bonneville Power Administration
Environmental Protection Agency
National Oceanic & Atmospheric Association
USDA Northwest Climate Hub
USDA U.S. Forest Service

Appendix B: Process for Developing the NW CASC 2025-2030 Science Agenda

Synthesis and review of science conducted under the 2018-2023 NW CASC Science Agenda

In early 2022, the NW CASC initiated the development of science synthesis reports to summarize and assess the knowledge developed through NW CASC funded science projects under the 2018-2023 NW CASC Science Agenda for each of the six management priorities (Aquatic Resources, At-risk Species & Habitats, Invasive Species & Diseases, Forest Ecosystems, Shrubland Ecosystems, and Working Lands & Waters).

As these reports were developed, NW CASC shared the results with the NW CASC Advisory Committee (AC) in a series of virtual meetings, both to inform the AC about funded science and to gather input about what format(s) and summary metrics would be most useful for climate adaptation applications in their organizations in finalized versions of the synthesis reports.

Identification of ongoing and emerging climate adaptation challenges

In May 2023, the AC met with NW CASC staff at an in-person meeting in Vancouver, WA to identify high-level climate adaptation management priorities to incorporate into the new Science Agenda, agree on the guiding principles and structure for the new agenda, and have a shared understanding of agencies' and Tribes' climate adaptation management priorities and the future of climate adaptation science.

Guiding Principles

The Guiding Principles presented in this agenda were developed based on the Advisory Committee input. They also incorporate the USGS Guiding Principles and reflect how both climate adaptation science and societal values about changing conditions have developed since 2018.

The NW CASC Advisory Committee reviewed the guiding principles for the 2018-2023 Science Agenda and provided three key recommendations for revising the principles for the 2025-2030 Science Agenda:

- Carefully consider terminology
- Integrate social science/human dimensions of climate adaptation into NW CASC work
- Let resource management and community priorities drive research and products

Structuring the new Science Agenda

During the May 2023 meeting, the AC and NW CASC identified ecosystems and species of greatest concern, climate-linked drivers of ecological change for these ecosystems, and management challenges that AC organizations are facing. The AC also provided feedback on desired products from NW CASC science and overall desired outcomes.

NW CASC staff synthesized input from the AC during summer 2023 and developed a draft NW CASC Science Agenda Framework. During October 2023-March 2024, six workgroups comprised of NW CASC staff and AC members met virtually to refine climate adaptation challenges and concerns for priority ecosystems.

Workgroup input was used to finalize the Science Agenda Framework and provided additional structure and organization for the Science Agenda. The NW CASC shared a draft Science Agenda with the AC at an in-person meeting in May 2024; feedback from the AC was used to finalize the Science Agenda.

This Science Agenda will guide the science investments of the NW CASC from 2025-2030 and builds on the science and processes developed under the 2018-2023 NW CASC Science Agenda. We have introduced new cross-cutting considerations to ensure that our science program develops and shares knowledge that addresses ecological climate adaptation challenges and honors the Tribal treaty and trust responsibilities of the Federal government across the lands in our region. This Science Agenda has been structured as a living document where emerging climate adaptation challenges and priorities can be submitted to the NW CASC over the life of the agenda to better track climate adaptation needs of our partners across the region and Administration priorities.

Appendix C: Climate Change in the Northwest

The Northwest is comprised of many ecosystems and landscapes encompassing rocky shorelines, wet temperate rainforests, snow-packed volcanic mountains, and large expanses of dry sagebrush steppe. Abundant snowmelt and rainfall have historically filled salmon- and trout-laden streams and large hydroelectricity-producing rivers. East of the Cascade Range, native bunchgrasses sustain large herds of mule deer (*Odocoileus hemionus*), pronghorn (*Antiliocapra americana*), and cattle (*Bos taurus*) while sagebrush (*Artemisia* spp.) provides habitat for greater sage-grouse (*Centrocercus urophasianus*) and pygmy rabbits *(Brachylagus idahoensis*). Mixed conifer forest, aspen (*Populus tremuloides*), whitebark pine (*Pinus albicaulis*), and juniper (*Juniperus* spp.) woodlands support gray wolves *(Canis lupus*), mountain lions *(Puma concolor*), bighorn sheep *(Ovis canadensis*), wolverine *(Gulo gulo),* and numerous at-risk bird species. These ecosystems also provide food, housing, recreation, and income that support the health and well-being of almost 14 million residents including 43 Federally Recognized Tribes.

Climate change has already impacted ecosystems across the Northwest and these effects will continue to cause transformational change across the region. Communities in the region have been employing various climate adaptation strategies; however, additional efforts to mitigate climate change will be essential for the long-term effectiveness of adaptation actions. Climate change observations for the Pacific Northwest reported in the 5th National Climate Assessment showed similar trends as prior National Climate Assessments (USGCRP 2023).

Increases in air and water temperatures

Average annual air temperature has risen by almost 2^0F since 1900. Oregon has warmed by 2.5^0F, while Idaho and Washington have warmed by nearly 2^0F. Over the 21st Century, annual average temperatures are projected to increase by an average of 4.7°F under a low-emissions scenario (SSP1-2.6) and by an average of 10.0°F under a very high emissions scenario (SSP5-8.5) relative to the period 1950–1999.9 for the Pacific Northwest (Fleishman et al. 2023, USGCRP 2023, Climate Impacts in the Northwest (EPA)). Marine heat waves are projected to increase in frequency and intensity during the 21st century. Impacts of marine heat waves will vary, with some species decreasing while others increase or shift their ranges. A marine heat wave in 2014-2016 resulted in domoic acid poisoning of marine mammals off the Washington coast, mass mortalities of seabirds, and closures of shellfish fisheries (USGCRP 2023).

Changes in water and snow availability, streamflow, and drought

Mountain snowpack has been declining as winter temperatures increase, particularly in areas with warm maritime climates and a greater proportion of winter precipitation is falling as rain rather than snow. Snow-line elevation is also increasing as snow-dominated watersheds transition to mixed rain-and-snow watersheds and mixed rain-and-snow watersheds transition to rain-dominated watersheds. More frequent, longer, and more severe regional drought conditions that increase wildfire risk and decrease water availability will increase as summer precipitation continues to decrease (Fleishman et al. 2023).

Warming temperatures and decreased snow accumulation are causing glaciers to recede which affects regional water systems and winter recreation areas. Basins historically fed by glaciers are expected to experience streamflow reductions. Debris flows and landslides will become more frequent as glacier recessions leave more bare land exposed to direct precipitation.

Interannual variability in precipitation is projected to persist, and summer streamflow are expected to decrease further from reduced snow storage, increased evapotranspiration, and longer lags between summer rain events. It is projected that some permanent streams will transition to ephemeral streams, affecting aquatic species and ecosystems as well as regional water supply.

Changes in fire frequency and intensity

Wildfires are increasing in size, frequency, and intensity across the Pacific Northwest as temperatures have increased and summer precipitation has decreased. Concurrent heat and drought have become more common, resulting in increased fuel loads as amounts of stressed or dead vegetation in many landscapes continue to increase. Additionally, many previously burned forests are reburning. In low-elevation and drier areas, some forest is converting to shrubland after wildfires, and these ecosystem transitions are becoming more common across the Northwest (USGCRP 2023).

The distribution and abundance of non-native and highly flammable cheatgrass (*Bromus tectorum*) continues to increase before and after wildfires in arid woodlands and sagebrush ecosystems. Cheatgrass establishment is associated with relatively high precipitation during autumn and spring and with ground disturbance from wildfire, livestock grazing, and other types of land use (Fleishman et al. 2023). Non-climate stressors including recreation, development, transportation routing, and energy transmission will also continue to affect wildfire frequency in both shrubland and forested systems. The length of the wildfire season and the potential for human-caused ignitions in all Northwest ecosystems are expected to increase as drought frequency, duration, and intensity increase (USGCRP 2023).

Extreme events

According to the 5th National Climate Assessment (USGCRP 2023), the frequency and intensity of extreme precipitation events are projected to increase across the region, Atmospheric rivers associated with extreme precipitation in the western United States are likely to continue to cause severe damage as was observed during November 2021 in western Washington. A greater number of strong atmospheric river events and fewer moderate and weak events are projected to occur, although projected changes in the frequency of landfalling of atmospheric rivers varies across climate models. The average contribution of atmospheric rivers to annual precipitation is currently around 50% in coastal areas and impacts of atmospheric rivers are projected to reach farther inland in the future. Understanding how climate change alters the frequency, intensity, and reach of these events will be critical for estimating how the region's water supply will change.

Sea-level rise

Under all future climate scenarios, sea level is projected to increase across the Northwest, although net sea level changes will vary by location in response to rising sea levels and vertical land motion, or the long-term change in land surface elevation from processes such as tectonic forces (Miller at al.

2018). Long term climate cycles, such as El Niño, also influence sea level and can raise sea levels up to another 7.9 inches for periods of several months. Wave height and tidal surge are also projected to increase. Relative to the 1991–2009 average, sea levels in the Northwest are projected to rise 0.6 to 1.0 feet by 2050 for the Intermediate and High emissions scenarios, respectively placing physical structures and communities at risk. Inland migration of coastal species and habitats is anticipated with rising sea levels (USGCRP 2023).

Other climate-linked drivers of ecological change

Secondary effects of climate change on natural systems include increased spread and damage from invasive species, native pests, and pathogens. The spread of nonnative plants and animals causes extensive environmental damage in the Northwest, with consequences for ecosystem health, recovery of at-risk native species, commerce, agriculture, energy production, and tourism. Warmer air and water temperatures will allow many invasive species and pathogens to expand their ranges and increase the probability of surviving through the winter (Fleishman et al. 2023, USGCRP 2023).