NORTHWEST CLIMATE ADAPTATION SCIENCE CENTER

2025 Deep Dive: Too Hot to Handle? Managing the Ecological Impacts of Extreme Heat in the Northwest

This is one of three working group syntheses describing the state of the 1) biophysical science, 2) management and practice and 3) policy and human dimensions of the ecological impacts of extreme heat.

POLICY AND HUMAN DIMENSIONS WORKING GROUP SYNTHESIS

Extreme heat events[1] in the Pacific Northwest can affect ecosystems in a myriad of ways, impacting humans that rely on these ecosystems. Policy can alter the ability of natural resource managers to mitigate or respond to the ecological impacts of extreme heat. Meanwhile, policy is intrinsically tied to the knowledge, preferences and values that a community holds. Throughout the Northwest, communities, governments and institutions are starting to address extreme heat events, but responses are often limited as well as spatially variable and disjointed. In 2021, an unprecedented extreme heat wave across the Pacific Northwest — including record-breaking high temperatures across much of Oregon, Washington and western Idaho — sparked this growing attention in a region that has not historically faced high temperatures compared to other parts of the U.S. However, the extent to which existing policies or tools consider, plan for and effectively mitigate impacts of extreme heat on ecological communities is not well understood. Additionally, there appears to be a lack of focus on proactive planning and a need to coordinate the diversity of disciplinary roles needed for heat governance. This report summarizes the policy and human dimensions of the ecological impacts of extreme heat and identifies opportunities and barriers to action therein.

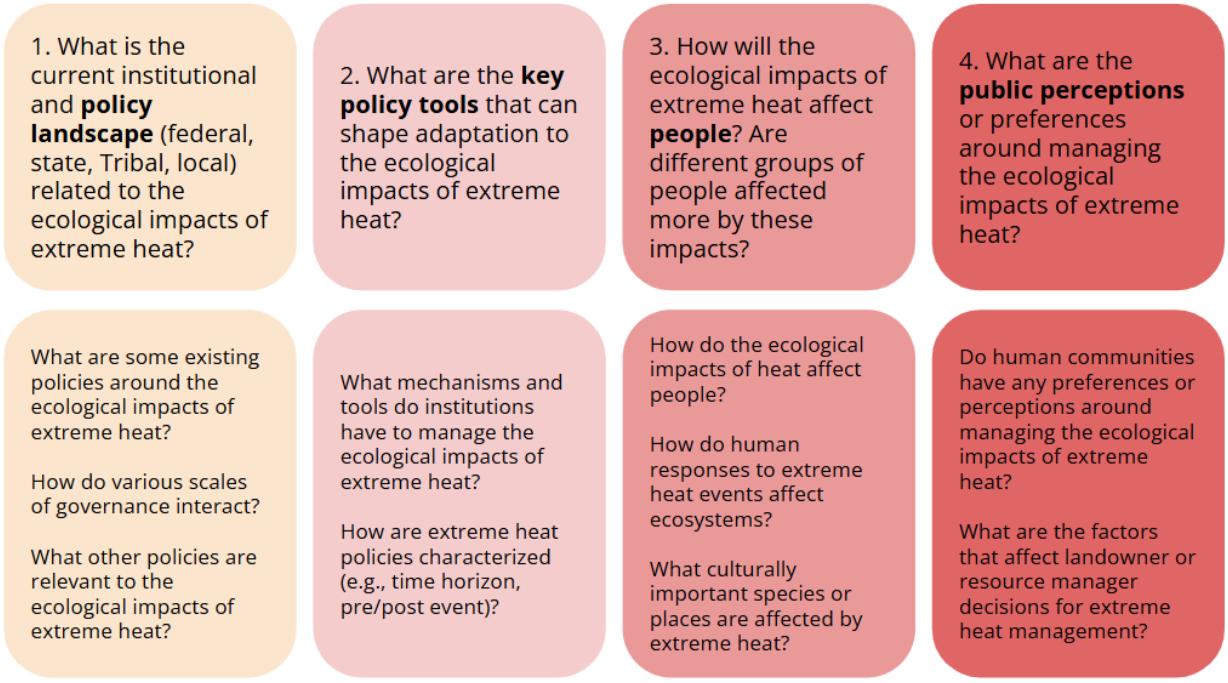
Goal: *Identify the state of knowledge and decision-relevant research on the policy and human dimensions of the ecological impacts of extreme heat.*

The Policy and Human Dimensions working group sought to understand four main topics for this synthesis. These topics include the current policy landscape around the ecological impacts of extreme heat, various policy tools that help institutions address the ecological impacts of extreme heat, social and human impacts and responses to the ecological impacts of extreme heat, and public perceptions around the management of extreme heat. The Policy and Human Dimensions synthesis working group developed a series of guiding sub-questions for each topic to shape this synthesis (Figure 1).

[1] There is not a shared definition of extreme heat among policy leaders in the Pacific Northwest. We used key words including “extreme heat,” “heat event,” “heat dome,” “high temperatures,” and “hotter summers” in our literature review.

To answer these questions, the workgroup searched for and collated information from peer-reviewed publications, grey literature (e.g., white papers, management plans), other government reports and documents and responses from the Management and Practice working group's survey of the Deep Dive network.

Figure 1: Main topics and guiding questions



1. What is the current institutional and policy landscape (federal, state, Tribal, local) related to the ecological impacts of extreme heat?

The policy landscape around extreme heat is spatially variable and fragmented, with a lack of consistent definitions or clear responsibility. Some climate and sustainability-related plans and species or natural resource management plans discuss heat impacts and adaptation. However, few policies or plans are specific to extreme heat hazards. The ecological impacts of extreme heat are underrepresented in policy in the Northwest, but plans and policies from other regions (e.g., Southwest) and other sectors (e.g., hazard mitigation, public health) may provide some transferable takeaways.

Policy landscape

While a variety of governmental and quasi-governmental entities (including federal, Tribal, state, and local) are likely key players in mitigating and managing the ecological impacts of extreme heat events, there is currently no single organization tasked with addressing the issue (Keith et al., 2019). Multiple institutions at different scales manage ecosystems and engage in heat governance, which means the policy landscape is very fragmented (Turek-Hankins et al., 2021).

Challenges for effective and localized extreme heat management include poor coordination, limited regulations specific to heat, low prioritization of heat issues relative to other hazards and uncertainty around the most effective strategies (Keith et al., 2023).

Broader climate adaptation literature also highlights institutional fragmentation, lack of political leadership, limited public support and scarce human and financial resources as persistent obstacles (Eisenack et al., 2014). Additionally, challenges include limited capacity to integrate available information into daily planning and a lack of clear, direct and centralized sources of region-specific heat-related information, all of which hinder effective ecological adaptation and management (Zottarelli et al., 2022).

There is a lack of consistency or consensus among institutions and communities on what constitutes an extreme heat event, with various terminologies used to describe extreme heat phenomena, including heat islands, heat waves, extreme heat days, high temperature/warm days and heat domes (Smith, 2022). Deep Dive participants noted that there is inconsistency around whether to measure the change in the warmest day of the year, number of days where temperatures exceed a threshold or rise in average daytime or nighttime heat. The lack of consistency makes it difficult to confirm the status of existing attention to extreme heat events in policies and plans, because different organizations use different terms, like heat waves, heat events, heat domes and more (Meerow & Keith, 2022). Another dimension to the policy landscape is that it appears uncommon for jurisdictions or entities to have heat-specific plans, though Deep Dive workshop participants noted that extreme heat is often addressed under the umbrella of other types of management plans, including climate mitigation, climate adaptation or species management plans.

Multidisciplinary collaboration is a driving force for addressing extreme heat. Workgroup members noted that while formal coordination is limited (e.g., funded collaboratives), some institutions still engage in opportunistic activities that address heat governance (e.g., learning networks, listservs). These activities improve knowledge sharing and coordination when there is a lack of formal policy development or planning. In fact, over 75% of Deep Dive survey participants indicated they engage in some form of formal or informal partnership, collaboration or co-management effort for heat governance.

Transferable policy lessons from other sectors

Many policies and plans address impacts to ecosystems, species or natural resources from various climate and non-climate stressors, but limited policies explicitly address impacts of extreme heat events alone (Turek-Hankins et al., 2021). In sectors outside the ecological and natural resources space — such as public health and hazard mitigation — many policies and plans address extreme heat events, though not the ecological impacts of extreme heat (Turek-Hankins et al., 2021). While not specific to the ecological impacts of extreme heat, other sectors could offer insights into how the Northwest could design effective governance systems to improve policy responses and interventions.

For example, hazard mitigation policies are often characterized by pre-disaster preparedness, immediate emergency responses and post-disaster recovery (Bahmani & Zhang, 2022). Much of the policy for the ecological impacts of extreme heat in the Northwest, as discussed below, has primarily been focused in the latter two categories — immediate responses and post-event recovery — primarily in response to the 2021 PNW heat wave. For example, natural resource managers and urban forestry officials continue to reflect on the impacts the 2021 PNW heat wave had on trees in the Northwest. While regional coordination among some natural resource management institutions is happening to better prepare for future extreme heat events (as described below), there may be an opportunity for more proactive efforts to better cope with the effects of future extreme heat events. For example, natural resource and urban forestry policymakers can anticipate future heat events.

Additionally, public health sectors across the world are preparing for extreme heat events, often relying on the collaboration of multiple governance institutions to prepare health systems to support communities during extreme heat events. Conditions that enable effective collaboration include clear governance architecture (i.e., which institutions are in charge of implementing which strategies), pathways to manage for uncertainty and shared policy goals and outcomes. Understanding the lessons learned and enabling factors for effective multi-institutional collaboration from other sectors can help inform regional policy responses to manage the ecological impacts of extreme heat (Singh et al., 2024).

2. What are the key policy tools that can shape adaptation to the ecological impacts of extreme heat?

There are not many heat-specific plans or policies outside of climate adaptation and mitigation plans in the Pacific Northwest. Some of the existing planning and policy tools to address the ecological impacts of extreme heat include state and local climate action and adaptation plans, sustainability plans, natural resource management plans and Tribal plans. Attention to extreme heat is often broad and related to general climate impacts and adaptation. While many heat-related plans primarily focus on human health and infrastructure impacts, there is some specific policy and planning attention to heat impacts on forests, agriculture, shellfish, fish and outdoor workers. There is an opportunity to add more comprehensive and robust attention to preparing for, managing and responding to the ecological impacts of heat in a wide range of state and local level plans and policies.

Policy tools vary across governance scales and few are specific to the ecological impacts of extreme heat

The federal government, states, Tribes, natural resource management agencies, municipalities and other public actors all have potential important roles in addressing the ecological impacts of extreme heat. Certain institutions are better equipped to use different policy tools.

For example, federal agencies can help scale policies that build resilience against extreme heat through coordination, technical assistance and guidance, funding of programs and data provision. Tribal institutions lead climate adaptation plans, as well as education and outreach, to address extreme heat. Natural resource entities can develop ecosystems and species-specific guidance. At the local level, heat planning involves coordination across multiple city departments and levels of government (Keith et al., 2019; Meerow & Keith, 2022).

Despite the many policy tools that institutions could use to address the ecological impacts of extreme heat, there are limited examples of policies that simultaneously address both issues together. Most policies address either the impacts of extreme heat (though not specific to ecological impacts) or how ecosystems and natural systems are affected by climate change (though not specific to extreme heat). The sections below highlight some of the existing policy tools in the Northwest that could be used to address the ecological impacts of extreme heat.

Regulations

There is no federal-level regulatory framework that explicitly and comprehensively guides governance for the ecological impacts of extreme heat. Some regulatory frameworks exist at state levels to establish guidelines for addressing extreme heat, usually with a focus on human health and infrastructure rather than on the ecological impacts. As one example, Washington's Growth Management Act requires the state's fastest-growing cities and counties to update their comprehensive plans and related development regulations every ten years. Recent legislation (HB 1181) now requires these plans to address climate hazards, including the impacts of heat on natural systems and environmental and weather resources, as relevant to the jurisdiction. It is too soon to assess how effective these new requirements are at addressing the ecological impacts of extreme heat (Washington State Department of Commerce, 2024). Oregon's statewide land use program also requires local comprehensive plans to address Oregon's natural hazards, although the program does not specify extreme heat hazards, likely because extreme heat events were uncommon when the original program was designed in the 1970s (State of Oregon, 2002).

Worker safety is another area of regulation. In 2022, Oregon's Occupational Safety and Health Division adopted new rules for heat illness prevention, including requiring access to shade, water and additional high-heat practices to protect workers from heat-related illnesses (State of Oregon, 2022). In 2023, the Washington State Department of Labor & Industries revised its heat protection rules to require access to preventive cool-down periods during extreme heat days. While this is not explicitly an ecological issue, it does affect farmworkers, park rangers and other workers in natural resource management or outdoor industries.

Guidance and technical assistance

Guidance and technical assistance facilitate heat governance by providing an outline for how to prepare for and address extreme heat impacts. Several federal agencies have offered guidance and technical assistance on dealing with extreme heat, though the continuation of these programs may be uncertain. For example, the nation's first ever National Heat Strategy 2024–2030, which was coordinated among 29 departments and agencies, outlined a comprehensive approach to managing heat risks across various agencies and sectors. The Strategy acknowledges the impact of heat on the health and wellbeing of humans, other animals and ecosystems, among other impacts, and identifies science-based solutions for heat resilience (National Integrated Heat Health Information System & Working Group on Extreme Heat, 2024). Meanwhile, the Environmental Protection Agency (EPA) conducts research on the ecological impacts of heat and offers guidance, assistance and funding to address heat-related challenges. The EPA's Excessive Heat Events Guidebook (2016) provides practical information for communities to prepare for and respond to extreme heat events, including strategies for mitigating the impacts on ecosystems. The EPA also promotes green infrastructure, such as trees and vegetation, to reduce urban heat islands and their ecological consequences (EPA, 2016). Other agencies — such as the Center for Disease Control and Prevention and the Federal Emergency Management Agency — have various guidelines and guidance documents that help jurisdictions plan for extreme heat events, although their focus is on human health, public safety and critical infrastructure.

Extreme heat is a relatively new type of extreme event that the Pacific Northwest is now experiencing. Jurisdictions across the region are beginning to develop new tools and guidance documents on how to prepare for heat. For example, Oregon's 2020 Natural Hazards Mitigation Plan included a chapter on heat for the first time (Oregon Department of Emergency Management, 2025). However, similar to some other resources, these policy tools primarily address impacts to public health, infrastructure and occupational safety, although there is some guidance on mitigating heat impacts to agriculture and livestock.

Grant programs

Policymakers consistently identify the lack of funding as a significant barrier to heat governance. Existing grant programs are limited, and there often is high competition for limited resources. At the federal level, the EPA currently offers a Climate Resilience and Adaptation Funding Toolbox, which provides an overview of EPA funding programs as well as links to climate risk tools including ones that consider heat (EPA, 2025). States are also providing funding resources to support local heat resilience. For example, the Washington State Department of Natural Resources has an Urban and Community Forestry Grant program, which awards funds to communities to plant and maintain urban forests.

At the city-level, the Portland Clean Energy Fund program — funded by a surcharge on the profits of large corporations — funds community- and government-led efforts to address heat, including ecological-focused interventions like tree planting and maintenance programs in addition to more general public health interventions like subsidized mobile heat pumps. While these grant programs can improve ecological resilience to extreme heat, particularly for urban systems, the primary intent of these programs is to mitigate health impacts of extreme heat events for human communities rather than improving the ability of urban forests to withstand heat events.

Data services

Reliable and trustworthy data on heat enables policymakers to fully understand the problems they are addressing, supports practitioners' abilities to measure progress, and strengthens data transparency (EPA, 2025; FEMA, 2023; Indian School of Public Policy, 2024; Sun et al., 2024; Sustainability Directory, 2025). As mentioned above, a challenge to heat governance is that there is a lack of agreement on definitions or data sources, and there generally is not enough ecosystem- or species-specific data to inform tailored heat governance at more local levels. A majority of Deep Dive survey respondents noted they use a variety of tools to aid in heat governance, such as community or public participation, geospatial data, field observations and forecasts and climate projections. Deep Dive survey respondents also noted they encountered barriers to accessing useful tools, data or resources for heat governance. This unequal access to resources could be due, in part, to a lack of staff, inadequate funding, non-standardized data collection, limited platforms to share data/information, reduced localized climate data or underperforming predictive tools.

At the federal level, some agencies offer tools to show long-term, nation-wide trends and patterns and short-term forecasts. The National Oceanic Atmospheric Administration (NOAA) publishes information that supports predicting and preparing for upcoming heat events. Meanwhile, the National Integrated Heat Health Information System (NIHHIS), a collaboration among federal agencies, aims to be a source of heat and health information to reduce the health, economic and infrastructural impacts of extreme heat. One specific tool linked from the NIHHIS is the National Weather Service HeatRisk map (National Weather Service, n.d.) which provides a short-term forecast risk of heat-related impacts. However, continued access to these federally produced tools may be uncertain.

Tribes and local governments often need more localized and community-based data than available from federal tools. Some Tribes address the ecological impacts of extreme heat through "values-driven" data, meaning data that is grounded in how Tribal members define health, including their health priorities and preferred actions (Schramm et al., 2020). The City of Seattle is addressing local data needs within the city's Climate Action Plan by including strategies to use thermal imaging to identify areas that are likely to be more heavily impacted by heat events in order to inform urban forest and tree planting programs (Seattle Office of Sustainability & Environment, 2013).

Coordination

State and municipal heat planning is characterized by multidisciplinary coordination across departments and levels of government (Keith et al., 2019; Meerow & Keith, 2022). Heat governance is often planned for through a variety of mechanisms. It is often written into public health, parks and recreation and urban forestry plans. Though these plans often address heat at a very high level and do not typically focus on the ecological impacts of extreme heat, they do lay some groundwork in interdisciplinary planning for heat governance.

As an example, Washington and Oregon have state-level climate adaptation strategies that facilitate multi-agency coordination to coordinate heat governance across sectors, including for the protection of ecosystem services, natural resource industries, infrastructure and public health (Oregon Department of Land Conservation and Development, 2021; Washington State Department of Ecology, 2024).

Natural resource and recreation agencies can act as coordinators across management scales to implement policies related to species-specific responses to extreme heat. One example is the Shellfish Rapid Response Network, which connects natural resource managers across state, local and Tribal jurisdictions to improve coordination and response during extreme heat events to mitigate impacts to shellfish habitats (find a case study about the Network on our Extreme Heat Deep Dive webpage). Meanwhile, recreation agencies can redirect recreational use to optimize changing recreational opportunities (such as more shoulder season activities) and protect areas vulnerable to damage by recreationists (Miller et al., 2022; Peterson, et al. 2022).

In the Northwest, heat planning is also addressed through broader climate resilience or resource management plans. This type of planning helps coordinate what should be done, but it does not necessarily offer guidance on or create regulation for how implementation should occur. Developing implementation guidelines can support the review of current plans and tools and assist in the identification of potential heat governance barriers and opportunities. In some cases, however, these plans can be reactive rather than proactive, which results in limited evaluation of a plan's effectiveness and reduced efforts to achieve intersectional coordination (National Academies of Sciences, Engineering, and Medicine, 2023).

Municipal planning

With federal climate leadership currently in retreat, local-level activities will likely take on a more critical role in the short term. Municipal planners are increasingly concerned with the risks posed by extreme heat, especially its environmental and public health impacts associated with climate change. Although extreme heat is less regulated compared to other hazards, approximately 65% of respondents in a survey of U.S. planners reported addressing heat in at least one of their community's plans (Meerow & Keith, 2022).

Addressing heat through city planning and coordinating these efforts so they support each other can be a strategy to holistically address extreme heat in a specific location — especially when designing strategies to support community preparedness to heat.

For example, the 2024 Portland Climate Emergency Work Plan and the 2021 Boise Climate Action Roadmap emphasize the need for collaboration with sensitive community groups, such as outdoor workers or low-income households, to improve policy design and delivery (Chang et al., 2021; The City of Boise, 2021). The 2021 Boise Climate Action Roadmap also includes nature-based strategies (e.g., urban forests) that can mitigate urban heat island impacts and discusses how future restoration efforts should consider long-term temperature change (The City of Boise, 2021). Even though these municipal-level plans do not yet typically address the ecological impacts of extreme heat on specific species, collaborating across disciplines and levels of government can produce multi-faceted, context-specific strategies that address the unique needs and challenges of a place (Fu et al., 2024).

Limitations of policy tools

To plan effectively, policy leaders need better information about policy thresholds and implementation guidelines. Deep Dive Workshop participants noted that there are different temporal considerations in planning efforts: proactive pre-event preparedness, management actions and policies during an extreme heat event and post-event management and policies that focus on assessing and learning about the ecological effects of extreme heat.

Deep Dive Workshop participants raised questions about guidance in when a policy response is triggered (e.g., an estimated temperature threshold or estimated number of die-offs). They also noted the lack of substantive evaluation of the impacts of policies.

"There is not a lot of information on what is successful policy. [For example], was shading actually successful? So more information is needed in order to develop effective policies."

—Deep Dive Workshop participant

Another concern raised by Deep Dive participants was that policy may be limited in its ability to mitigate impacts.

"If extreme heat kills off most of the population of an area how do you even begin to create a policy for that?"

—Deep Dive Workshop participant

Findings about key policy tools suggest there is an opportunity to strengthen heat governance in climate resilience and sustainability planning by state, Tribal and municipal natural resource management agencies and actors. In the Pacific Northwest, there are limited plans or policy tools that fully address the ecological impacts of extreme heat.

Most heat-related policies are embedded in broader plans related to general climate impacts and adaptation, and heat is often addressed only briefly (Turek-Hankins et al., 2021). Workshop participants expressed that existing policy tools could be better used, and new ones could be developed, to address the ecological impacts of extreme heat.

3. How will the ecological impacts of extreme heat affect people? Are different groups of people affected more by these impacts?

How a community is impacted by extreme heat is spatially variable because extreme heat is not evenly distributed across the landscape, with some areas — such as cities — experiencing greater impacts. This spatial variability can cause localized ecological impacts that affect communities by changing species richness and diversity and associated ecosystem services. Among the most commonly mentioned industries and economies impacted were agriculture, fisheries and forestry as well as the communities and individuals who rely on them. Additionally, culturally significant resources for Northwest Tribes are impacted by extreme heat. Extreme heat can impact how communities use natural resources, especially for individuals who need to use more energy and water during extreme heat. Individuals also alter their patterns of recreation and visitation to natural areas and parks, creating potential detrimental effects with increased usage.

Social and cultural dimensions of the ecological impacts of extreme heat

The spatial variability of extreme heat across the landscape causes some communities, typically cities, to experience greater impacts (Meerow & Keith, 2022). Even within urban environments, communities do not experience extreme heat and its impacts the same way; however, what makes a community vulnerable is highly context specific and challenging to accurately predict (Turek-Hankins et al., 2021).

The impacts of extreme heat on society vary across multiple different systems including the economy, essential infrastructure (e.g., energy and water), public health and urban ecology (Turek-Hankins et al., 2021). In urban environments, extreme heat erodes the richness and diversity of urban ecosystems (Brans et al., 2018) and affects plants' growth and ranges (Nitschke et al., 2017), which in turn impacts people's enjoyment and ability to cool off. During extreme heat periods people tend to use more water and energy, such as increasing their use of air conditioning, which can create feedback loops that create more greenhouse gas emissions and further raise local ambient temperatures (Ravishankar & Howarth, 2024).

Climate change is impacting recreation. For example, the United States Department of Agriculture Northwest Climate Hub reports that in the Northwest, wildfire and smoke are affecting access to campgrounds and altering landscapes, decline in snowpack is changing skiing, and there is decreased opportunity for anglers of cold-water fish. Changes in human behavior, in turn, affect natural areas and ecosystems.

For example, increased visits to areas that are cooler — such as natural areas, areas higher in elevation or areas near water bodies — can have negative impacts on the environment, such as degrading trails, campsites and surrounding habitats (Halofsky et al., 2022b). Deep Dive survey respondents reflected these impacts, with more than half observing increased usage in energy and water and just under half of respondents self-reporting increased visits to cooler areas during extreme heat events.

Economic dimensions of the ecological impacts of extreme heat

During extreme heat events, economic productivity is also impacted due to decreased labor hours and impacts to natural resources and other ecosystem services (Meerow & Keith, 2022). Agriculture, fisheries and forestry provide services and goods to many communities in the Northwest, and extreme heat is expected to affect these ecosystem services. In agriculture, extreme heat can reduce crop yields and increase livestock stress (Lesk et al., 2016; Turek-Hankins et al., 2021). The Spokane Tribe Climate Plan also mentions that some traditional crops are less productive under high temperatures, and Deep Dive participants noted that the 2021 extreme heat event caused crop loss for Tribes (Fisher, 2024). Similarly, the Coeur d'Alene Tribe's Forestry Program reported 85% mortality in their planted seedlings due to compounding impacts of the 2021 PNW heat wave and chronic drought conditions (Coeur d'Alene Tribe, 2023). Notably, other Tribal resources are also impacted by extreme heat, such as increased mortality of Western red cedar (Deep Dive Participant), shrinking of huckleberry habitat along drier lower elevation portions of its current range (Prevéy et al., 2020) and smaller huckleberry harvests (The Spokesman-Review, 2021).

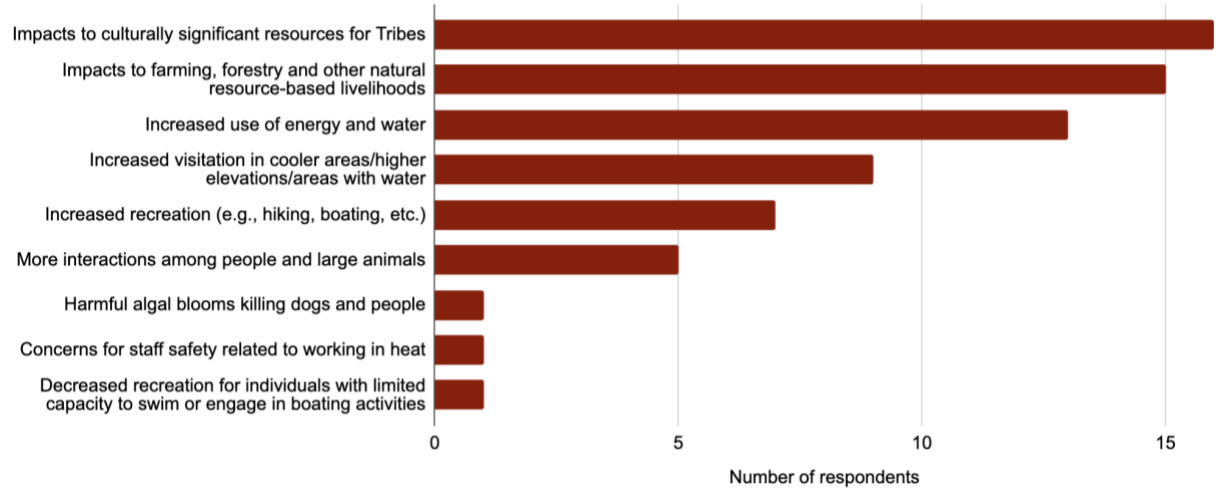
"Extreme heat events often lead to die-offs of varying scales of intertidal shellfish. Mass mortality of shellfish significantly reduces accessible cultural resources and weakens tideland ecosystems. It can take many years to rebuild those resources and habitat."

—Deep Dive survey respondent

Extreme heat can impact fisheries through either direct die-off of species, harmful algal blooms that restrict fishing or cause die-off, reduced water levels or habitat loss (Cline et al., 2022; Halofsky et al., 2022a; Raymond et al., 2022). Many Deep Dive participants noted that fish and shellfish are culturally significant foods and a source of revenue for Tribes, and they shared their observations of mass mortality events during the 2021 PNW heat wave. Additionally, fisheries make up a large portion of tourism and industry in the Pacific Northwest, so these impacts on fish and shellfish habitats can have large impacts on revenue generation for communities (Cline et al., 2022). The combination of extreme heat and the resulting intensified water usage by municipalities and agriculture can cause some fisheries to be deemed no longer viable and salvage orders to be enacted. The latter was seen in the Mormon and Fish Creek reservoirs in 2021, where fisheries management officials closed a dam earlier than usual and enacted a fish salvage order enabling people to collect fish before they perished (Magic Valley Regional Office of Fish and Game, 2021).

Most Deep Dive survey respondents (80%) also indicated they observed impacts to culturally significant resources for Tribes and to farming, forestry, fisheries and other natural-resource based livelihoods (75%), highlighting how salient these ecological impacts of extreme heat are (Figure 2).

Figure 2: Deep Dive survey responses to the question, "In what ways have you observed ecological impacts due to the effects of extreme heat on people?"



4. What are the public perceptions or preferences around managing the ecological impacts of extreme heat?

Overall, the literature relating to public perceptions or preferences around managing the ecological impacts of extreme heat is limited, and this appears to be a large research gap. The limited research may be an artifact of the lack of consistent terminology used in policies. Typically extreme heat policy is tied to climate mitigation/adaptation rather than specific extreme events. This area could be explored further to understand the preferences and perceptions that different peoples, groups, and communities have around managing the ecological impacts of extreme heat. It could also be explored to investigate which management strategies landowners and managers employ are most successful and what impacts their decision making.

The literature review revealed a lack of consistency or consensus among institutions and communities on the definition of an extreme heat event — with various institutions using their own terminology such as heat dome, heat wave and heat islands — making it difficult to discern what constitutes an extreme heat event versus high heat (Smith, 2022; White et al., 2023). Deep Dive participants noted that there is also inconsistency among the methodologies used to monitor extreme heat events.

The lack of overall consistency in definitions makes it difficult to confirm the status of existing research on public perceptions and preferences around the management of extreme heat and its impacts (Meerow & Keith, 2022). Thus, the current state of knowledge on public perceptions and preferences surrounding the management of the ecological impacts of extreme heat is extremely limited. Several research questions could be investigated to gain a greater understanding into community response and decision making. One potentially beneficial research question is around how landowners and managers make decisions related to extreme heat management. From our workshop, a number of participants noted that they use government or institutional plans and guidance documents (e.g., federal agency plans, local, municipal and state plans, Tribal plans, resource management plans and species management plans). Understanding which strategies have the highest rate of adoption can help to ascertain the social perceptions of policy implementation. Additionally, research into understanding inter- and intra-community perceptions and preferences around extreme heat policy can help design policies and communications to equitably prepare for the ecological impacts of extreme heat. One participant in the Deep Dive noted that the most successful tools or strategies may vary based on the goal of the community.

The Policy and Human Dimensions working group identified several research and capacity-building needs, summarized in the following two sections.

Research needs

- **Understanding the social and human dimensions of the ecological impacts of extreme heat** such as the social impacts of ecological degradation from extreme heat in the short- and long-term, the social responses to extreme heat events and coupled ecological impacts, human-wildlife interactions that occur during or after an extreme heat event, and co-benefits and trade-offs between social and ecological responses.

- **Public perception and preferences around managing ecological impacts of extreme heat** appears to be a severely understudied area of research. Understanding the public perceptions and policy preferences can help policymakers create socially and politically viable policies that allow for investments in preparedness and timely responses to extreme heat events.

- **Investigation into the impacts that extreme heat has on Tribal communities.** Ecological impacts from extreme heat will affect Tribal industries and culturally important resources. Understanding the Tribal dimensions of the ecological impacts from extreme heat — such as cultural impacts from acute die-offs of culturally important species and reduced access to areas to gather cultural foods — can help inform policies that address Tribal priorities.

- **Policy and governance frameworks** that support preparedness and response from jurisdictions across multiple scales. This research need includes understanding the effectiveness of different types of policy tools — such as plans, incentives, technical assistance, data coordination or other policy levers institutions may rely on — as well as research on the enabling conditions and dimensions of effective heat governance and preparedness.

Capacity-building needs

- **Several policy tools — such as sustained funding through public grants or data- and information-sharing platforms — can enable more collaborative and coordinated work** to manage the ecological impacts of extreme heat.
- Creating **standardized policy tools and methods — such as guidance documents or ready-to-use data at a relevant scale —** to aid in management/policy decisions.
- Building capacity to **evaluate the** effectiveness of policies and policy responses that are designed to be implemented before, during and after extreme heat events. This capacity could be built via partnerships with universities to evaluate policy effectiveness and support for network organizations like associations of governments to reflect on and share best practices.

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