TOO HOT TO HANDLE?

Managing the Ecological Impacts of Extreme Heat in the Northwest

2025 DEEP DIVE SUMMARY REPORT

NORTHWEST Climate Adaptation Science Center

CLIMATE IMPACTS GROUP

RECOMMENDED CITATION

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EXECUTIVE SUMMARY

An unprecedented heat wave affected the Pacific Northwest in the summer of 2021, with dramatic impacts observed across a variety of organisms and ecosystems, the extent of which is still unfolding. This event, popularly referred to as a “heat dome,” set all-time high temperature records in dozens of locations across Washington, Oregon and Western Idaho, with temperatures soaring to well above 100°F. The impacts of these sustained extreme temperatures included mass shellfish die-offs, distressed wildlife and heat-scorched trees. With such events expected to become more common under future climate scenarios, Northwest scientists and resource managers require a greater understanding of the ecological risks posed by extreme heat events of a similar magnitude, as well as potential management responses and policy options to address those risks.

The Northwest Climate Adaptation Science Center’s (NW CASC) *2025 Deep Dive* convened natural resource managers and scientists from across the Northwest in a virtual working group process to review what is known and unknown about managing the ecological impacts of extreme heat in the Northwest. This review yielded the following key findings:

- Documented ecological impacts of the 2021 PNW heat wave are primarily negative, ranging from minor physiological damage to large-scale mortality. Observation of additional, longer-term impacts is anticipated as time unfolds. Variation in observed impacts could be a function of varying levels of exposure, sensitivity and adaptive capacity to extreme heat across localities, species and ecosystems.

- Few strategies have been proposed or evaluated for reducing ecological vulnerability to extreme heat, beyond a general need for climate adaptation. However, the 2021 PNW heat wave’s impacts may inform efforts to lower exposure, reduce sensitivity and enhance adaptive capacity for future extreme heat events in the Northwest. Monitoring will be crucial to evaluate the effectiveness of actions to reduce vulnerability to extreme heat.

- Available tools and datasets can provide managers with estimates of exposure to extreme heat, help evaluate the impacts of extreme heat on focal ecosystems and organisms and forecast the occurrence and impacts of extreme heat. However, few, if any, tools and datasets holistically consider vulnerability to extreme heat.

- Many Northwest resource managers have observed direct mortality and ecosystem stress in response to extreme heat, as well as disrupted management efforts and diminished Tribal cultural resources, but their management responses are affected by variability in the nature of events such as their intensity, timing or duration.

- Many Northwest resource managers respond to extreme heat reactively by changing management activities and/or collecting data during or after events, and, when possible, respond proactively by planning in anticipation of future events.
- Many Northwest resource managers draw on a variety of technical data and information to understand and prepare for extreme heat, as well as community/place-based knowledge, collaborative networks and planning and guidance documents. They also access a range of funding sources to support their responses.
- Staff time is the primary limit on Northwest resource managers' responses to extreme heat, but they also describe related challenges ranging from coordinating data collection to needing more actionable information and tools.
- Extreme heat policy frameworks are inconsistent and varied, reflecting the complexity of addressing ecological impacts from extreme heat. Addressing inconsistencies requires collaboration and consensus across governance levels and sectors.
- Human dimensions of the ecological impacts of extreme heat are complex, but most existing heat governance focuses on human health and infrastructure. The limited research and policy available for ecological impacts of extreme heat present challenges and opportunities.

The *2025 Deep Dive* also identified research and capacity-building needs for effective ecological management of extreme heat in the Northwest. Research needs include more comprehensive understanding of the the impacts of the 2021 PNW heat wave on Northwest species and ecosystems, a greater mechanistic and predictive understanding of the vulnerability of Northwest species and ecosystems to extreme heat, identification and evaluation of potential management actions and policy approaches for reducing impacts, understanding impacts and adaptation responses for Tribes and assessment of public preferences and attitudes toward management options. Capacity-building needs include support for long-term and post-event monitoring, improved accessibility and communication of predictive models and decision-support tools, development of knowledge-sharing and response networks, funding for proactive management actions, increased staff capacity and guidance in preparing for future extreme heat events.

Results and products of the *2025 Deep Dive* will help inform actionable science investments by the NW CASC and its partners to support management of the ecological impacts of extreme heat in the Northwest. In addition, the co-production of *2025 Deep Dive* results and products by scientists and managers helped build a Northwest community of practice around this emerging climate risk through peer-to-peer learning, networking and a cross-disciplinary exchange of knowledge and ideas.


Eelgrass monitoring following transplant experiment. Photo Credit: Christine Nolan.

INTRODUCTION

An extreme heat wave affected the Pacific Northwest in the summer of 2021 with dramatic impacts on a wide range of organisms and ecosystems, the extent of which are still unfolding. This event, popularly referred to as a “heat dome,” set all-time high temperature records in dozens of locations across Washington, Oregon and Western Idaho, with temperatures soaring to well above 100°F. These sustained extreme temperatures led to mass die-offs of shellfish, wildlife distress, heat-scorched trees and other ecological impacts. In anticipation of future Northwest heat events of a similar magnitude, scientists and resource managers require a greater understanding of the ecological risks posed by extreme heat as well as management responses and policy options for addressing those risks.

The Northwest Climate Adaptation Science Center (NW CASC) convened natural resource managers and scientists from Northwest Tribes, universities, non-profit and private sectors, and federal and state governments in a 2025 *Deep Dive* into the ecological impacts of extreme heat. Participants collaboratively reviewed what is currently known about managing the ecological impacts of extreme heat in the Northwest, and identified research and capacity-building needs to support informed decision-making to reduce risks to Northwest ecosystems and associated fish and wildlife populations. In addition, the *Deep Dive* engaged participants in peer-to-peer learning and networking aimed at building a strong regional community of practice around this emerging climate risk.

Key findings of this effort, as well as a description of the *Deep Dive* process and participants, are described in the sections below. Additional details and underlying evidence (e.g., citations, participant survey results) for these findings are available in the three synthesis reports described in our Deep Dive products alongside additional resources to support understanding of the risks and response options for ecological impacts of extreme heat in the Northwest.

KEY FINDINGS

Documented ecological impacts of the 2021 PNW heat wave are primarily negative, ranging from minor physiological damage to large-scale mortality. Observation of additional, longer-term impacts is anticipated as time unfolds. Variation in observed impacts could be a function of varying levels of exposure, sensitivity and adaptive capacity to extreme heat across localities, species and ecosystems.

As only four years have elapsed since the 2021 heat wave, most observations of its ecological impacts have been immediate or short-term, with most published research focusing on impacts on forests and intertidal shellfish. Quickly following the 2021 heat wave, researchers, natural resource managers and the public noted ecological impacts including shellfish dieoff, tree scorch, overheated wildlife, and juvenile birds jumping nest to escape the heat. The 2021 PNW heat wave also contributed to an increase in wildfire activity and resultant tree mortality, and exacerbated summer 2021 drought conditions. As time goes on, additional and longer-term impacts are expected to emerge, though tracing these back to the 2021 PNW heat wave may prove difficult.

Impacts of the 2021 PNW heat wave, along with research on factors influencing exposure, sensitivity and adaptive capacity to temperature extremes, provide some guidance on which organisms and ecosystems may be most vulnerable to future extreme heat events. *Exposure* to extreme heat depends on geographic patterns in the magnitude of temperature extremes as well as local microsite factors. For example, impacts of the 2021 PNW heat wave on forests were lower in areas where coarse woody debris and canopy cover buffered exposure by lowering temperatures and increasing soil moisture availability, whereas impacts on the intertidal zone were greater in areas where peak temperatures coincided with low tides. *Sensitivity,* or the response of organisms to extreme temperature exposure, can vary among and within species. Information on heat tolerance thresholds may help predict species vulnerability to extreme heat, but such data is limited for Northwest species and may vary in the specific conditions it represents. Heat tolerance can also vary with age and life stage. For example, needle browning after the 2021 PNW heat wave decreased with tree age. Finally, *adaptive capacity* is the ability of individuals, populations, species or ecosystems to cope with or adjust to the impacts of extreme heat. For example, higher mobility species that can relocate to cooler microclimates may be less vulnerable to extreme heat, such as butter clams that can escape the heat by burrowing more deeply than other, co-occurring bivalve species. Phenotypic plasticity, the ability of an organism to modify its observable traits (e.g., appearance, behavior) in response to environmental changes, can also contribute to adaptive capacity to extreme heat.

Few strategies have been proposed or evaluated for reducing ecological vulnerability to extreme heat, beyond a general need for climate adaptation. However, the 2021 PNW heat wave's impacts may inform efforts to lower exposure, reduce sensitivity and enhance adaptive capacity for future extreme heat events in the Northwest. Monitoring will be crucial to evaluate the effectiveness of actions to reduce vulnerability to extreme heat.

Few actions have been proposed to specifically manage the ecological impacts of extreme heat in the Northwest or elsewhere. Observed impacts of the 2021 PNW heat wave may help inform predictions of species and locations that may be more vulnerable to extreme heat. However, the accuracy of such predictions will be limited without thorough understanding of the mechanisms underlying observed impacts. There is also need for further consideration of how management approaches for reducing impacts of extreme heat may conflict with other common management objectives (for example, retaining canopy cover and coarse woody debris to reduce exposure of seedlings to extreme heat may conflict with fuel reduction goals or the needs of species that require high-light environments).

Past and predicted exposure to extreme heat can be used to inform prioritization of sites for conservation, restoration and management. For example, in intertidal environments, aspect, inner or outer coast location, timing of the low tide relative to the time of the day and presence of cooling groundwater or meltwater appeared to mediate high temperature exposure during the 2021 PNW heat wave. South and southwest-facing slopes are also linked to higher heat exposure in terrestrial environments, and at a smaller scale, canopy cover and coarse woody debris can buffer exposure by providing cooling shade and moisture retention in forest ecosystems.

When some level of exposure to extreme heat is unavoidable, limited management actions may be taken immediately preceding and during an extreme event to reduce the sensitivity and boost the adaptive capacity of priority species and organisms. Such management responses may include targeted protective measures such as watering recently planted seedlings or misting fledgling nests to limit local drought stress and facilitate cooling. Beyond immediate responses, proactive options to reduce sensitivity to future extreme heat include manipulating community and population composition to include more heat-tolerant species or genotypes (e.g., during seed sourcing for planting efforts), but there are significant knowledge and capacity gaps around the efficacy and implementation of such strategies.

Ecological monitoring data is needed to better understand the impacts of extreme heat relative to baseline conditions and other stressors and to evaluate the efficacy of management strategies. Ensuring monitoring data is useable to evaluate the impacts and efficacy of management through extreme heat events will require the continuation of ongoing monitoring efforts and plans for post-extreme heat event rapid response monitoring to measure local exposure and impacts, with a focus on areas predicted to remain relatively cool during extreme heat events (i.e., climate refugia) to assess their temperature-buffering capacity.

Available tools and datasets can provide managers with estimates of exposure to extreme heat, help evaluate the impacts of extreme heat on focal ecosystems and organisms and forecast the occurrence and impacts of extreme heat. However, few, if any, tools and datasets holistically consider vulnerability to extreme heat.

Three main types of tools and datasets are available that address different aspects of vulnerability to extreme heat: geospatial data, ecological monitoring data, and predictive models. Geospatial climate data can approximate extreme heat exposure, and remote-sensing data has been used to determine large-scale forest impacts of the 2021 PNW heat wave. Data from pre-existing and ongoing monitoring protocols have opportunistically been used to evaluate the ecological impacts of the 2021 PNW heat wave, but data collected for other purposes can pose challenges when used to detect impacts of an extreme event (for example, shellfish biologists and managers found existing monitoring protocols did not effectively capture the variation in impacts of the 2021 PNW heat wave). Finally, models and tools are available that can predict vulnerability to future extreme heat events, but existing options are often inaccessible or difficult for managers to use. Studies have also shown potential for improved methods, such as machine learning, for predicting the 2021 heat wave and forecasting where and when similar events may occur in the future. Microclimate models could provide finer-scale predictions of which areas are more likely to serve as thermal refugia from rising temperatures, which could also be more likely to serve as refugia during extreme heat events.

Limitations of these tools include issues of accessibility, usability and comprehensiveness; no tool incorporates all components of extreme heat vulnerability (exposure, sensitivity, and adaptive capacity) at scales relevant to management. To assist Northwest researchers, planners and policymakers in finding tools and datasets to predict and manage the impacts of extreme heat, we compiled relevant geospatial data, ecological data and predictive tools into a central database (Tool & Resource Database).

Many Northwest resource managers have observed direct mortality and ecosystem stress in response to extreme heat, as well as disrupted management efforts and diminished Tribal cultural resources, but their management responses are affected by variability in the nature of events such as their intensity, timing or duration.

Deep Dive participants' descriptions of the observed impacts of extreme heat events focused on direct mortality and species and habit stress, which are likely the most directly observable and immediate impacts of these events. Participants also emphasized that these impacts undermine Tribal cultural resources, including access. Some working in Eastern Oregon/Eastern Washington also described the 2021 event as having exacerbated wildfire risk. Many managers reported that extreme heat events disrupt management or planning efforts because of the need to delay planned management interventions such as plantings, redirect limited resources to address impacts and limit staff exposure to dangerous conditions. Many managers also reported that the intensity, timing or duration of extreme heat events affects their impact. The potential for variability in the nature of these events complicates efforts to understand how to manage resources in the face of them. The 2021 event is currently a novel one and it is unlikely a future event would completely replicate the conditions that produced the specific impacts managers observed during and after it. Developing a better understanding of ecological thresholds (e.g., physiological, reproductive, phenological, behavioral, biogeochemical, etc.) may help inform efforts to draw lessons from more frequent, less extreme heat events and pursue greater overall resilience to the impacts of extreme heat.

Many Northwest resource managers respond to extreme heat reactively by changing management activities and/or collecting data during or after events, and, when possible, respond proactively by planning in anticipation of future events.

Responses to extreme heat reported by managers generally fit into three categories: changing management activities, pursuing data collection and preparing and planning. These different types of responses were often interconnected. For example, one participant described that they "attempted to adapt fishery management surveys to assess losses during the 2021 heat dome event" (pursuing data collection), "modified harvesting seasons to address species-specific losses" (changing management activities) and were "working to develop a rapid response assessment survey to deploy in the event of similar heat events" (preparing and planning). Deep Dive participants expressed that there are likely important temporal distinctions between when responses take place and anticipation about how these responses fit into larger management efforts. There are immediate responses during extreme heat events, such as restricting harvesting or fishing; reactive responses following an event to assess or address its impacts, such as post-event surveys; and proactive responses to help ensure better outcomes from future events, such as developing refugia or rethinking larger management strategies. Understanding such distinctions might be particularly useful for diagnosing, mobilizing and addressing resource needs at different points in time in relation to extreme events.

Discussions among Deep Dive participants revealed those working with different species and ecosystems differ in the extent to which they may be able to identify the effects of the 2021 event and draw lessons to plan for future events. For example, participants working in forestry expressed surprise at the existence of proactive activities related to extreme heat events while those working with shellfish in the Puget Sound described extensive efforts related to updating monitoring protocols, network building and planning. A case study on the work of the Shellfish Rapid Response Network developed as a product of this Deep Dive describes some of these proactive efforts (Case Study: Mobilizing to Beat the Heat with the Shellfish Rapid Response Network).

Many Northwest resource managers draw on a variety of technical data and information to understand and prepare for extreme heat, as well as community/place-based knowledge, collaborative networks and planning and guidance documents. They also access a range of funding sources to support their responses.

Northwest resource managers participating in the Deep Dive described utilizing a wide variety of tools, data and information in their responses to extreme heat events. Among those most commonly used were technical data describing biophysical systems like real-time or local-scale monitoring, climate projections, and species heat-tolerance data. Community and place-based knowledge was also used by a variety of different types of organizations. However, managers appear to be cobbling together resources to address their needs due to lack of more efficient tools or resources. The least commonly-used resources were more actionable ones like adaptation frameworks, scenario planning/modeling and decision-support tools.

Similarly, many Northwest resource managers participating in the Deep Dive shared that plans, policy tools and coordination efforts shaped their adaptation responses to the ecological impacts of extreme heat. Managers commonly used resource management plans, best management practices or emergency protocols, species management plans and local/municipal/state plans. However, as noted by both the Management and Practice and Policy and Human Dimensions working groups, very few of these plans or protocols explicitly address extreme heat events. It is not clear how much more beneficial such resources would be if they addressed the ecological impacts of extreme heat specifically. Even if managers have information about current and future conditions, adaptation may be limited by a lack of integration of tools and frameworks for navigating uncertainty and dynamic decision-making into planning and implementation. Many Deep Dive participants are already involved in partnerships, collaborations or co-management efforts that could play a key role in helping them adapt and apply existing resources in their responses to the ecological impacts of extreme heat.

Staff time is the primary limit on Northwest resource managers' responses to extreme heat, but they also describe related challenges ranging from coordinating data collection to needing more actionable information and tools.

Deep Dive participants emphasized that staff time, availability or training were the primary limits on efforts to respond to the ecological impacts of extreme heat events. Extreme heat events place Northwest resource managers under time-sensitive duress and threaten to stretch existing management capacities to their breaking points. The need to prepare, mobilize and share limited resources to most effectively respond to these events has spurred collective efforts like the Shellfish Rapid Response Network. Such collaborative efforts can help address a number of other information-related challenges that intersect with these staffing limitations. First, there are tradeoffs between protecting staff and collecting informative data during extreme heat events. Coordination and data-sharing between organizations can help ease the burden on any particular organization's staff to collect data during an event and limit staff exposure to dangerous conditions. Second, publicly available environmental datasets are often extremely large and burdensome to download, store, manage and analyze. Managers throughout the region may benefit from data either being available in a more accessible shared format on the cloud or available in smaller files that are pre-cleaned and tailored to common uses. Third, a lack of information sources tailored to extreme heat, specifically, stresses managers that lack the time to make sense of the breadth of existing information.

Coordinated efforts to make existing resources more actionable and adapted to address the specific challenges of managing extreme heat events could help meet the shared needs of managers throughout the region. Workshop participants emphasized the need to do this work as proactively, collaboratively and transparently as possible because the tailoring needed to support management efforts may not be immediately apparent. For example, the Shellfish Rapid Response Network found that existing data collection protocols were not effective at detecting acute extreme event impacts and that they would have to leverage their network to develop new ones.

Extreme heat policy frameworks are inconsistent and varied, reflecting the complexity of addressing ecological impacts from extreme heat. Addressing inconsistencies requires collaboration and consensus across governance levels and sectors.

Approaches to extreme heat policy differ across scales of governance. There is no single organization tasked with addressing extreme heat, which suggests a lack of problem ownership. Instead, heat governance is conducted by multiple organizations using a range of levers with differing goals. There is also insufficient consensus among institutions on what constitutes an extreme heat event, with various terminologies used (including heat islands, heat waves, extreme heat days, high temperature/warm days, and heat domes) to describe extreme heat phenomena. Deep Dive participants noted challenges around identifying and accessing the best datasets or indicators to inform policy responses.

Varied planning and policy tools relevant to addressing the ecological impacts of extreme heat do exist, including planning documents, coordination mechanisms, technical assistance and data and information sharing. However, policy tools that explicitly address the ecological impacts of extreme heat are limited. Deep Dive Workshop participants noted certain temporal considerations in planning efforts: proactive pre-event preparedness, management actions/policies during an extreme heat event and post-event management/policies that focus on assessing and learning about the ecological effects of extreme heat. Structural challenges persist that limit the capacity of institutions to effectively prepare for and respond to extreme heat events, including institutional fragmentation, limited public support and scarce human and financial resources.

Human dimensions of the ecological impacts of extreme heat are complex, but most existing heat governance focuses on human health and infrastructure. The limited research and policy available for ecological impacts of extreme heat present challenges and opportunities.

Most research on the impacts of extreme heat events tends to focus on how extreme heat affects human health and infrastructure. There is limited research on the social and human dimensions of the ecological impacts caused by extreme heat. Species die-offs can affect people's ability to enjoy outdoor spaces or their ability to gather local foods, with the latter impact being particularly salient for Tribal communities that rely on gathering plants, berries, roots or other resources during certain times of the year. Extreme heat events can also degrade or kill commercially and culturally important species and habitats, such as shellfish or agricultural produce, that can affect natural resource-dependent communities.

Some evidence documents how extreme heat events can induce human responses that may further degrade or stress ecosystems. For example, extreme heat events can increase visitation rates to outdoor areas that provide natural shade for cooling, which could lead to additional visitation-related disturbances on natural habitats and areas. Additionally, households tend to increase use of electricity for cooling, which can have cascading ecological impacts.

ACTIONABLE SCIENCE AGENDA

Deep Dive participants identified key research and capacity-building needs to advance science-based management of extreme heat in the Northwest. Examples of potential projects that could address many of these needs are provided in "Example Project Ideas Supporting Research and Capacity Needs."

I. Key Research Needs

- **Quantify and synthesize the ecological impacts of the 2021 heat wave**, including impacts in non-forest terrestrial and freshwater ecosystems, emerging longer-term responses and variation in individual, population, community, and ecosystem-level responses.
- **Understand the mechanisms and drivers of interspecific and intraspecific variation in sensitivity and adaptive capacity to extreme heat,** including heat tolerance and underlying genetics and plasticity, especially for priority species in the Northwest.
- **Characterize the interactive ecological effects of extreme heat and other anthropogenic, biotic and abiotic disturbances and stressors.**
- **Develop and evaluate management and restoration actions** to reduce vulnerability to extreme heat events and co-occurring stressors.
- **Analyze the impacts, effectiveness and logistical considerations of immediate, reactive and proactive policy and management responses** to extreme heat events, especially how to best allocate, share and leverage existing resources.
- **Assess and improve the effectiveness and accessibility of existing tools to measure and predict general and extreme heat exposure and impacts,** including seasonal and long-term projections of the likelihood of heat events, and create new extreme-heat-specific tools as needed.
- **Develop and standardize protocols** to facilitate safe, consistent, efficient and effective assessment of the ecological impacts of extreme heat events, particularly ones that are transferable across sectors, geographies and ecosystems.
- **Understand the social and human dimensions of the ecological impacts of extreme heat,** such as the social impacts of ecological degradation from extreme heat, the social responses to extreme heat events and coupled ecological impacts, public perceptions and preferences around managing ecological impacts of extreme heat, and impacts in Tribal communities and culturally-important species and ecosystems.

II. Key capacity-building needs

- **Support long-term and post-event rapid ecological and microclimate monitoring** to generate robust data that is findable, accessible, interoperable, and reusable (FAIR). These data can be used not only to establish ecosystem baselines and assess the effects of heat events and adaptation actions, but also to test mechanistic understanding of ecological impacts and generate testable hypotheses for future experiments.

- **Improve, operationalize and expand the accessibility of existing tools and datasets** to better incorporate field observations, provide data and predictions at scales relevant to management and policy decisions, and address management needs.

- **Provide and synthesize guidance:** Develop guidance on how to use existing tools and datasets to predict and quantify the ecological impacts of extreme heat events and inform management decision-making. Translate data and models into easy and ready-to-use formats.

- **Integrate knowledge from different disciplines:** Facilitate communication among Northwest atmospheric, geospatial, ecological and management experts to produce and operationalize ecologically-relevant models that provide spatially explicit predictions on ecological vulnerability & resilience to extreme heat, and to enhance understanding of the applications and limitations of current models.

- **Facilitate preparation for future events:** Support efforts to plan and establish directories and procedures ahead of time for swift response during a potential future extreme heat event.

- **Enhance and better leverage staff capacity** to pursue data collection and other technical or informational needs that enhance understanding of the ecological impacts of extreme heat events and their management.

- **Aid and support collaborations and network-building:** Fund, facilitate and sustain networks and partnerships to boost capacity to manage the ecological impacts of extreme heat and share information and lessons learned across sectors, geographic boundaries and ecological systems.

Setting up oyster long-line monitoring experiment, Willapa Bay WA
Photo Credit: Christine Nolan

DEEP DIVE PROCESS & PARTICIPANTS

The *2025 Deep Dive* was a virtual, working-group based process designed to facilitate the co-production of findings and products by participants. Key steps in this process included:

- **Kick-Off meeting** (February 19, 2025). In this first, online meeting, we introduced participants to the *2025 Deep Dive* topic, brought in three panelists to share their own experiences of managing the ecological impacts of the 2021 heat wave and described the collaborative process we would employ and the roles and expectations of participants. A follow-up survey allowed participants to provide input on the process and sign up to participate in one or more synthesis working groups.

- **Synthesis working groups** (March-May 2025). Three working groups, each led by a NW CASC researcher/associate and supported by NW CASC Fellows, developed reports synthesizing the state of the 1) biophysical science, 2) management and practice and 3) policy and human dimensions relevant to managing extreme heat (Working Group Syntheses). Working groups included both scientists and managers and met for three, one-hour meetings to provide input and direction on synthesis progress. These syntheses helped lay the foundation for the actionable science agenda identifying priority research and capacity needs for managing extreme heat.

- **Final workshop** (June 10 and 12, 2025). This final, online workshop for all participants focused on 1) sharing results of the three syntheses; 2) crafting the actionable science agenda, which identified future research priorities and capacity-building needs to fill key gaps identified by the syntheses; and 3) discussions on how to move forward to implement the science agenda in support of effective management of extreme heat (see Example Project Ideas Supporting Research and Capacity Needs).

A total of 92 participants registered for at least one of the above activities. Participants were selected to represent the diverse regions and ecosystems (Figure 1), roles (Figure 2) and organizations (Figure 3) relevant to managing the ecological impacts of extreme heat in the Northwest. Participants determined their own level of involvement in the Deep Dive process, from directly working on synthesis products to participating only in one or both of the virtual workshop days and providing input on draft reports and recommendations.

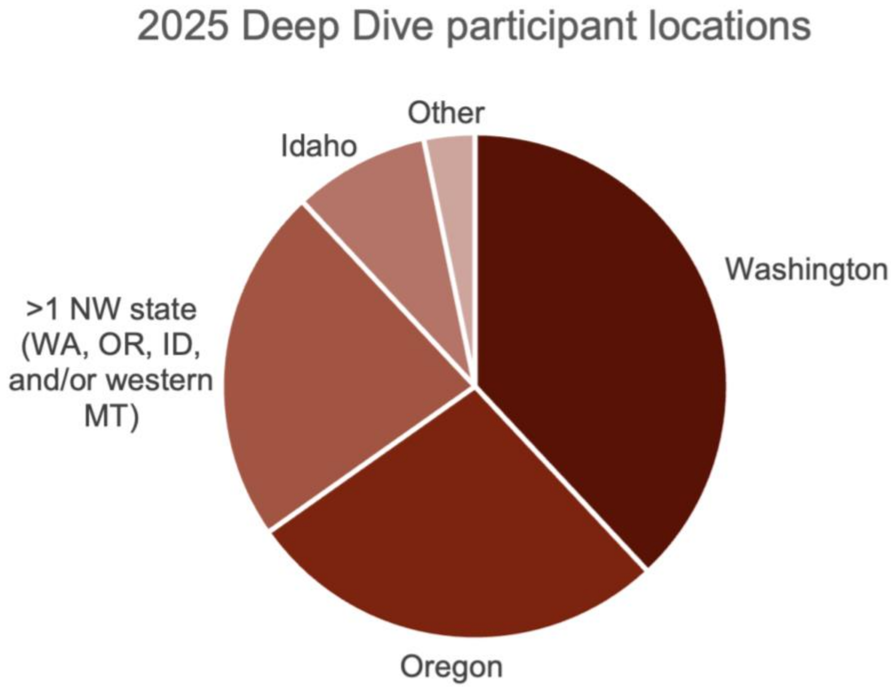

Figure 1: Deep Dive participant locations. *2025 Deep Dive* participants work primarily in Washington (35), Oregon (25), Idaho (8), or a combination of Northwest states (Washington, Oregon, Idaho and/or western Montana; 21). Other participants work primarily in British Columbia (1), Alaska (1) and Oklahoma (1).

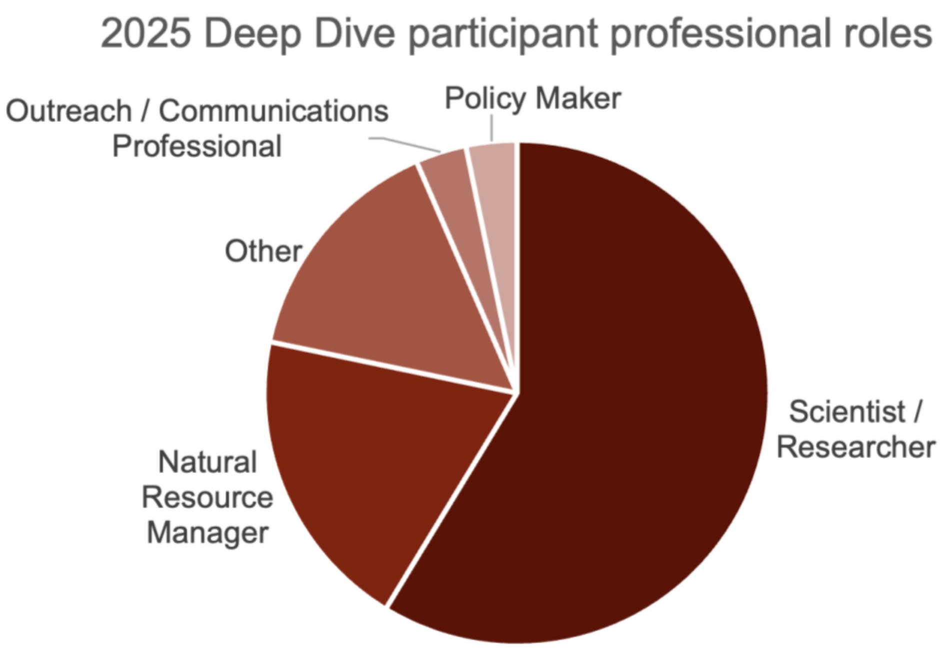

Figure 2: Deep Dive participant professional roles. *2025 Deep Dive* participants represented a wide range of professional roles relevant to managing the ecological impacts of extreme heat, though the majority identified as scientists (54) or natural resource managers (18). Three each identified as outreach/communications professionals and policy makers. Other participants (14) represented boundary-spanners, wildlife veterinarians, climate adaptation specialists, and other roles.

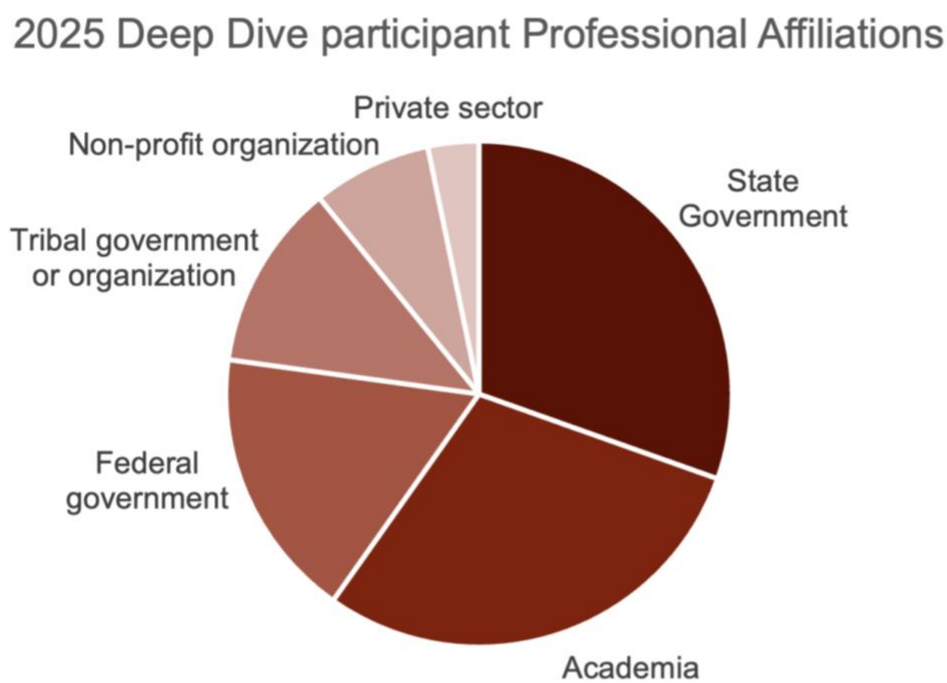

Figure 3: 2025 Deep Dive participant professional affiliations. *Deep Dive* participants represented a wide range of entities, including state (28 participants) and federal (16 participants) government; academia (27 participants), tribal governments or organizations (11 participants), non-profit organizations (7 participants) and private sector (3 participants).

DEEP DIVE PRODUCTS

The following resources developed through this year's Deep Dive can be found through the **NW CASC's Extreme Heat Deep Dive webpage**.

Working Group Syntheses
These detailed reports describe the results of the three Deep Dive working groups that contributed to the key findings above and include citations, survey results and other supporting evidence.

- Biophysical Synthesis Report
- Management & Practice Synthesis Report
- Policy & Human Dimensions Synthesis Report

Example Project Ideas Supporting Research and Capacity Needs
During the 2025 Deep Dive workshop, participants explored novel research and capacity project ideas to manage the ecological impacts of extreme heat. This table of proposed project ideas was generated by workshop participants to help address the research needs described in this report.

Tool & Resource Database
The tool & resource database includes links and descriptions of over 40 different tools and resources of potential use in the research and management of the ecological impacts of extreme heat. These tools have not been vetted by us in any way, and further action would be required to assess their quality and appropriateness for use in different contexts.

Case Study: Mobilizing to Beat the Heat with the Shellfish Rapid Response Network
In the wake of the 2021 PNW heat wave, members of the shellfish community around the Puget Sound came together to enhance their understanding of the impacts of the event and better prepare for future ones. The experiences of the Shellfish Rapid Response Network are a source of lessons and inspiration for how the Northwest can enhance its collective capacity to deal with extreme heat events through collaboration.