



NORTHWEST CLIMATE ADAPTATION SCIENCE CENTER

CYCLE 1 REPORT

SUBMITTED TO:

U.S. Geological Survey

SUBMITTED BY:

University of Washington, on
behalf of the Northwest Climate
Adaptation Science Center
Consortium

1 AUGUST 2024



PURPOSE AND OBJECTIVES

The Northwest Climate Adaptation Science Center (NW CASC) delivers science to help fish, wildlife, water, land and people adapt to a changing climate. The Center combines academic expertise with federal resources to advance climate science development and delivery for managers and policy makers across Washington, Oregon, Idaho and Western Montana.

The University of Washington became the host of the NW CASC in August 2017, leading a consortium including Boise State University, University of Montana, Washington State University and Western Washington University. In Year 3 of its first funding cycle, the NW CASC expanded to bring on Oregon State University as its sixth consortium institution. The NW CASC Consortium members function as part of the collaborative network that defines the NW CASC, which also includes the external partners that it serves — federal, state and Tribal entities responsible for managing and protecting the land, water and natural resources of the Northwest.

This report provides a summary of the NW CASC Consortium activities during its first cycle of funding, from August 2017 through June 2023. The Consortium completed the agreed-upon deliverables for these years, which are described throughout this report and include accomplishments in partnership-building, science, capacity-building and communications. This report will provide a special emphasis on Year 6 activities, as they have not yet been reported. The remainder of this section will list key highlights from each funding year:

Year 1 Highlights

- Hired and trained new core personnel, adding to a team of newly dedicated existing staff;
- Spun up new programming and offerings, including the Research Fellowship Program and skills-building webinars;
- Funded nine research projects in support of the NW CASC's science agenda and involving NW CASC Fellows and a diverse suite of partners from federal, state, and Tribal resource management agencies;
- Provided nine NW CASC Fellows with actionable science skills through a capacity-building curriculum developed and coordinated by the University Host; and
- Maintained existing communications channels inherited from previous NW CASC host, while assessing priorities for a new communications program to connect NW CASC research and capacity-building activities with priority audiences in the Northwest and national CASC network.

Year 2 Highlights

- Funded ten research projects in support of the NW CASC's science agenda, which involved NW CASC Fellows and a diverse suite of partners from federal, state, and Tribal resource management agencies;
- Provided ten NW CASC Fellows with actionable science skills through a capacity-building curriculum developed and coordinated by the University Host;
- Organized the NW CASC's first Deep Dive, which brought together forest managers, emergency managers, and firefighters to address emerging western Washington wildfire risk under a changing climate;

- Developed and delivered seven actionable science skills-building webinars and two applied science webinars;
- Launched a new, tailored NW CASC website and logo and began strategic communications planning efforts; and
- Supported NW CASC USGS leadership transitions.

Year 3 Highlights

- Funded 13 research projects in support of the NW CASC's Science Agenda, which involved NW CASC Fellows and a diverse suite of partners from federal, state and Tribal resource management agencies;
- Provided 13 NW CASC Fellows with actionable science skills through a capacity-building curriculum developed and coordinated by the University Host;
- Organized a Deep Dive virtual working group process to bring together scientists and managers to co-produce an actionable-science agenda for managing climate-driven, post-fire ecological transformation;
- Developed and delivered six actionable science skills-building webinars, reaching over 430 people;
- Launched new *NW CASC Connections* electronic newsletter to share NW CASC science, products opportunities and resources with NW CASC audiences;
- Hosted first Advisors' Welcome Call to onboard new Research Fellow Advisors from across the NW CASC's Consortium;
- Continued in-depth and collaborative Consortium strategic planning efforts across NW CASC programs,
- Deepened Tribal engagement through recurring Tribal climate partnership meetings with the NW CASC Tribal liaison, Affiliated Tribes of Northwest Indians and NW CASC USGS director to explore ways to better integrate the work of the NW CASC Tribal liaison and the NW CASC;
- Added Oregon State University to the NW CASC Consortium, bringing expertise in forestry, freshwater ecology and habitat restoration; wildlife and coastal resource management; and management strategy modeling. Brought co-PI Dr. Selina Heppell onto the University Leadership Team.
- Expanded NW CASC collaborations across the consortium universities, hosting a full-day University Leadership Team retreat and involving ULT participation in planning the 2020 Deep Dive.

Year 4 Highlights

- Funded 13 research projects in support of the NW CASC's *Science Agenda*, involving NW CASC Fellows and a diverse suite of partners from federal, state and Tribal resource management agencies;
- Provided 13 NW CASC Fellows with actionable science skills through a capacity-building curriculum developed and coordinated by the University Host;

- Hosted a Deep Dive into the science and practice of managing climate-driven, post-fire vegetation transitions in the Northwest that brought together ~100 natural resource managers and scientists to identify actionable science and co-production priorities (in response to COVID-19 pandemic restrictions, redesigned approach from a multi-day gathering to a five-month virtual working group process);
- Expanded NW CASC research to include human dimensions-focused work through the Deep Dive process and Year 5 NW CASC Fellows recruitment;
- Developed and delivered three actionable science skills-building webinars reaching over 300 people;
- Published a peer-reviewed, open-access paper titled, "Building capacity for societally engaged climate science by transforming science training," in the journal *Environmental Research Letters* that draws from NW CASC experiences to offer a perspective on improving academic development, training and support for scientists to conduct societally relevant climate adaptation research;
- Surveyed former NW CASC Fellows and UW Climate Impacts Group alumni for insights into how to expand and improve NW CASC education, training and career development opportunities;
- Strengthened cross-CASC collaborations through the 2020 Deep Dive (with the SW and NC CASCs); participating in developing the Climate Adaptation Postdoctoral Fellows Program; facilitating regular network-wide meetings of the CASC University Directors and Deputy/Assistant Directors; leading efforts to develop collaborative, cross-CASC, university, USGS and Tribal working groups; and facilitating cross-CASC communications collaboration.

Year 5 Highlights:

- Funded 13 research projects in support of the NW CASC's Science Agenda, involving NW CASC fellows and a diverse suite of partners from federal, state and Tribal resource management agencies;
- Provided 13 NW CASC fellows with actionable science skills through a capacity-building curriculum developed and coordinated by the University Host;
- Planned and hosted a Deep Dive into the science and practice of managing stream drying in the Northwest that brought together ~100 natural resource managers and scientists to identify actionable science and co-production priorities. In response to continued COVID-19 pandemic restrictions, used the same, months-long approach we designed in 2020;
- Developed and delivered six actionable science skills-building webinars, garnering over 300 registrants;
- Brought on former NW CASC Fellow Dr. Kendra Kaiser as a NW CASC co-PI at Boise State University. Kendra helped promote the NW CASC Research Fellowship Program at BSU, launching proposal-writing workshops and information sessions to help increase the pipeline of students interested in and pursuing opportunities to conduct actionable science; and
- Underwent transitions in leadership with the retirement of University Director Dr. Amy Snover, advancement of Dr. Meade Krosby from University Deputy Director to University Director, and the hiring of new University Deputy Director Dr. Scott Kalafatis.

Year 6 Highlights:

- Funded 11 research projects in support of the NW CASC's Science Agenda, involving NW CASC Fellows and a diverse suite of partners from federal, state and Tribal resource management agencies;
- Provided 11 NW CASC Fellows with actionable science skills through a capacity-building curriculum developed and coordinated by the University Host;
- Planned and hosted a Deep Dive into the science and practice of managing the inland migration of coastal habitats in response to sea level rise using a similar approach to our previous two Deep Dives, which involved a months-long virtual working group process; and
- Developed and delivered two actionable science skills-building webinars, garnering over 180 registrants.

ORGANIZATION

In Years 1-6, the NW CASC Consortium was led by a University Leadership Team composed of the University Director, Deputy University Director and co-PIs from each of the Consortium universities (Tables 1 and 4). The University Leadership Team collaboratively developed and advertised the Consortium's call for research proposals, evaluated and selected projects for funding in consultation with the NW CASC USGS Director and oversaw award and sub-award administration. The Team made strategic decisions around current needs and future directions of the Consortium. The University Leadership Team met roughly every other month by virtual calls convened by the University Director or Deputy University Director and was in frequent contact via email and phone regarding Consortium operations, strategic opportunities and Consortium-member specific management issues. The University Director oversaw, managed and supervised NW CASC-funded ("core") personnel at the University of Washington (Table 1).

RESULTS

Partnerships

The NW CASC's goal is to respond to high priority natural and cultural resource management challenges and foster substantive, sustained engagement between scientists and managers. During Years 1-6, the University Consortium focused on enhancing partnerships between the NW CASC and NW CASC external partners, between the NW CASC and host institution programs and between the NW CASC and other federal programs.

NW CASC EXTERNAL PARTNERS. NW CASC Advisory Committee. During Year 1, University Director Snover facilitated a discussion of the benefits Advisory Committee members' organizations currently derive from participation on the Committee and additional benefits their organizations would like to derive from interacting with the NW CASC. They also discussed the types of support their organizations were prepared to provide to the NW CASC and any changes that would improve the likelihood of this mutual benefit coming to fruition. During Years 1-6, NW CASC personnel continued to participate in the USGS-organized NW CASC Advisory Committee meetings, which provide an opportunity to build new and deepen existing relationships with both the agencies and individuals represented on the Committee. In Year 6, NW CASC personnel also participated in the process to develop the updated Science Agenda for 2024-2029 and provided input on its design and content as requested.

HOST INSTITUTION PROGRAMS. Climate Impacts Group. During Years 1-6, the NW CASC was hosted as a program within the Climate Impacts Group (CIG) at the University of Washington (UW). The NW CASC provided CIG staff with information about NW CASC activities, products and funding opportunities for distribution to their scientific partners and stakeholders. In turn, CIG personnel delivered insights about regional science needs to NW CASC leadership. **EarthLab.** CIG and the NW CASC are housed administratively within EarthLab, a visionary institute connecting faculty, students and staff at UW with community collaborators to co-produce actionable research that generates solutions and strategies for local and global impact. **Doris Duke Conservation Scholars Program (DDCSP).** During Years 2-6, the NW CASC partnered with the DDCSP to support climate adaptation internships with DOI-relevant partners (e.g., state natural resource management agencies, Tribes) for students and recent graduates from underrepresented groups. In Years 2 and 3, NW CASC-supported interns worked with the Quinault Indian Nation to monitor changes in stream temperatures affecting Tribally important salmon runs. In Year 4, NW CASC-supported interns worked with the Affiliated Tribes of Northwest Indians, Northwest Indian Fisheries Commission, Upper Snake River Tribes Foundation and the Suquamish Tribe. In Year 5, NW CASC-supported interns worked with the Tulalip Tribes to support its climate adaptation efforts. In Year 6, a NW CASC-supported intern worked with DDCSP staff and Tribal partners to evaluate past internships and identify needs and best practices for future collaboration in Cycle 2.

University of Washington Program on Climate Change and School of Public Health. During Years 1 and 2, the NW CASC collaborated with the University of Washington's Program on Climate Change, School of Public Health and Climate Impacts Group to develop and host a *Wildfire Smoke Risk Communication Stakeholder Synthesis Symposium*. This Symposium convened scientists and local practitioners to 1) discuss the current state of wildfire science and risk communication research and 2) identify and prioritize needs, barriers, collaborative solutions and funding sources to promote effective wildfire smoke risk communication.

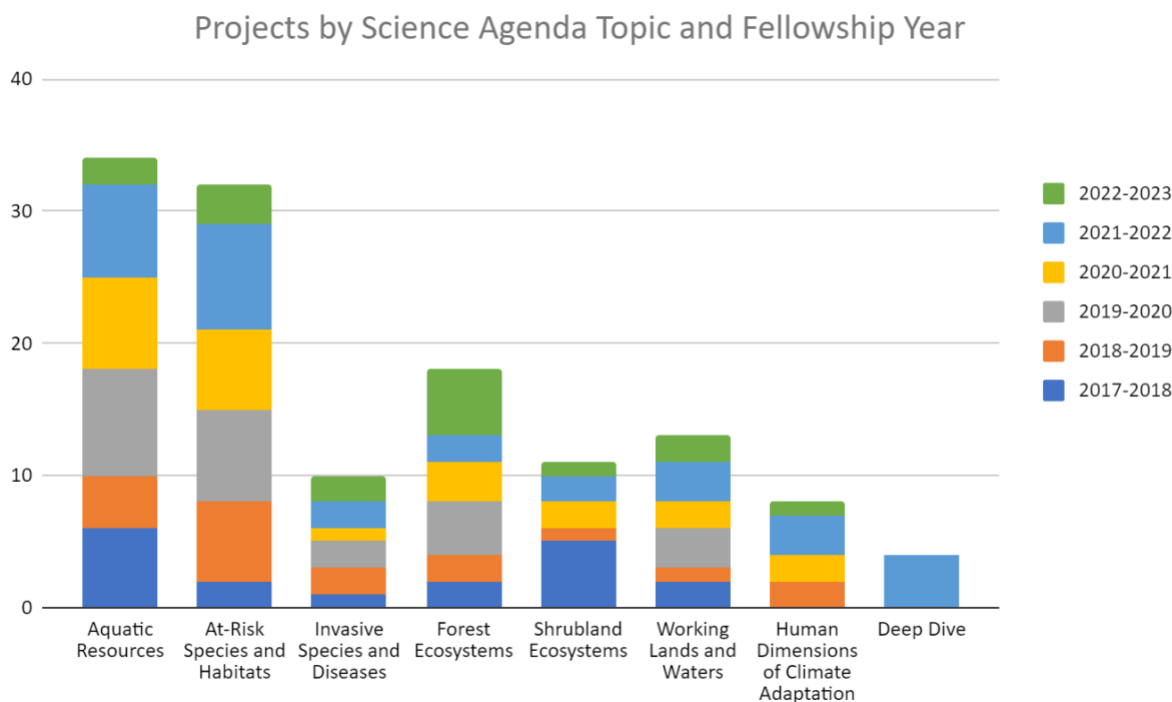
OTHER FEDERAL PROGRAMS. Washington Cooperative Fish and Wildlife Research Unit. The Washington Cooperative Fish and Wildlife Research Unit is a partnership among the USGS, University of Washington, Washington State University, Washington Department of Ecology, Washington Department of Fish and Wildlife, and Washington Department of Natural Resources. Throughout Cycle 1, NW CASC explored avenues of potential collaboration with the Washington Cooperative Fish and Wildlife Research Unit. In Year 5, the NW CASC supported its first NW CASC Research Fellow associated with the Washington Cooperative Unit, whose project was titled *Mediating impacts of climate change on streaked horned larks through prairie-oak management*. **NOAA Regional Integrated Science and Assessment (RISA) Programs.** In Cycle 1, the Consortium established and maintained strong linkages with three NOAA RISA programs. In Years 1-5, the NW CASC engaged with the Western Water Assessment (WWA) at the University of Colorado, Boulder, through NW CASC University Director Snover's participation on the WWA Advisory Board, as well as the Climate Assessment for the Southwest (CLIMAS) at the University of Arizona, through a research collaboration on evaluating the efficacy of graduate education in linking science with action. In Year 5, the Consortium also established ties to the Northwest Climate Resilience Collaborative at the University of Washington Climate Impacts Group (NW CASC host program at UW), through NW CASC University Director Snover's participation as NCRC PI (Year 5) and University Deputy Director Krosby's participation as NCRC Co-PI (Years 5-6).

RESULTS

Science

NW CASC FELLOWS' RESEARCH. In Cycle 1, Consortium supported 69 climate adaptation projects through its Research Fellowship Program. The Consortium supported 58 research projects in Years 1-5 and 11 research projects in Year 6. Collectively, these projects supported each of the six Management Priorities and all three of the Human Dimensions Goals identified in the *NW CASC Science Agenda (2018-2023)* as well as key science and capacity needs identified through the NW CASC Actionable Science Deep Dives. Figure 1 provides a summary of how these research projects supported the Science Agenda by year. In total, 34 projects addressed aquatic resources, 32 addressed at-risk species and habitats, 10 addressed invasive species and diseases, 18 addressed forest ecosystems, 11 addressed shrubland ecosystems, 13 addressed working lands and waters, 8 addressed human dimensions of climate adaptation, and 4 addressed needs identified by our Deep Dives in Cycle 1. These projects have resulted in more than 40 publications in peer-reviewed journals.

Figure 1. NW CASC Research Fellowship Projects by Science Agenda Topic and Fellowship Year



To provide a snapshot of how these projects addressed the Science Agenda, the following section highlights one project under each of the six Science Agenda Management Priorities and Human Dimensions Goals, as well as key science and capacity needs from the Deep Dives:

MANAGEMENT PRIORITY 1: AQUATIC RESOURCES

How will seasonal streamflow in coastal, rain-dominated watersheds respond to changes in precipitation under climate change? (2020-2021 cohort) NW CASC Science Agenda Priorities: 1.1.1, 1.1.3, 1.2.1, 6.1.1, 6.1.2.

In this project, NW CASC Research Fellow Rosemary Pazdral collaborated with the U.S. Forest Service and the Oregon Department of Fish and Wildlife to evaluate coastal freshwater sensitivity to projected changes in precipitation patterns. Rosemary used streamflow and chemistry data to investigate streamflow processes in coastal, rain-dominated watersheds. In both analyses of stream flow and chemistry, streams in watersheds with more permeable bedrock appeared to be less sensitive to seasonal fluctuations in precipitation, since the permeable bedrock slows the rate at which rainwater travels to the stream, moderating how quickly the stream rises and falls in response to winter rain and extended summer low flows. Conversely, the findings suggest that streams in coastal watersheds with less permeable aquifers may be particularly vulnerable to higher winter rainfall intensity and longer dry seasons. In watersheds with less permeable bedrock, fewer, yet more intense, winter storm events may not adequately recharge aquifers, potentially threatening sustainability of late season flows. This is the case throughout much of the Oregon Coast Range, and therefore important to consider in assessing potential threats to water quality and water availability as the climate changes. Identifying those watersheds that may be most vulnerable to changing climate will help guide decisions about water management and efforts to promote sustainability in the Oregon Coast Range.

MANAGEMENT PRIORITY 2: AT-RISK SPECIES AND HABITATS

Detecting Population Changes in Wolverines and Other Snow-Loving Carnivores in the Cascades Using Wildlife Cameras (2017-2018 cohort) NW CASC Science Agenda Priorities: 2.1.5, 2.2.2.

In this project, NW CASC Research Fellow Robbie Emmet evaluated the distribution and status of the Canada lynx through a multi-institutional, large-scale survey effort using remote camera traps across the mountains of northern Washington. In Washington, the endangered Canada lynx (*Lynx canadensis*) is a sensitive indicator species for impacts of climate change. Because it is adapted to persisting in forested, high-elevation, deep-snow environments, Canada lynx in Washington is threatened by increases in temperature and declines in snow extent and depth. The research team successfully collected occupancy data on lynx, discovered lynx populations in the Kettle Falls River mountain range in Colville National Forest (where they were previously believed to be extirpated), and collected valuable data on other federally/state listed species including gray wolves (*Canis lupus*). This data was used to develop suitability maps and large-scale, multi-species survey techniques that can be repeated in the future.

MANAGEMENT PRIORITY 3: INVASIVE SPECIES AND DISEASES

Does a new, invasive beachgrass hybrid affect species diversity and climate change-induced flooding risk in Pacific Northwest coastal dunes? (2021-2022 cohort) NW CASC Science Agenda Priorities: 2.2.1., 3.1.1., 6.1.2.

In this project, NW CASC Research Fellow Risa Askerooth investigated the characteristics of a hybrid, invasive beachgrass discovered in northern Oregon and southern Washington, to understand how the hybrid differs from that of its parents and how these differences may affect dune biodiversity and coastal protection. Pacific Northwest coastal dunes have been dramatically transformed through the intentional introduction of two invasive beachgrasses, European beachgrass (*Ammophila arenaria*) and American beachgrass (*A. breviligulata*). These beachgrasses form dunes that protect coastlines from flooding and erosion, although they also lead to declines in some native species, posing complex management tradeoffs. This project built off previous research that detected a hybrid of the two beachgrasses in northern Oregon and southern Washington where these species overlap in their range. As part of a citizen science project with CoastWatch, the project team worked with community members to map the hybrid beachgrass and its parent species using iNaturalist. Researchers and community scientists discovered many more hybrid occurrences than was previously known. The abundance of the hybrid, coupled with results that show it exceeds its parent species in certain dune-building traits, suggest that this newly discovered beachgrass may have consequences for coastal protection, species diversity and other dune services.

MANAGEMENT PRIORITY 4: FOREST ECOSYSTEMS

Developing cultural fire regime models to inform landscape-scale wildfire and climate adaptation strategies in Northern California (2020-2021 cohort) NW CASC Science Agenda Priorities: 2.1.1, 4.1.1, 4.1.2, 4.2.2, Human Dimensions Goals 1 & 2.

For this project, NW CASC Research Fellow Skye Greenler worked with a team of Tribal knowledge keepers, resource managers and scientists to better understand how eco-cultural fire regimes drove historical landscape dynamics in the Western Klamath Mountains. Skye focused on mapping Indigenous ignition patterns across the landscape and developing a culturally informed State and Transition Model which integrates Tribal and Western knowledge to describe vegetation change through time and disturbances.

To do this, the project team developed estimates of cultural ignition locations, timings and frequencies with Traditional Knowledge Keepers using generational knowledge, historical maps, recent ecological studies and contemporary mapping products. To develop descriptions of vegetation change, the project team used national fire data products, data products from the Karuk Tribe, local knowledge and fire ecology. This work contributed to a better shared understanding of historical forest conditions, awareness of current management trade-offs and a holistic vision for future climate-and wildfire-adapted ecosystems and communities in the Klamath mountains of Northern California.

MANAGEMENT PRIORITY 5: SHRUBLAND ECOSYSTEMS

How will a changing climate affect the landscape-scale competition between perennial grass, exotic annual grass and sagebrush after fire? (2018-2019 cohort) NW CASC Science Agenda
Priorities: 2.2.2, 3.1.1, 5.1.1.

This project, led by NW CASC Research Fellow Cara Applestein, explored landscape-level interactions between exotic annual grass, perennial grass and sagebrush, to better understand how climate change will impact post-fire regeneration of sagebrush. This project explored a 30-year dataset from southwestern Idaho to model how past precipitation and temperature variability, timing of fires, and species interactions led to changes in plant abundances. The study findings suggested that annual grasses were more sensitive to recent weather, particularly precipitation in the spring, while they did not seem to be affected by the timing of fire in relation to weather patterns. Perennial grass was affected by cumulative precipitation in the first several years after fire, indicating that the weather during this window of time has the potential to change long term trajectories. The study found sagebrush to be most responsive to longer-term climate trends than weather in specific time windows. Plant competition did not seem to affect changes in plant abundance. Overall, these findings indicate that wetter annual conditions in southwestern Idaho could result in more recovery of perennial grasses after fire, and that spring precipitation would be especially favorable for annual grasses. The findings also suggest that accounting for competitive interactions in climate effects scenarios is not necessary, as it's unlikely to change prediction accuracy in a meaningful way.

MANAGEMENT PRIORITY 6: WORKING LANDS AND WATERS

Increasing data availability for water management in southwest Idaho (2019-2020 cohort) NW CASC Science Agenda Priorities: 6.1, 6.1.1.

For this NW CASC-supported project, Research Fellow Kendra Kaiser worked with irrigation districts and water managers to better understand how the timing and availability of water will change with continued population growth and land use change in Treasure Valley, Idaho. Through this project, the research team gained access to and compiled data from 12 existing, real-time monitoring sites and installed two new streamflow monitoring sites on drains in the Pioneer Irrigation District. Developing relationships with local irrigation districts was a major accomplishment of the project, as these relationships provided the research team with a deeper understanding of these systems and how they are operated and helped them identify major data gaps and limitations. The project team discovered that although there are over 150 monitoring stations across the Valley, data from very few of those locations is being saved for long-term monitoring. Storing and analyzing this data is critical in understanding how this increasingly human-dominated landscape uses, stores and releases water into the Boise River, a major tributary of the Snake and Columbia Rivers.

An additional data limitation is the lack of a complete, and up-to-date map of the irrigation network, particularly in the suburban neighborhoods where irrigation is pressurized for irrigation of green spaces. The findings from this project improved the research teams' understanding of the hydrology of the Treasure Valley, which is currently being modeled by the Idaho Department of Water Resources. The suite of data made available through relationships with the irrigation district also provides starter data for an effort to catalog all available streamflow data in the Pacific Northwest. Gaining a better understanding of these systems through increased data and experimentation will be increasingly valuable as the Valley continues to grow and explores a range of novel water management practices.

HUMAN DIMENSIONS GOALS:

Understanding climate change impacts on the nutrition and cultural benefits of the Makah Tribe's traditional seafood species (2018-2019 Cohort) NW CASC Science Agenda Priorities: Human Dimensions Goal 2.

In this study, NW CASC Research Fellow Laura Nelson investigated climate impacts on the marine subsistence resources of the Makah Tribe, a Tribal community on the Washington coast. Fish are an important source of protein and micronutrients for certain groups of Indigenous people of the Pacific Northwest, such as the Makah Tribe, who consume seafood at rates much higher than the average American. The importance of traditional seafood to culture and as a food source makes these communities particularly vulnerable to climate change impacts on marine resources. In collaboration with the Tribe, Laura conducted household seafood consumption surveys of Tribal members living in Neah Bay, Washington. This survey assessed species and rates of subsistence seafood consumption and perceptions of changes in the availability of resources. The survey also asked people for their thoughts on what food security means for the Makah Tribe. Through these surveys, the research team identified key subsistence species and estimated their contribution to micronutrient intake using the U.S. Department of Agriculture FoodData Central database. This data will be used to understand some of the consequences of climate impacts on local marine resources. This information will also be used by the Tribe in their ongoing climate adaptation planning and will contribute to our greater understanding of how climate impacts affect the contribution of seafood to community food security.

KEY SCIENCE NEEDS (example from the 2020 DEEP DIVE)

Projecting mid-21st century forest type distribution in Oregon for climate-informed management (2022-2023 Cohort) NW CASC Science Agenda Priorities: 4.1.2., 4.1, Actionable Science Agenda on Post-Fire Vegetation Transformation Key Research Need: "Identify likelihood of post-fire transitions and their impacts"

In this project, NW CASC Research Fellow Svetlana Yegorova explored where Oregon forests may remain in their historic states and where forests are likely to transition to different states, by modeling potential forest redistribution in Oregon for the 2041-2070 period under the high-warming scenario. The results suggest that climate is becoming less favorable to coniferous forests and more favorable to mixed broadleaf evergreen-conifer forests and shrublands. Though areas vulnerable to vegetation shifts are distributed throughout the state of Oregon, forests of the northern Coast Range and the Cascade Crest are projected to remain stable in the next thirty to fifty years. This research was performed in collaboration with several representatives of public land management agencies and Tribal partners, including The Nature Conservancy, Oregon Department of Forestry, Bureau of Land Management, and U.S. Forest Service.

Through two workshops, Svetlana used these partners' input to modify modeling inputs and to shape the final products of this research to make sure that the research products were useful for forest management decision-making.

2018 DEEP DIVE, *Managing Western Washington Wildfire Risk in a Changing Climate*. The NW CASC partnered with the Puget Sound Climate Preparedness Collaborative, the Tulalip Tribes and the Climate Impacts Group to convene a one-day, in-person workshop focused on managing western Washington wildfire risk in a changing climate. The workshop was hosted by the Tulalip Tribes and brought together almost 100 participants from city, county, state, federal and Tribal organizations to share what was known and unknown about wildfire risk west of the Cascades; work together to identify research and coordination needs for managing westside fire risk; and discuss actions that may help reduce this risk. Workshop participants shaped five themes related to what is known about westside fire and identified key considerations surrounding management strategies. This workshop occurred before unprecedented wildfire seasons west of the Cascades in following years.

2020 DEEP DIVE, *Ecological Transformation Now? Managing Post-Fire Vegetation Change in a Warming Climate*. The NW CASC Consortium convened ~100 natural resource managers and scientists from across the Northwest in a five-month virtual working group process to review what is known and unknown about managing climate-driven, post-fire vegetation transitions in the Northwest. This Deep Dive resulted in several products, including a summary report, three synthesis reports (State of the Science, State of the Practice, State of the Policy), an interactive map of post-fire vegetation case studies, a tools database for research and management, and a peer-reviewed publication in *Frontiers in Ecology and the Environment*. The summary report describes key synthesis findings as well as research and capacity-building needs for informing management of post-fire vegetation transitions. These research needs were used to direct future funding to both USGS and Consortium research projects.

2021 DEEP DIVE, *A Deep Dive Into Shallow Waters: Managing Climate Change Effects on Stream Drying in the Northwest*. The NW CASC convened more than 120 natural resource managers and scientists from Northwest Tribes, universities, non-profit and private sectors, and federal, state and local governments to collaboratively review what is currently known about stream permanence and how it affects people and places in the region. In consultation with a 42-person advisory group, over the course of five-months, the NW CASC produced a state of the science synthesis and conducted a three-day virtual workshop. This process also yielded a list of priority research and capacity needs, a brainstorm of novel ideas for new research and capacity-building projects and collaborations, a database of tools related to the stream permanence and a series of graphic recording story maps of key parts of the discussion.

2023 DEEP DIVE, *Rising Seas and the Coastal Squeeze: Managing Inland Migration of Coastal Habitats in Response to Sea Level Rise*. Over the course of six months, the NW CASC engaged with ~100 natural resource managers and scientists from across the Northwest in a virtual working group process to review what is known and unknown about managing coastal squeeze — potential habitat loss and declines in fish and wildlife populations resulting from human-made and natural barriers challenging inland migration of coastal habitats in response to sea level rise. Three working groups synthesized the state of the science on the biophysical, management and practice, and policy and human dimensions of coastal squeeze. The Consortium hosted a virtual workshop to discuss these syntheses, identify cross-cutting themes, identify key research and capacity-building needs, and brainstorm novel project ideas supporting these needs. The process yielded a summary report, three synthesis reports, and a tools database to organize existing resources.

RESULTS

Capacity Building

The NW CASC's goal is to build a community of practice of researchers and managers engaged in climate-adaptation oriented work and to foster their leadership in science-based resource management. Throughout Cycle 1, the Consortium designed programming to advance novel research and promote the use of existing knowledge in support of climate adaptation decision making. To enhance researchers' proficiency to co-produce knowledge, the University Consortium facilitated professional development opportunities in the form of three education, training and capacity-building activities, described below.

NW CASC RESEARCH FELLOWSHIP PROGRAM. In Cycle 1, the University Consortium supported 69 Research Fellows (58 Research Fellows in Years 1-5 and 11 in Year 6) selected through an annual competitive RFP process. Table 5 provides a summary of the number of Research Fellows from each of the six Consortium universities (note that, in Cycle 1, UW provided match funding that doubled the number of UW Fellows that could be supported). As described in the Science section above, their research has spanned the *NW CASC Science Agenda (2018-2023)* and all four Northwest states (WA, ID, MT, OR). All Research Fellows participated in a University of Washington graduate seminar, *The Theory and Practice of Linking Knowledge with Action to Address Modern Environmental Challenges*. During the seminar, the Research Fellows learned key theories and best practices for producing actionable science. They met with practitioners from academic, government and non-government entities working on actionable science to ground their learning in real-world, applied contexts. Fellows also participated in monthly video cohort training calls covering topics including career pathways, building networks for co-production, communicating science to policy makers and journalists, and developing compelling scientific presentations. The NW CASC also supported current and former Research Fellows' attendance at the Northwest Climate Conference throughout Cycle 1. NW CASC covered the expenses of 7, 9, 16 and 20 Research Fellows at the 8th, 9th, 10th, 11th and 12th Annual Conferences, respectively. Twelve former Research Fellows also participated as research assistants in the Deep Dives described above. These fellows supported working groups of managers and scientists, building skills in collaborative, transdisciplinary research and synthesizing different types of knowledge (literature, survey responses, meeting summaries) into key findings and actionable science recommendations.

NW CASC ACTIONABLE SCIENCE POSTDOCTORAL FELLOWSHIP. In Cycle 1, the NW CASC recruited and hosted two Actionable Science Postdoctoral Fellows. The first was recruited and worked for NW CASC in Year 1. During that time, the Actionable Science Fellow taught the seminar described above and facilitated the monthly Research Fellow cohort calls.

Table 5. NW CASC Research Fellows by Institution in Years 1-5 and Year 6

Institution	Years 1-5	Year 6
BSU	6	1
OSU	9	2
UM	9	2
UW	18	4
WSU	8	1
WWU	8	1

The Actionable Science Fellow's responsibilities included evaluating these capacity building efforts. Their evaluation efforts included a pre-, mid- and post-survey of students attending the seminar course, as well as surveying attendees of the Actionable Science webinar series described below. The Fellow also acted as a science mentor for EarthGames 2018: Surviving Climate Change, which developed games allowing players to respond to the new reality of rising temperatures and all of its social, biological and geophysical consequences. The Consortium recruited its second Actionable Science Fellow in Year 2, who worked with Northwest CASC until Year 5. During this time, they also taught the seminar course and facilitated the monthly Research Fellow cohort calls. The Fellow supported the 2020 Deep Dive and helped lead the 2021 Deep Dive. They supported other evaluation and capacity building efforts, including a survey of former Research Fellows as well as scientists and managers who have followed co-production career pathways, to better understand training and capacity needs. Their work resulted in three peer-reviewed publications related to their work with the Research Fellows and on the Deep Dives.

NW CASC WEBINARS. In Cycle 1, the Consortium planned and delivered ten actionable science skills-building webinars series comprising 29 individual webinars. These webinars were designed to build regional capacity for generating and applying actionable climate science. These webinars focused on a range of topics emphasizing the process behind ethical and effective engagement between research and management communities. Each cohort of NW CASC Research Fellows was expected to attend the webinars occurring during their fellowship year as part of their training in actionable science. These webinars were also advertised broadly through NW CASC channels, and though most attendees comprised research and management communities in the Northwest, participants also joined from other regions and countries. In total, these webinars garnered over 2,600 registrants and over 1,300 attendees.

As a result of thoughtful and consistent evaluation, the Consortium's approach to these webinars evolved with its learning. Early webinar evaluation surveys designed by the NW CASC social science lead helped inform topics of interest to its audiences, registration questions and post-webinar surveys. Throughout Cycle 1, the Consortium experimented with different numbers of speakers and webinar structures, adjusting offerings to fit its capacity. All of the webinars were recorded and are hosted on the NW CASC website. The Consortium continues to use these recordings as resources, to which it directs Research Fellows and others interested in the principles of actionable science. In Cycle 1, these actionable science skills-building webinars not only expanded the NW CASC's reach in the Northwest, it helped the Consortium build relationships with its invited speakers, including many thought leaders in the actionable science space.

RESULTS

Communications

In Cycle 1, the Consortium built a successful communications program to support its external and internal communications. Its external communications activities facilitated information sharing and action within and beyond the NW CASC network, while its internal communications activities sustained efficient and effective operations across its multi-layered and distributed organizational structure. The Consortium communications program also played an important role in supporting the training of early career professionals and connecting scientists and managers to foster co-production. The sections below walk through the different elements of the NW CASC communications program.

OVERARCHING COMMUNICATIONS STRATEGY + EVALUATION. Strategic Communications Plan.

The Consortium launched its strategic communications planning efforts in Year 2. To start this process, the Consortium first worked with its USGS partners to develop overarching organizational goals to guide development of its programmatic goals, including its communications goals. The strategic communications process continued throughout Years 2 and 3, during which time the communications manager collected information about how the communications program could support the NW CASC's audiences and new programs. The resulting plan, completed in Year 3, lays out its communications goals, which align with and support NW CASC's organizational goals and overarching mission. The Consortium implemented the plan in Years 4-6. **Communications Evaluation.** The NW CASC communications model is based on continuous feedback and improvement. In Cycle 1, the Consortium was thoughtful in developing communications products with built-in flexibility to allow for evaluation and refinement. The Consortium used a formative evaluation approach to assess its communications channels and efforts, including its website, webinars, newsletter and social media activity.

INTERNAL COMMUNICATIONS | SUPPORTING NW CASC TEAM + FUNDED RESEARCHERS, STAYING CONNECTED TO REGIONAL + NATIONAL CASCs. NW CASC Team.

In Years 1-6, the communications manager helped establish and implement processes to keep internal lines of communications flowing within the Consortium Host team and across the distributed Consortium and USGS teams. The manager did this through leading weekly Consortium Host calls, monthly University-USGS calls, and one-on-one calls with various team members; helping organize in-person meetings; and interacting through Slack, Microsoft Teams and email. **NW CASC Research Fellows.** In Years 1-6, the communications manager provided communications support to each of the six NW CASC Research Fellowship cohorts, while maintaining contact with a growing number of Research Fellowship alumni. The communications manager provided one-on-one communications guidance to fellows for distilling their research into plain-language summaries. Throughout their Fellowship, the manager promoted their research through NW CASC channels; connected them to relevant funding and training opportunities; developed webinars based on their learning interests, and led an annual cohort call about effective meeting planning and facilitation. In Year 4, the communications manager collaborated with UW College of the Environment to plan a science communication training for Year 4 Research Fellows and interested alumni. **USGS-Funded Researchers.** In Years 1-6, the communications manager supported the NW CASC's growing portfolio of USGS-funded research projects. They stayed apprised of new publications and science products through quarterly requests for updates, which they used to keep the NW CASC website up to date. The manager also met with new PIs to discuss project-specific communication opportunities and worked with individual PIs to develop "Science Spotlight" articles to share in *NW CASC Connections* newsletters. When time allowed, the manager also supported several PIs on developing research products like one-pagers and infographics. **CASC Network Collaboration Calls.** Early in Cycle 1, the communications manager participated in bimonthly Network Collaboration Calls, designed to keep communications and project management staff informed of each others' activities and to promote learning across the network. These calls evolved into separate Communications Calls and Project Management Calls mid-way through Cycle 1. **CASC Communication Calls.** For the remainder of Cycle 1, the communications manager participated in monthly Communications Calls with staff across the network, which provided a space for communications staff to come together to ask questions, share best practices and receive communications guidance from the National CASC. In Years 4-5, the NW CASC communications manager coordinated and led these calls.

While leading these calls, the communications manager facilitated processes to plan cross-CASC communication campaigns (e.g., Refugia Special Issue in *Frontiers in Ecology and the Environment*, Status of Tribes and Climate Change Report); reflect on cross-CASC communications goals (e.g., Mural brainstorming session to set cross-CASC communication priorities); and keep communications staff apprised of communications activities across the network (e.g., Pecha Kucha-style virtual event in which all CASCs presented). During this time, the manager also tried to increase consistency in CASC communications evaluation (invited guest Alison Meadow to discuss evaluation) and explore ways for CASC communications programs to better support the work of the Tribal Liaisons. The National CASC transitioned to leading and coordinating the calls in June 2022, at the end of Year 5. **USGS Highlights & Climate Adaptation Insights Newsletter.** In Years 1-6, the communications manager submitted routine highlights to inform USGS of upcoming, high-profile activities within the NW CASC network, as well as regular entries for consideration in the National CASC's Climate Adaptation Insights newsletter.

EXTERNAL COMMUNICATIONS | BUILDING AND SUSTAINING COMMUNICATIONS CHANNELS.

NW CASC Website. The University Consortium team assumed responsibility for maintaining and updating the existing NW CASC website when Cycle 1 funding began. The team used this existing site while building a new site on the Wordpress platform, which is easier to update and is fully supported by the University of Washington's College of the Environment Marketing and Communications Team. In designing the new site, the University Consortium aimed to organize content more efficiently, improve navigation, and move from a clearinghouse of information to a more manageable amount of content better tailored for NW CASC audiences. The University Consortium launched the new site early in Year 2. Throughout the remainder of Cycle 1, the communications manager updated the website with the latest NW CASC announcements, publications, projects and resources, while also building out new content. For example, in Year 5, the team published a new *Introduction to Actionable Science* page, which walks users through the stages of a co-produced, actionable science research process and offers considerations for building effective partnerships along with curated lists of relevant literature and other resources. **NW CASC Logo.** In Year 2, shortly after launching the new website, the University Consortium worked with a local design consultancy to develop a clean and modern logo that represents the range of ecosystems and resources of the Northwest and complements the new website. **NW CASC Connections Newsletter.** The Consortium launched its *NW CASC Connections* electronic newsletter in Year 3 to help meet its communications goals. The team worked collaboratively to produce a newsletter plan with a clear purpose and goals that support NW CASC communications goals, while having built-in flexibility to evolve over time. *NW CASC Connections* is distributed every other month and connects NW CASC audiences to its science products, opportunities and resources, along with opportunities and events from its close partners. Each newsletter issue also features an interview from a NW CASC team member or member of its Advisory Committee in its "Faces of Adaptation" section. In Years 3-6, the NW CASC distributed 23 newsletter issues, which are all linked from its website. It also used the newsletter Mailchimp account to send out special, time-sensitive announcements, such as upcoming webinars and funding opportunities. **Actionable Science & Informational Webinars.** In Years 1-6, the Consortium hosted 10 actionable science skills-building webinar series, made up of 29 individual webinars, as well as two applied science webinars. The Consortium designed these skills-building webinars to promote regional co-production of actionable science by emphasizing the process behind effective engagement between research and management communities. It advertised the webinars broadly to Northwest academic and practitioner communities.

The webinars featured co-presentations by scientists and practitioners, including Tribal resource practitioners, with special emphasis on themes related to helping early-career scientists navigate collaborative research careers and ethical considerations of collaborative research. The topics for these series were based on concrete feedback from webinar attendees and NW CASC Research Fellows. These webinars also served as valuable capacity-building opportunities for the University Consortium team, who built relationships with guest webinar presenters, including members of other regional CASCs. The Consortium also hosted two applied science webinars, which shared results and lessons learned from NW CASC-funded research projects. All NW CASC webinars are archived on its website and act as ongoing resources for researchers and managers. Starting in Year 3, the NW CASC began hosting a variety of annual, informational webinars for participants of its programs and funding opportunities. These included annual welcome calls for NW CASC Research Fellows and their advisors, as well as informational webinars for prospective applicants of its annual Research Fellowship Program. **Twitter.** The University Consortium inherited its Twitter account from the previous consortium host and continued to use and build out this established communications platform throughout the entirety of its first cycle. Though this platform has a broad audience, it was most helpful in connecting NW CASC University Consortium partners and other academics in the region with relevant opportunities and science. It was also used to help amplify the work of other regional CASCs. **LinkedIn.** The University Consortium launched a LinkedIn company page in Year 6 to connect with its network of NW CASC Research Fellow alumni and to connect Northwest researchers and other regional audiences with funding and capacity-building opportunities.

OUTREACH

Publications

In Cycle 1, NW CASC Research Fellows published more than 40 peer-reviewed papers in scientific journals describing their NW CASC-supported research, with an additional three peer-reviewed papers published by NW CASC staff. These peer-reviewed publications appeared in a wide range of journals, including Conservation Biology, Ecosphere, Fire Ecology, Freshwater Biology, Journal of Wildlife Management, Proceedings of the National Academy of Sciences, Science Advances, and Rangeland Ecology & Management.

Additionally, NW CASC Research Fellows and staff published at least eight reports. These reports were developed for Tribal organizations, the Joint Fire Science Program, and NW CASC Deep Dive audiences. The NW CASC Consortium periodically provided financial support to help offset publication costs for Research Fellows, including costs to make publications open access.

Peer-Reviewed Publications

Agne, M.C., J.B. Fontaine, N.J. Enright, S.M. Bisbing, and B.J. Harvey. 2022. Demographic processes underpinning post-fire resilience in California closed-cone pine forests: the importance of fire interval, stand structure, and climate. *Plant Ecology* **223**: 751–767.

Agne, M.C., J. B. Fontaine, N. J. Enright, and B. J. Harvey. 2022. Fire interval and post-fire climate effects on serotinous forest resilience. *Fire Ecology* 18:22.

Al-Chokhachy, R., R.P. Kovach, A. Sepulveda, **J. Strait,** B.B. Shepard, and C.C. Muhlfeld. 2019. Compensatory growth offsets poor condition in native trout populations. *Freshwater Biology* 64:2120–2130.

- Applestein, C.,** T.T. Caughlin, and M.J. Germino. 2021. Weather affects post-fire recovery of sagebrush-steppe communities and model transferability among sites. *Ecosphere* 12:e03446.
- Applestein, C.,** and M.J. Germino. 2021. Detecting shrub recovery in sagebrush steppe: comparing Landsat-derived maps with field data on historical wildfires. *Fire Ecology* 17:5.
- Applestein, C.,** M.J. Germino, D.S. Pilliod, M.R. Fisk, and R.S. Arkle. 2018. Appropriate sample sizes for monitoring burned pastures in sagebrush steppe: How many plots are enough, and can one size fit all? *Rangeland Ecology & Management* 71:721–726.
- Applestein, C.,** A.B. Simler-Williamson, and M.J. Germino. 2021. Weather and distance to fire refugia limit landscape-level occurrence of fungal disease in an exotic annual grass. *Journal of Ecology*:1365-2745.
- Barrett, H.S.,** and J.B. Armstrong. 2022. Move, migrate, or tolerate: Quantifying three tactics for cold-water fish coping with warm summers in a large river. *Ecosphere* 13: e4095.
- Bell, D.A.,** R.P. Kovach, C.C. Muhlfeld, R. Al-Chokhachy, T.J. Cline, D.C. Whited, D.A. Schmetterling, P.M. Lukacs, and A.R. Whiteley. 2021. Climate change and expanding invasive species drive widespread declines of native trout in the northern Rocky Mountains, USA. *Science Advances* 7:eabj5471.
- Bell, D.A.,** R.P. Kovach, Z.L. Robinson, A.R. Whiteley, and T.E. Reed. 2020. The ecological causes and consequences of hard and soft selection. *Ecology Letters* 24:1505–1521.
- Buonanduci, M.S.,** D.C. Donato, J.S. Halofsky, M.C. Kennedy, and B.J. Harvey. 2023. Consistent spatial scaling of high-severity wildfire can inform expected future patterns of burn severity. *Ecology Letters* 26:1687–1699.
- Carter, S., **C.B. van Rees,** B.K. Hand, C.C. Muhlfeld, G. Luikart, and J.S. Kimball. 2021. Testing a Generalizable Machine Learning Workflow for Aquatic Invasive Species on Rainbow Trout (*Oncorhynchus mykiss*) in Northwest Montana. *Frontiers in Big Data* 4:734990.
- Cartwright, J.M., **C.E. Littlefield,** J.L. Michalak, J. J. Lawler, and S. Z. Dobrowski. 2020. Topographic, soil, and climate drivers of drought sensitivity in forests and shrublands of the Pacific Northwest, USA. *Scientific Reports* 10:18486.
- Dashti, H.,** A. Poley, N.F. Glenn, N. Ilangakoon, L. Spaete, D. Roberts, J. Enterkine, A.N. Flores, S.L. Ustin, and J.J. Mitchell. 2019. Regional scale dryland vegetation classification with an integrated lidar-hyperspectral approach. *Remote Sensing* 11:2141.
- Dashti, H.,** N.F. Glenn, S. Ustin, J.J. Mitchell, Y. Qi, N.T. Ilangakoon, A.N. Flores, J.L. Silvan-Cardenas, K. Zhao, L.P. Spaete, and M.A. de Graaff. 2019. Empirical methods for remote sensing of nitrogen in drylands may lead to unreliable interpretation of ecosystem function. *IEEE Transactions on Geoscience and Remote Sensing* 57:3993-4004.
- Diaz, D.D.,** S. Loreno, G.J. Ettl, and B. Davies. 2018. Tradeoffs in timber, carbon, and cash flow under alternative management systems for Douglas-fir in the Pacific Northwest. *Forests* 9:447.
- Dittbrenner, B.J.,** J.W. Schilling, C.E. Torgersen, and J.J. Lawler. 2022. Relocated beaver can increase water storage and decrease stream temperature in headwater streams. *Ecosphere* 13:4168.
- Emmet, R.L.,** R.A. Long, and B. Gardner. 2021. Modeling multi-scale occupancy for monitoring rare and highly mobile species. *Ecosphere* 12:e03637.

- Hahlbeck, N., K.J. Anlauf-Dunn, S.J. Piotrowski, **J.D. Ortega**, W.R. Tinniswood, E.J. Eliason, K.G. O'Malley, M.R. Sloat, M.A. Wyatt, M.E. Hereford, B.S. Ramirez, and J.B. Armstrong. 2023. Habitat fragmentation drives divergent survival strategies of a cold-water fish in a warm landscape. *Ecosphere* 14:e4622.
- Healy, S.M.**, and A.L. Khan. 2022. Mapping glacier ablation with a UAV in the North Cascades: A structure-from-motion approach. *Frontiers in Remote Sensing* 2:764765.
- Healy, S.M.**, and A.L. Khan. 2023. Albedo change from snow algae blooms can contribute substantially to snow melt in the North Cascades, USA. *Communications Earth & Environment* 4:142.
- Howard, L., **C.B. van Rees**, Z. Dahlquist, G. Luikart, and B.K. Hand. 2022. A review of invasive species reporting apps for citizen science and opportunities for innovation. *NeoBiota* 71:165–188.
- King, T. W.**, C. Vynne, D. Miller, S. Fisher, S. Fitkin, J. Rohrer, J.I. Ransom, and D. Thornton. 2020. Will lynx lose their edge? Canada lynx occupancy in Washington. *The Journal of Wildlife Management* 84:705-725.
- King, T.W.**, C. Vynne, D. Miller, S. Fisher, S. Fitkin, J. Rohrer, J.I. Ransom, and D.H. Thornton. 2021. The influence of spatial and temporal scale on the relative importance of biotic vs. abiotic factors for species distributions. *Diversity and Distributions* 27:327–343.
- Kislik, C., **L. Genzoli**, A. Lyons, and M. Kelly. 2020. Application of UAV imagery to detect and quantify submerged filamentous algae and rooted macrophytes in a non-wadeable river. *Remote Sensing* 12:3332.
- Littlefield, C.E.**, S.Z. Dobrowski, J.T. Abatzoglou, S.A. Parks, and K.T. Davis. 2020. A climatic dipole drives short- and long-term patterns of postfire forest recovery in the western United States. *Proceedings of the National Academy of Sciences* 117:29730–29737.
- Lyons, D.S.**, S.Z. Dobrowski, Z.A. Holden, M.P. Maneta, and A. Sala. 2021. Soil moisture variation drives canopy water content dynamics across the western U.S. *Remote Sensing of Environment* 253:112233.
- McGill, L.M.**, J.R. Brooks, and E.A. Steel. 2021. Spatiotemporal dynamics of water sources in a mountain river basin inferred through $\delta^2\text{H}$ and $\delta^{18}\text{O}$ of water. *Hydrological Processes* 35:e14063.
- McGill, L.M.**, E.A. Steel, J.R. Brooks, R.T. Edwards, and A.H. Fullerton. 2020. Elevation and spatial structure explain most surface-water isotopic variation across five Pacific Coast basins. *Journal of Hydrology* 583:124610.
- Olson, L.E., N. Bjornlie, G. Hanvey, J.D. Holbrook, J.S. Ivan, S. Jackson, B. Kertson, **T. King**, M. Lucid, D. Murray, R. Naney, J. Rohrer, A. Scully, D. Thornton, Z. Walker, and J. R. Squires. 2021. Improved prediction of Canada lynx distribution through regional model transferability and data efficiency. *Ecology and Evolution* 11:1667–1690.
- Pandit, K., **H. Dashti**, N.F. Glenn, A.N. Flores, K.C. Maguire, D.J. Shinneman, G.N. Flerchinger, and A.W. Fellows. 2019. Developing and optimizing shrub parameters representing sagebrush (*Artemisia* spp.) ecosystems in the northern Great Basin using the Ecosystem Demography (EDv2.2) model. *Geoscientific Model Development* 12:4585–4601.

- Reisinger, A.J., J.L. Tank, R.O. Hall, E.J. Rosi, M.A. Baker, and **L. Genzoli**. 2021. Water column contributions to the metabolism and nutrient dynamics of mid-sized rivers. *Biogeochemistry* 153:67–84.
- Robinson, Z.L., **D.A. Bell**, T. Dhendup, G. Luikart, A.R. Whiteley, and M. Kardos. 2021. Evaluating the outcomes of genetic rescue attempts. *Conservation Biology* 35:666–677.
- Rozance, M.A., M. Krosby, A.M. Meadow, A. Snover**, D.B. Ferguson, and G. Owen. 2020. Building capacity for societally engaged climate science by transforming science training. *Environmental Research Letters* 15:125008.
- Russell, M.**, M.B. Olson, and B.A. Love. 2022. Surf smelt accelerate usage of endogenous energy reserves under climate change. *PLOS ONE* 17:e0270491.
- Shah, A.A., S. Hotaling, A.B. Lapsansky, **R.L. Malison**, J.H. Birrell, T. Keeley, J.J. Giersch, L.M. Tronstad, and H.A. Woods. 2023. Warming undermines emergence success in a threatened alpine stonefly: A multi-trait perspective on vulnerability to climate change. *Functional Ecology* 37:1033–1043.
- Sorel, M.H.**, A.R. Murdoch, R.W. Zabel, C.M. Kamphaus, E.R. Buhle, M.D. Scheuerell, and S.J. Converse. 2023. Effects of population density and environmental conditions on life-history prevalence in a migratory fish. *Ecology and Evolution* 13:e10087.
- Sorel, M.H.**, A.R. Murdoch, R.W. Zabel, J.C. Jorgensen, C.M. Kamphaus, and S.J. Converse. 2023. Juvenile life history diversity is associated with lifetime individual heterogeneity in a migratory fish. *Ecosphere* 14:e4366.
- Strait, J.T.**, L.A. Eby, R.P. Kovach, C.C. Muhlfeld, M.C. Boyer, S.J. Amish, S. Smith, W.H. Lowe, and G. Luikart. 2021. Hybridization alters growth and migratory life-history expression of native trout. *Evolutionary Applications* 14:821–833.
- Strauch, R.**, E. Istanbuluoglu, and J. Riedel. 2019. A new approach to mapping landslide hazards: a probabilistic integration of empirical and physically based models in the North Cascades of Washington, USA. *Natural Hazards Earth System Sciences* 19:2477–2495.
- Thornton, D.H., **T.W. King**, A. Scully, and D. Murray. 2019. Reassessing the success of experts and nonexperts at correctly differentiating between closely related species from camera trap images: A reply to Gooliaff and Hodges. *Ecology and Evolution* 9:6172–6175.
- Vadeboncoeur, Y., M.V. Moore, S.D. Stewart, S. Chandra, K.S. Atkins, J.S. Baron, K. Bouma-Gregson, S. Brothers, S.N. Francoeur, **L. Genzoli**, S.N. Higgins, S. Hilt, L.R. Katona, D. Kelly, I.A. Oleksy, T. Ozersky, M.E. Power, D. Roberts, A.P. Smits, O. Timoshkin, F. Tromboni, M.J.V. Zanden, E.A. Volkova, S. Waters, S.A. Wood, and M. Yamamuro. 2021. Blue waters, green bottoms: Benthic filamentous algal blooms are an emerging threat to clear lakes worldwide. *BioScience* 71:1011–1027.
- Van Rees, C.B.**, B.K. Hand, S.C. Carter, C. Barger, T.J. Cline, W. Daniel, J.A. Ferrante, K. Gaddis, M.E. Hunter, C.S. Jarnevich, M.A. McGeoch, J.T. Morissette, M.E. Neilson, H.E. Roy, **M.A. Rozance**, A. Sepulveda, R.D. Wallace, D. Whited, T. Wilcox, J.S. Kimball, and G. Luikart. 2022. A framework to integrate innovations in invasion science for proactive management. *Biological Reviews* 97:1712–1735.

Reports

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Chang, M., H. Kennard, and **L. Nelson.** Makah Traditional Knowledge and Cultural Resource Assessment: A preliminary framework to utilize traditional knowledge into climate change planning. US/ICOMOS Report. Forward Together: A Culture-Nature Journey Towards More Effective Conservation in a Changing World.

Genzoli, L. 2020. Distribution of rooted aquatic plants and filamentous algae in the Klamath River, CA. Prepared for the Klamath Tribal Water Quality Consortium. 22 p.

Genzoli, L., D.J. Bandrowski, S. Fricke, B. McCovey, D. Hillemeier, M. Belchik, T. and Soto, Eds. 2021. Klamath dam removal science coordination workshop summary report. Workshop Proceedings, Medford, Oregon, February 12-13, 2020. Yurok Tribe Fisheries Department. 65 p.

Krosby, M., K. Davis, M.A. Rozance, A. Bagley, C. Dohrn, D. Lyons, K. Swensen, M. McClure, and C. Walls. 2021. Managing post-fire, climate-driven vegetation transitions in the Northwest: A synthesis of existing knowledge and research needs. Northwest Climate Adaptation Science Center, Climate Impacts Group, University of Washington, Seattle.

Krosby, M., R. Hasert, **S. Kalafatis,** R. Askerooth, K. Kuhn, and O. Zimmerman. 2023. Rising Seas and the Coastal Squeeze: Managing Inland Migration of Coastal Habitats in Response to Sea Level Rise. Northwest Climate Adaptation Science Center, University of Washington, Seattle.

Mauger, G.S., M.A. Rozance, M. Agne, R. Pazdral, J. Robinson, K. Swensen, K.E. Kaiser, P. Pitt, and B. Glenn. 2021. A deep dive into shallow waters: Understanding and responding to climate-induced impacts on stream permanence in the Northwestern US. Northwest Climate Adaptation Science Center, University of Washington, Seattle.

Morgan, H.A., **A. Bagley, L. McGill,** and C.L. Raymond. 2019. Managing Washington Wildfire Risk in a Changing Climate. Workshop summary report prepared by the Northwest Climate Adaptation Science Center and the Climate Impacts Group, University of Washington, Seattle.

OUTREACH

Presentations

In Years 1-5, NW CASC Consortium personnel, including NW CASC University Consortium-funded Fellows, UW cost share-funded Fellows and climate science affiliates, delivered over 170 presentations to diverse audiences. In Year 6, NW CASC Consortium personnel delivered 12 presentations on NW CASC-funded research to diverse audiences at academic departments, academic society meetings, non-profit organizations, regional conferences and working groups. Year 6 presentations delivered by the NW CASC Consortium-funded University Leadership Team (*) and Fellows (+), UW cost share-funded Fellows (++) and climate science affiliates (^) and NW CASC Fellow Advisors (#) include:

Pradhan, Kavya++, Ettinger, A.E., Case, M.J., and Hille Ris Lambers, J. Aug 2022. Adapting to climate change: Applying climate change refugia to forest management and old-growth restoration. Ecological Society of America, Canadian Society for Ecology and Evolution, Montreal, CA.

John, A., **Pradhan, Kavya**++, Case, M.J., Ettinger, A.E., Hille Ris Lambers, J. Aug 2022. Microclimate during an extreme heat event varies across forest management types. Poster, Ecological Society of America, Canadian Society for Ecology and Evolution, Montreal, CA.

Bloom, Daphne.+ Oct 2022. Reforested conifer seedling responses to post-fire hotter, drier environments. Biology Seminar, Grinnell College.

Bloom, Daphne.+ Oct 2022. Success in science: fellowship and graduate school info session. Lecture for Grinnell Careers, Life, and Services.

Nelson, Laura.++ Oct 2022. Climate impacts on the traditional seafood species and food security of the Makah Tribe. University of Washington School of Marine and Environmental Affairs fall speaker series, Seattle, Washington.

Ortega, Jordan,+ and Armstrong, J. Nov 2022. Characterizing riverscape variation in patterns of dissolved oxygen in the Sprague River Basin. Klamath Basin Monitoring Program annual meeting, virtual.

Askerooth, Risa,+ Mostow, R., Antaki, R., Ly, H., Thieme, M., Scrafford, D., Harper, B., Hacker, S., Barreto, F. Nov 2022. Hybrids hiding in plain sight: Mapping the distribution and abundance of a newly-discovered, invasive beachgrass hybrid on Oregon and Washington coastal dunes. State of the Coast Annual meeting, Newport, OR. **Won first place juried poster*

Askerooth, Risa,+ Antaki, Barreto, F., R., Harper, B., Ly, H., Mostow, R., Scrafford, D., Thieme, C., Hacker, S. Feb 2023. Mapping hundreds of hidden beachgrass plants: The range, distribution, and abundance of a newly-discovered, invasive hybrid (*Ammophila arenaria* x *A. breviligulata*). 2023 Dunes Restoration Conferences, virtual.

Buonanduci, Michele++, D.C. Donato, J.S. Halofsky, M.C. Kennedy, and B.J. Harvey. Feb 2023. Examining wildfires from other regions and fire regimes yields insights into future patterns of burn severity in western Cascadia. Oregon Post-Fire Research and Monitoring Symposium, Corvallis, OR.

Jantsch, Sydney.+ Mar 2023. A Characterization of Hyporheic Temperatures with Applications for Salmon Habitat Restoration in a Thermally Impaired River. WA-BC Chapter of the American Fisheries Society annual meeting, Bellingham, WA.

King, Kelsey.+ Mar 2023. Adapting management to phenological shifts of nectar resources. Annual Fender's blue butterfly working group meeting.

Genzoli, Laurel.+ Mar 2023. Widespread anatoxin detected from attached cyanobacteria in the Klamath River and tributaries. 2023 Oregon Cyanobacterial Harmful Algal Bloom Stakeholder Meeting, Oregon State University.

OUTREACH

Stakeholder Engagement

Stakeholder engagement through research in Cycle 1 was conducted through the NW CASC Research Fellowship Program and Actionable Science Deep Dives (both described in the Science section above). Taken together, these two programs engaged with 183 different agencies and organizations in Cycle 1 (148 in Years 1-5 and 35 in Year 6) across a wide variety of sectors. Research supported by the NW CASC in Cycle 1 was conducted in close partnership with natural resource managers.

Partner engagement was supported by the actionable science skills-building activities and cohort calls provided by the NW CASC Research Fellowship Program. As shown in Table 6, the 69 Fellows in Cycle 1 worked with 81 different agencies and organizations. Projects funded by the NW CASC Research Fellowship in Cycle 1 worked with an average of three partner organizations. Partnering organizations included other academic institutions, multi-partner collaborations, federal agencies, local governments, NGOs, private businesses, state natural resource agencies and Tribal organizations. Fellows communicated extensively with resource managers and other partners through regular meetings, organized workshops, presentations and consultations through one-on-one meetings, phone conversations and email communications. These collaborations have shaped research questions, methodologies and analyses and have given Fellows first-hand experience collaborating with resource managers outside their university setting.

In Cycle 1, four Deep Dives engaged with 402 participants (376 different individuals)

who represented at least 130 organizations and agencies, including academic institutions; Tribes and intertribal organizations; federal, state and local government; NGOs and private entities.

Table 6. Summary of agency and organizational partners in Research Fellows' projects

Type	Years 1-5	Year 6	Cycle 1
Academic	6	4	10
Collaboration	5	2	7
Federal-DOI	7	2	15
Federal-non DOI	6	0	6
Local	4	1	5
NGO	8	2	10
Private	1	0	1
State	12	1	13
Tribal	17	3	20
Total	66	15	81

OUTREACH

Other Products

To support the integration of climate adaptation into resource management, NW CASC supports the development of useful products and tools through its funded research. In addition to peer-reviewed publications and reports, these products include maps, models, databases and protocols. Since we have previously reported on these types of products in Years 1-5, the following section focuses on products from Year 6:

PRODUCT: Series of maps hosted on ArcGIS online that illustrate the changes in suitability between two threatened bumble bees (*B. morrisoni* and *B. occidentalis*) and their recorded floral hosts across the Pacific Northwest (PNW) as well as specific maps that illustrate overlaps in suitability between these two bees and their floral partners.

Climate-resilient planting lists for both of these bumble bees specific to each PNW ecoregion were also developed in response to requests from Washington Department of Fish and Wildlife.

RESEARCH: Mapping the Effects of Climate Change on Plant-Pollinator Communities.

PRODUCT: File geodatabase showing predictions of restorable groundwater, alluvial storage, and stream channel scour throughout the three major forks of the watershed. This data was also used to develop maps highlighting areas to prioritize for restoration in the West and Middle Fork Rivers. This data and maps were used by partners to facilitate a decision making process and dialogue around which sections of the Middle and West Forks to prioritize for in-stream wood placement and restoration of floodplain, alluvial storage, and salmon and trout habitat. **RESEARCH:** How is Groundwater Storage Related to Coldwater Habitat in the Teanaway River Basin?

PRODUCT: Maps showing spatial predictions of western larch across its distribution in the Northwest, highlighting years and locations that are more or less climatically suitable for regeneration. Study also contributed essential findings to incorporate western larch into the U.S. Forest Service RegenMapper management tool, enhancing the tool's capacity to identify when and where regeneration of this particular conifer species may be at risk, thereby guiding any necessary reforestation efforts. **RESEARCH:** Climate and Wildfire Effects on Post-Fire Regeneration of Western Larch.

PRODUCT: A two-day, in-person workshop to get partners' buy-in, build connections, and solicit feedback about inputs for modeling potential, future forest redistribution in Oregon under a high warming scenario. This initial workshop was followed by a final, two-day workshop to present project findings. Findings included a series of maps developed through climate-analog modeling, showing climate-informed, possible vegetation distribution for 2041-2070 and maps showing vulnerability to disturbance-facilitated vegetation turnover. **RESEARCH:** Projecting Mid-21st Century Forest Type Distribution in Oregon for Climate-Informed Management.

SUMMARY

In its first cycle of funding (August 2017 - July 2023) as NW CASC University Host, the University of Washington successfully led the NW CASC Consortium in developing and delivering actionable science to support natural resource management in a changing climate. It did this by effectively leveraging the broad and deep expertise of faculty, staff and students at UW and Consortium partners Boise State University, University of Montana, Washington State University and Western Washington University, as well as Oregon State University beginning in Year 3. The NW CASC Consortium completed its agreed-upon deliverables, including notable accomplishments in partnership-building, science, capacity-building and communications.

During Years 1-6, the NW CASC Consortium focused on enhancing partnerships between the NW CASC and NW CASC external partners; between the NW CASC and its host institution programs; and between the NW CASC and other federal programs. In Cycle 1, the NW CASC Consortium built and sustained relationships with external partners, including its USGS-led Advisory Committee of natural and cultural resource managers, and internal partners, including its host institution program, the University of Washington Climate Impacts Group. The Consortium also invested in relationships with other federal programs, such as the Washington Cooperative Fish and Wildlife Research Unit and NOAA RISA/CAP programs.

In Cycle 1, NW CASC Consortium-supported science addressed two sets of challenges: 1) generating *new* knowledge through transdisciplinary research addressing all stages of the climate adaptation cycle, and 2) assessing and interpreting *existing* knowledge to make available science more readily applied by decision makers. It addressed the first of these challenges — generating *new* knowledge — through its annual Research Fellowship Program, which supported science needs identified in the NW CASC’s 5-year Science Agenda and in the Actionable Science Deep Dives. In Cycle 1, the Research Fellowship Program supported 69 climate adaptation research projects, while providing skills-building for graduate and postdoctoral researchers in the principles and practices of actionable science. Through these projects, NW CASC Research Fellows partnered with 81 different agencies and organizations, including other academic institutions, multi-partner collaborations, federal and state resource agencies, local governments, NGOs, private businesses, and Tribal governments and organizations. These collaborations shaped research questions, methodologies and analysis and gave Fellows first-hand experience collaborating with resource practitioners to co-produce actionable adaptation science. NW CASC Research Fellows published more than 40 peer-reviewed papers in scientific journals describing their NW CASC-supported research, and produced dozens of other useful products (e.g., maps, models, databases, and protocols).

The NW CASC Consortium addressed the second challenge — assessing and interpreting *existing* knowledge — through its Actionable Science Deep Dives. NW CASC Deep Dives are facilitated processes that bring scientists, managers and students together to assess the state of knowledge and practice associated with managing an emerging science risk. In Cycle 1, four Deep Dives engaged over 400 participants representing at least 130 organizations and agencies. These four Deep Dives generated a diverse suite of synthesis products including reports, tools, databases and peer-reviewed publications.

In Cycle 1, the Consortium recruited and hosted two Actionable Science Postdoctoral Fellows, who supported capacity-building for actionable science through teaching the Research Fellowship Program seminar course and supporting Deep Dive efforts.

Additional NW CASC programming supported capacity building for actionable science more broadly. In Cycle 1, the Consortium developed and delivered 10 skills-building webinar series, totalling 29 individual webinars. These webinars, which attracted over 2,600 registrants and over 1,300 attendees, were designed to build regional capacity for generating and applying actionable climate science. These webinars focused on a range of topics emphasizing the process behind ethical and effective engagement between research and management communities.

Strong communications and evaluation underpinned the NW CASC’s programming throughout Cycle 1. The communications program built clean and consistent branding to share its science with external audiences through its website, newsletter and social media accounts, while its robust internal communications kept its operations running smoothly. The Consortium’s formative evaluation of its programs allowed for continuous learning and improvement throughout Cycle 1 and allowed it to build upon these programs in Cycle 2.