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.

MANAGEMENT AND PRACTICE WORKING GROUP SYNTHESIS

Goal: *Identify the state of practice around managing the ecological impacts of extreme heat as well as research and capacity gaps to inform an actionable science agenda.*

Many Northwest natural resource managers draw on a wide variety of resources to reactively and proactively respond to the ecological impacts of extreme heat[1], but a lack of staff time and related technical and information challenges limit their responses. *This overall conclusion emerges from pursuing answers to a series of questions about the state of management and practice surrounding the ecological impacts of extreme heat events. Each section of this synthesis is structured around one of these questions and includes an assertion in response to that question followed by support for that assertion. This synthesis is primarily based on a summary of responses to a survey designed for this Deep Dive collected during April and May 2025. The contact list of invitees for the Deep Dive provided 68 potential respondents whose positions and organizations are involved in managing natural resources. Out of the potential 68 respondents, twenty responded. These respondents were not necessarily representative of the array of entities and individuals responsible for natural resource management in the Northwest. The results are anonymized, but Appendix A summarizes information about the identity and work of survey respondents. Most notably, the twenty respondents heavily lean towards those working in the Puget Sound part of the region (thirteen respondents), those who work with shellfish (eight respondents) and those working for a Tribe or Tribal organization (nine respondents) or state government (eight respondents). There were no responses from those working for the federal government. The results of this survey are therefore a source of insight into the kinds of actions, considerations and challenges related to the ecological impacts of extreme heat experienced by many of those participating in the 2025 Actionable Science Deep Dive, rather than a comprehensive assessment of what is and isn't happening throughout the region. Unless otherwise mentioned, the questions were open-ended and we coded their responses to identify common themes.*

[1] In this Deep Dive, we define extreme heat events as periods of exceptionally high temperatures lasting from days to weeks that can affect ecosystems, species, infrastructure and management, and specifically reference an unprecedented heat wave that affected the Pacific Northwest from late June to early July 2021 (hereafter referred to as the "2021 PNW heat wave").

Additionally, examples and input from Deep Dive Workshop participants are included to provide additional context and illustrate observations and themes raised throughout this process.

1) How do the ecological impacts of extreme heat affect efforts to manage Northwest ecosystems and species?

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.

"Mass mortality of shellfish significantly reduces accessible cultural resources and weakens tideland ecosystems. It can take many years to rebuild those resources and habitat."

The survey included three questions that provided insight into the observed impacts of extreme heat events on efforts to manage the region's ecosystems and species. First, the survey provided a definition to encourage consistency in responses: "We define extreme heat events as periods of exceptionally high temperatures lasting from days to weeks (e.g., the 2021 'Pacific Northwest heat dome') that can affect ecosystems, species, infrastructure and management." It then asked respondents to "provide an example of how these events impact the ecosystems, species or Tribal cultural resources you work with." There were three common themes in these responses: direct mortality (twelve respondents), species or habitat stress (ten respondents) and undermining Tribal cultural resources/access (four respondents). Additionally, two respondents primarily working in Eastern Oregon/Eastern Washington detailed that these events produced conditions that exacerbated wildfire risks following the event. Only one respondent mentioned that they had not seen any noticeable effects yet (they worked primarily on the Oregon/Outer Washington Coast). One workshop participant emphasized that direct mortality and stress might be the easiest impacts to identify immediately and that these catastrophic mortality events during the field season can make management particularly challenging.

The survey included questions that addressed two specific considerations that the Management and Practice Working Group raised about the ecological impacts of extreme heat events. The first consideration was whether extreme heat events disrupted management efforts. Based on a yes or no question, extreme heat events disrupted the management or planning efforts of seventeen (89%) respondents (two answered that they hadn't experienced disruptions and one answered that this wasn't applicable to their organization). The second consideration was that the intensity, timing or duration of extreme heat events influences responses to these events.

A yes or no question assessed how much this was a concern for respondents. Eighteen (95%) respondents answered that the intensity, timing or duration of extreme heat events affects their approach to responding to these events (one answered no and another answered that this question wasn't applicable to their organization). The near-consensus on both of these issues provides some indication these are important considerations associated with the management of the ecological impacts of extreme heat in the Northwest that merit attention.

Workshop participants underscored the extent to which the variable characteristics of extreme heat events pose challenges for understanding their impacts. For example, the timing of high and low tides relative to the hottest times of the day impacts shellfish mass mortality patterns.[2] Such nuances are further complicated by the potential for critical thresholds related to not only high temperatures, but other factors like the duration and magnitude of these temperatures. One workshop participant expressed that understanding thresholds is particularly important because it will inform efforts to draw lessons from more frequent less extreme heat events. Another workshop participant emphasized the importance of having scientific assessments verify and assess how relevant managers' anecdotal observations in context are for other parts of the Northwest.

2) How are NW natural resource managers responding to these impacts?

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.

The survey included a question inviting respondents to share up to three examples of ways they responded to or planned to respond to the impacts of extreme heat events. The responses they provided generally fit into three interconnected themes. Twelve respondents described **changing management activities**. Eight respondents described adjusting activities in the field to either reduce stress on species affected by extreme heat events, better assess the ecological impacts of extreme heat or provide potential refugia for species during future extreme heat events. Five respondents described restricting activities to protect staff from exposure to potentially dangerous conditions. Two respondents described efforts to pursue funding sources to support efforts to respond to extreme heat. Ten respondents described **pursuing data collection** to better assess the impact of these events on species or habitats or help species weather these events more successfully. Twelve respondents described **proactively preparing and planning** responses to anticipated future extreme events. Connections existed between these three themes.

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[2] Raymond, W.W., Barber, J.S., Dethier, M.N., Hayford, H.A., Harley, C.D.G., King, T.L., Paul, B., Speck, C.A., Tobin, E.D., Raymond, A.E.T., McDonald, P.S., 2022. Assessment of the impacts of an unprecedented heatwave on intertidal shellfish of the Salish Sea. Ecology 103, e3798. https://doi.org/10.1002/ecy.3798

For example, one 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, pursuing data collection). Three respondents emphasized collaboration and network-building efforts as an important part of their response strategies. Out of the twenty respondents to this question, three respondents did not provide an answer to this question and one said that they didn't know but were confused about how to respond.

"A rapid response to collect data is different from a rapid response to try and 'save' the shellfish DURING the event."

Based on the provided examples, there is a potentially important temporal distinction 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** that anticipate better outcomes during future events such as developing refugia or rethinking larger management strategies. The rest of this report focuses on existing capacities and limitations. This distinction between immediate, reactive and proactive responses might be particularly significant in relation to diagnosing, mobilizing and addressing resource needs at different points in time relative to events. One survey respondent explained this in terms of differences even between rapid response efforts, "a rapid response to collect data is different from a rapid response to try and 'save' the shellfish DURING the event".

Many workshop participants expressed surprise at the existence of proactive activities related to extreme heat events. Survey responses were weighted towards those working on shellfish in the Puget Sound, whereas many of the workshop participants worked in forestry, indicating important distinctions in the extent to which those working with different species and ecosystems may be able to identify the effects of the 2021 PNW heat wave and draw lessons for planning for future events. A case study on the work of the Shellfish Rapid Response Network (available on NW CASC's Extreme Heat Deep Dive webpage) developed as a product of this Deep Dive describes their proactive efforts related to protocol development, network building and planning. It is not clear how much those working in other areas or with other species or ecosystems can replicate these proactive efforts. For example, the Shellfish Rapid Response Network has focused on the Puget Sound where existing networks and relationships made developing such a network more feasible than the rest of the Washington coast.

3) What capacities and resources do NW natural resource managers use in these responses?

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.

Respondents were provided a check-all-that-apply list asking about the tools, data, or information resources they used to plan for or manage the ecological impacts of extreme heat. Table 1 summarizes responses to this question. Respondents reported utilizing a wide variety of tools, data and information; with all fourteen options selected by at least two respondents. Climate/hazard vulnerability assessments and real-time or local-scale monitoring were the two most popular responses. Many of the most popular options are technical data describing biophysical systems: real-time or local-scale monitoring, climate projections, species tolerance data, population or genetic data and seasonal temperature forecasts. Community/place-based knowledge was a notable exception (eleven respondents, 63%). This result is not just a product of the number of respondents representing Tribes or Tribal organizations. Of those with this response, five represented Tribes or Tribal organizations, four worked for state governments and two for non-profit organizations. Importantly, while respondents drew on a variety of data and technical resources, the least common responses were more actionable resources like adaptation frameworks, scenario planning/modeling and decision-support tools. This potentially indicates that Northwest resource managers are cobbling together resources to address their needs because they lack adaptation and decision-making tools and strategies that might meet these needs more efficiently.

Table 1. Number of Respondents Using Resources

Tool, Data or Information Resource	#
Climate/Hazard vulnerability assessments	12
Real-time or local-scale monitoring	12
Climate projections	11
Community/Place-based Knowledge	11
Species tolerance data	10
Geospatial data	9
Population or genetic data	9
Seasonal temperature forecasts	9
Traditional Ecological Knowledges (TEK)	7
Remote sensing/Satellite data	6
Community/Citizen Science	5
Adaptation frameworks (e.g., RAD)	3
Scenario planning/Scenario modeling	3
Decision-support tools	2

Fifteen respondents (75%) answered they were involved in a partnership, collaboration or co-management effort related to managing or responding to the ecological impacts of extreme heat. A follow-up question requested more detail about these partnerships.

Five respondents identified the Shellfish Rapid Response Network led by the Washington Department of Fish and Wildlife (for details of this effort, see our Case Study, found on NW CASC's Extreme Heat Deep Dive webpage). Other efforts were identified by only one respondent each and included the Cassia Crossbill Workgroup, the Pacific Shellfish Initiative, co-management efforts involving Tribal and federal partners and collaborations between Tribes and private actors in the shellfish industry.

"Collaboration with other organizations, particularly for technical support, has been our only path forward."

Practitioners utilize data-driven approaches that provide concrete information about current and projected conditions, valuing both scientific assessments and community knowledge. However, the low utilization of decision-support tools and scenario planning reveals a critical gap in adaptive management. While respondents leverage data to understand current and future conditions, few use tools for navigating uncertainty and dynamic decision-making. This disconnect between readily-accessible data and flexible management strategies may limit climate adaptation effectiveness.

The survey also asked respondents a check-all-that-apply question about what kinds of plans, policy tools and coordination efforts directly shape adaptation to the ecological impacts of extreme heat (summarized in Table 2). In reviewing available materials about responding to the ecological impacts of extreme heat, both the Management and Practice and Policy and Human Dimensions Working Groups identified a lack of policy or planning documents that explicitly address the ecological impacts of extreme heat. Despite this noted lack of materials that explicitly address the ecological impacts of extreme heat, most respondents reported that resource management plans, best management practices or emergency protocols (fifteen respondents), species management plans (twelve respondents) and local/municipal/state plans (twelve respondents) shaped their adaptation to the ecological impacts of extreme heat. This finding raises a couple of questions.

Table 2. Number of Respondents Using Plans

Plans, Policy Tools or Coordination Efforts	#
Resource management plans, best management practices or emergency protocols	15
Local/municipal/state plans	12
Species management plans	12
Federal agency plans	9
Tribal government or organization plans	9
Heat management plans	0
Other: Environmental observations	1
Other: Forestry planning	1

First, how effectively do these resources support efforts to address the ecological impacts of extreme heat if they aren't explicitly talking about extreme heat? Second, what benefits might come from more directly discussing the ecological impacts of extreme heat in existing policy or planning documents? The organizations these respondents work for may require them to consider existing plans and policies in their efforts regardless of how useful they are.

Similarly, many respondents described existing funding sources supporting their efforts. Respondents were asked a check-all-that-apply question about current funding sources supporting their work managing or responding to the ecological impacts of extreme heat events. Seventeen respondents (89%) reported using internal funding from their own agency or department, thirteen (68%) used external federal grants, nine (47%) used external state grants, four (21%) used external grants from non-profits and two (11%) used industry funding. While the availability of some funds is encouraging, it is still an open question whether the extent to which these funding sources are adequate or stable enough to support managing the ecological impacts of extreme heat.

To help narrow in on what resources were most important for respondents, the survey included an open-ended question about the most useful tools, data, technical support or information that best supported their efforts to manage the ecological impacts of extreme heat. Ten responses described available data. In line with the results from Table 1, these respondents described a variety of data sources including federal data sources, data their organization collected, climate projections, community observations and citizen science data like iNaturalist. Six responses described collaboration efforts. One respondent explained, "collaboration with other organizations, particularly for technical support, has been our only path forward". The collaborations described also featured a variety of relationships across sectors, between peers and with community members. Only two respondents mentioned policy or planning documents — one mentioned species management plans they were involved in developing and another mentioned a co-management plan their organization was involved in. Only one respondent mentioned funding received. This is consistent with concerns raised above about the extent to which the policies, plans and funding available described in previous answers is sufficient. Three respondents said there were no resources that were important for them and three others did not respond.

4) What currently limits NW natural resource managers' efforts to respond to the impacts of 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.

Respondents were asked to list up to three of the biggest capacity gaps that limit their ability to prepare for or respond to extreme heat events. Sixteen (84%) listed staff time, availability or training as a limitation, eleven (58%) listed funding, six (32%) described a lack of needed data or predictions/projections and six described limitations related to policy/planning or a lack thereof (one respondent answered that this question was not applicable to their organization). Respondents described a variety of issues related to staffing. Sometimes, there is simply a lack of staff. Sometimes existing staff are already working at full capacity and events like the 2021 PNW heat wave become stress points as described by one respondent: "staff capacity all shifted to dealing with the heatwave impacts and other job duties were left incomplete". Sometimes existing staff lack the training or expertise that they need to deal with extreme heat events.

Table 3. List of Tool, Data, or Technical Support Needs

Instream gauging and temp monitoring
Niche habitat temperature monitoring
Local SNOTEL data
Local sea surface temperature data
Beach temperature data
Real time monitoring
Climate and population models
Surveys that identify population effects
Biological thresholds for rare species
Standard protocols, data and centralization
Ready-to-use climate datasets
Better warning
Comprehensive ways to use data/tools
Tool quantifying acute impacts
A communication platform

Note: Items ordered from top-to-bottom based on pure data collection needs to more actionable information and tools

The survey also sought more insight into what might advance regional capacity by asking respondents to describe tools, data, resources, technical support or information they currently lack that limit their ability to manage or respond to the ecological impacts of extreme heat. Five respondents again emphasized that staffing was a limitation, but overall, the responses suggested a wide variety of data, tools or technical support needs listed in Table 3. Additionally, one respondent mentioned more policy-oriented needs: protection for refugia and assistance programs and incentives for farmers that encourage particular land management practices.

Survey respondents highlighted a couple of other notable complications related to existing limitations and extreme heat events. First, when attempting to assess the impact of the 2021 PNW heat wave, those working in the shellfish management community defaulted to established survey methods for resource management. However, these methods were not effective at detecting the kind of impacts that take place in acute extreme events.[3] Therefore, the tailoring that will be necessary for tools, data or technical support to enhance management efforts may not be immediately apparent and need further exploration. Second, the staffing capacity challenges respondents highlighted are both impacted by extreme heat events themselves and drive existing tool, data and technical support needs. Tradeoffs between protecting staff and collecting informative data during extreme heat events is one example. One respondent described: "During the 2021 heat dome we cancelled shellfish surveys. Ironically, we could have collected vital data during that period but we were trying to be protective of staff." Other data needs persist because there is a lack of staff time to address them and managers need greater tailoring of existing information sources like climate projections because, as one respondent described, "I don't have a lot of time to synthesize the data myself." These experiences emphasize that Northwest resource managers addressing the additional stressor of extreme heat face related challenges as they mobilize limited resources under time-sensitive duress during and in the immediate aftermath of events. There is a need to develop understanding and capacity to allocate, share and leverage existing resources to support resource managers during these critical bottleneck moments. Workshop participants raised another limitation which was that publicly available environmental datasets are often extremely large to the point of being burdensome to download, store and manage. 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.

"We only defaulted to running surveys using methods we already have in place…those surveys were fine for managing a resource but not good at detecting acute impacts."

– Survey Respondent

The survey also included an open-ended question that sought insight into whether existing policy or planning (or lack thereof) was a limitation: "Have you experienced any existing policies or has a lack of them been a barrier to your efforts related to the ecological effects of extreme heat?" Responses to this question conflicted about the extent to which a lack of policy or planning is an important limit.

[3] Raymond, W.W., Tobin, E.D., Barber, J.S., Hayford, H.A., Raymond, A.E., Speck, C.A., Rogers, D., Brown, R., 2024. Short-term effects of an unprecedented heatwave on intertidal bivalve populations: fisheries management surveys provide an incomplete picture. Frontiers in Marine Science 6, 1390763. https://doi.org/10.3389/fmars.2024.1390763

Eight responses were consistent with a lack of existing policy or planning. Several respondents focused on a lack of protocols as an example. Another was explicit about the larger need for guidance: “Some people like/need plans and justification to do things. A lack of a plan can limit participation.” One respondent compared their experience in the Northwest to other hot-weather areas they had lived in: “The NW is WAY behind the curve on local, public education about heat, harmful algal blooms, etc. NOAA NIDIS is the only shop doing this in a comprehensive way and WE NEED THAT and MORE.” On the other hand, five respondents said no and seven did not respond to this question. Furthermore, policy solutions risk unintended consequences. Tribal Nations have treaty rights that legally-protect access to culturally-essential resources. One Tribal respondent noted that resource access restrictions during extreme events could erode treaty rights. Protections for subsistence-based losses and commercial losses can present additional barriers to Tribal communities’ access rights and undermine the continuation of traditional lifeways.

The working group identified several research and capacity-building needs to address knowledge gaps, summarized in the following two sections:

Research Needs:

- 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.
- Explore where it’s possible to enhance management responses to extreme heat events through leveraging existing resources; connecting immediate, reactive and proactive efforts; or identifying strategies to effectively address variability in the characteristics and impacts of extreme heat events.

Capacity-Building Needs:

- Strategies to enhance or better leverage existing staff capacity to pursue data collection and other technical or informational needs that enhance understanding and management of the ecological impacts of extreme heat events.
- Support for collaborative networks to help address existing capacity gaps and contribute to information sharing about actions and lessons learned that cross sectors, geographic boundaries and ecological systems.
- More comprehensive, time-saving, actionable resources such as decision-support tools that make available information more relevant for extreme heat events; particularly ones that incorporate and provide localized data.

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Appendix A. Survey Respondent Summary

Table A1. Number of Respondents by Job Function

Job Function	#
Species or habitat management	15
Monitoring or data analysis	7
Tribal/Cultural resource management	6
Climate adaptation planning	5
Land or water resource management	2
Emergency response or contingency planning	1
Other	3

Table A2. Number of Respondents by Organization Type

Organization Type	#
Tribal government or organization	9
State government	8
Non-profit organization	2
Academic or research institution	1
Private sector organization	1
County or other local level government	0
Federal US government entity	0
Other	0

Table A3. Number of Respondents by Work Geographic Area of Focus

Geographic Area	#
Puget Sound	13
Outer Washington Coast or Oregon Coast	7
Eastern Oregon or Washington	3
Cascade Range	1
Southern Idaho	1
Northern Idaho	0
Other	2

Table A4. Number of Respondents by Habitat and Species Focus

Habitat Type	#	Species Type	#
Intertidal/estuaries	6	Shellfish	8
Lakes/wetlands	2	Birds	3
Nearshore marine	2	Invertebrates	2
Prairies	2	Salmonids	2
Riparian	2	Seaweed	2
Blue Mountains	1	Terrestrial mammals	2
Forests	1	Eelgrass	1
Sagebrush	1	Evergreens	1
Shrubsteppe conifer	1		