Northwest Fisheries Science Center

Northwest Fisheries Science Center 5–10-Year Strategy for Salmon Recovery Science

Developed **April 2021–December 2022**
by the NWFSC Salmon Recovery Science Planning Team

NOAA FISHERIES

Cover image: Male and female Chum salmon (*Oncorhynchus keta*) on a spawning redd in the Skagit River, Washington, 2015. Photograph by M. Bond, NMFS/NWFSC.

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December 19, 2022

Dear reader,

The Northwest Fisheries Science Center Leadership Team (LT), composed of the five division directors, the Deputy Science Director, and the Science Director, reviewed the recommendations developed by an internal team of Center scientists. We created this team to assist the LT in executing Objective 1 ("Robust Science Planning" in the Science in Service goal) of the Vivid Description of the Future Implementation Plan. We appreciate the team's hard work and tenacity in creating a suite of relevant, challenging, and thoughtful recommendations.

The Leadership Team endorses the Salmon Recovery Science Strategy, including its critical, high-priority eight research themes. We will begin implementing the strategy as we kick off the FY24 annual activity planning process. The eight themes will inform our annual science priorities for salmon recovery science. In the longer term, we will consider how best to implement the remainder of the recommendations, fostering communication and integration across our salmon science efforts within NWFSC and beyond, including SWFSC and WCR.

We are excited to see these recommendations pave the way for a more strategic approach to salmon recovery science in the next 5–10 years. This is an approach in which our Center's people and projects are working collaboratively toward a common goal and integrating new science efforts into the Center's portfolio.

Best regards,

The NWFSC Leadership Team

Kevin Werner (Science Director), Nicolle Hill (Deputy Science Director), Penny Swanson (EFS), Scott Hecht (FE), Nature McGinn (CB), Craig Russell (FRAM), and Mark Anderson (OMI).

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Introduction

What NWFSC's Salmon Recovery Science Strategy Is and Is Not

NWFSC's Salmon Recovery Science Strategy (the Strategy) provides a roadmap for effective, practicable salmon recovery science at the Center. In this Strategy, we use "salmon" as an inclusive term for salmon and steelhead species. This Strategy is not comprehensive of all salmon science or recovery but centers on the intersection of these ideas: salmon recovery science. Some salmon science is outside the scope of salmon recovery science.

In this Strategy, we identify key research focus areas that potentially impede recovery and for which we lack sufficient existing knowledge to provide actionable management advice. We also suggest organizational changes to increase the coordination and continuation of recovery science across the Center.

This Strategy is not an assessment of existing recovery plans, a review of effective management actions, or a summary of issues with larger NWFSC- or NOAA-wide importance. However, we mean for this Recovery Science Strategy to be consistent with and supportive of the identified critical uncertainties in NOAA Recovery Plans and periodic ESA Status Reviews.

Together, this Strategy and the NWFSC Annual Guidance Memorandum (AGM) lay out the priorities that inform the Center's Activity Plan Prioritization (APP) process. We will have successfully implemented this Strategy if it informs the APP and substantially refocuses the Center's salmon science. In this way, it outlines a context and process to keep the Center's salmon recovery science portfolio focused and relevant.

How Did We Get Here?

The Center's Leadership Team (LT) chartered a Salmon Science Planning Team (SSPT) to examine our anadromous salmonid recovery science work. Salmon science is the largest part of the Center's protected species portfolio. Salmon science work is conducted in all of our science divisions, across all of our facilities, and is a primary focus of many of our programs.

The LT asked the SSPT to develop a 5–10-year science strategy to guide our activities and the decisions about how the Center will resource them in a constantly changing environment. In response, the SSPT generated this strategy. It organizes our current salmon recovery science to create the maximum impact on species recovery. It also implements a forward-looking process to regularly evaluate science relevance, optimize resources, and maximize our organization's potential.

Mission and Vision

With these salmon recovery science mission and vision statements, the Salmon Science Planning Team wanted to convey the need for a shift in thinking about the role of our science in maximizing the recovery potential of Pacific salmonids. These statements represent a strategic, intentional, and focused shift toward a more holistic and comprehensive Center-wide approach to salmon recovery science.

Mission

Our mission is to inform the recovery and conservation of Pacific Northwest salmon and steelhead populations. The Center's salmon recovery science enterprise performs high-quality research on freshwater, estuarine, and marine ecosystems with field and lab work, quantitative analyses, and effective communication in service to the public and our trust resources.

Vision

NWFSC is the go-to source for salmonid recovery science in the Pacific Northwest. In the near term, we will lead our conservation and recovery community with science-based designs and implementation. In the long term, our science products will aid the recovery and sustainability of Pacific Northwest salmon and steelhead populations.

Guiding Principles

Everyone in the Center's salmon recovery science enterprise should see themselves in our mission, vision, science, and workforce. Below, we describe three guiding principles that exemplify our values, approaches to change the culture and practice of our work, and our path toward continuing and advancing the Center's leadership in salmon recovery science.

Valuing the Perspective of a Diverse Workforce

Diversity, equity, inclusion, and accessibility

Varied perspectives from a diverse workforce lead to innovation and robust solutions. In addition, salmon recovery science impacts many different groups and communities. Therefore, we should broaden our public engagement, build upon our public trust, and position ourselves to further our mission by supporting an inclusive, diverse, and multi-skilled workforce consistent with our organizational values.

Environmental justice

We recognize the value of social sciences and the importance of an environmental justice perspective to salmon recovery. Therefore, we should explicitly incorporate both into our work and decision-making. We also recognize the need to integrate indigenous knowledge into our research. Toward these ends, we should collaborate with members of the public, tribes, and other impacted communities to improve our understanding and accounting of the societal implications of our science.

Supporting Our Workforce Through Intentional Succession Planning

People are our greatest asset. We should position ourselves to support that asset over the long term. The Center should immediately begin coordinated succession planning to better familiarize early-career staff with institutional data, information, knowledge, and networks of senior staff. We can aid this process with relatively simple actions, such as:

1. Communicating the value of our various science efforts, including the long-term research and monitoring that enables us to address changing ecosystems and climate.
2. Standardizing the process of documenting workflow, so new hires can rapidly pick up where others left off.
3. Fostering opportunities and mentoring for early-career staff to participate in regional planning and coordination activities, where vital connections have been mandated or established between Center scientists and our partners and constituents.

Optimizing Our Communication Capabilities

Only through clear and consistent communication can our science be effective. We should use our communication expertise to develop outreach strategies that reach a broader, more diverse audience. We should reach out to build community involvement and inspire people who might not have pursued science careers to get involved with our work and build awareness and connection to local issues and concerns.

We should work with our West Coast Regional Office (WCR), the Southwest Fisheries Science Center (SWFSC), and state and tribal co-manager partners to target apathy toward salmon recovery, misinformation, and polarization across communities that have a large stake in salmon recovery.

We should also create a larger, more interactive presence on the web—particularly on social media.

Context

Since the early 1990s, 18 salmon Evolutionarily Significant Units (ESU) or steelhead Distinct Population Segments (DPS) across the Pacific Northwest have been listed as threatened or endangered under the Endangered Species Act. We have not delisted even one of these groups in the intervening years. However, through the direct application of Center science products, NOAA Fisheries conservation efforts have prevented the further extirpation of these populations.

Center science efforts have increased knowledge about these listed fish. This knowledge has led directly to changes in management practices and regulatory actions that positively affect the listed fish. However, much remains to be done. Recovery is becoming increasingly difficult as climate change and anthropogenic activities further imperil listed fish. Salmon face challenges across their entire life cycle in marine, estuarine, and freshwater ecosystems.

In freshwater, we have made great strides in understanding these challenges and the management actions we can take to address them. Sea-level rise will have the greatest impact on estuaries and the nearshore (in addition to changing river and ocean influences). The ocean is changing in ways that are not yet fully understood. Changes in salmonid marine survival suggest that we already see the direct effects of an altered marine environment.

Furthermore, potentially conflicting ESA-motivated management actions (e.g., increasing hatchery salmon production to support the recovery of endangered killer whales) point to the need for a complete understanding of the causal linkages for salmon ocean survival and the management actions that mitigate for changing ocean conditions. This understanding includes actions in estuaries and freshwater that indirectly affect marine survival.

We lack precise measures or estimates of the magnitude of biological benefits expected from large-scale management actions. However, we in no way lack confidence in their efficacy, nor do we justify inaction. Basic Center research supports process-based stream habitat restoration, hydropower dam removal, and ecosystem-based management as robust and powerful tools.

Conceptual Model

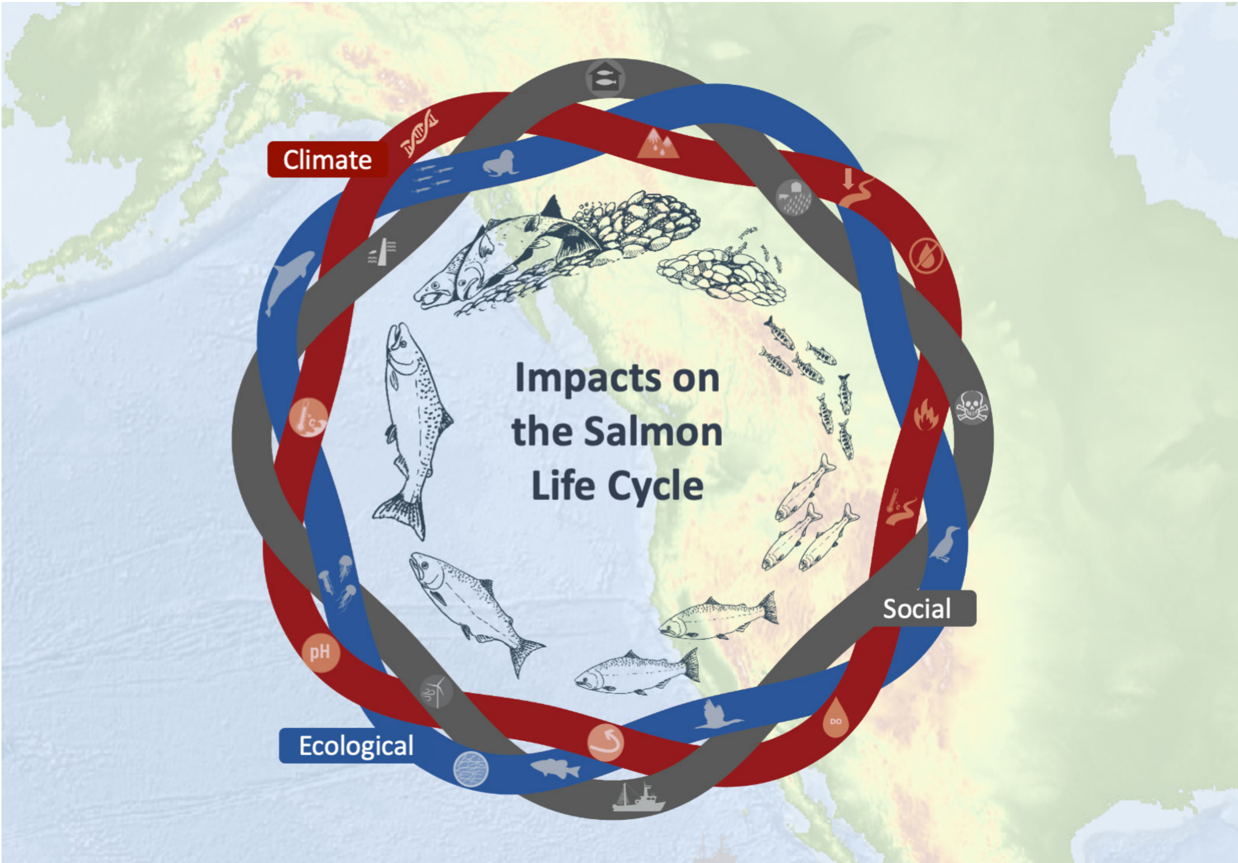

Figure 1. Salmon recovery science must incorporate the entire life cycle and recognize the interconnected nature of these life stages, making life cycle models an ideal framework for evaluation. Priority research areas exist throughout the life cycle and relate to ecological, social (human), and climate drivers.

The conceptual model in Figure 1 illustrates how interacting combinations of drivers and relationships affect salmon throughout their life cycle, and the science needs essential to promoting salmon recovery. Climate influences all other factors affecting salmon. We linked each of the research Themes to one or more life stages affected by climate. Importantly, life-cycle models are an appropriate tool for identifying the sensitivities of salmon to their ecosystem components cumulatively, and for comparing alternative management strategies.

This Strategy actively supports our ongoing efforts to be proactive with our salmon recovery science. Staying responsive and relevant in the face of climate change and changing human activities requires a) intentional focus on a whole-life-cycle perspective, b) cohesion across our salmon science, and c) the agility to adapt as we learn or as conditions change. Even the structure of this conceptual model should evolve as empirical data refine our understanding of key ecological processes.

Research Goals and Themes

Salmon recovery science at the Center is a complex, long-term enterprise. We have conducted salmon research for over 20 years, and we can reasonably expect it to continue for decades; however, not all components are long-term. The Center's overall planning and prioritization process must be responsive to emerging issues, immediate crises, developing technologies, and long-term, steady environmental change due to a shifting climate. Therefore, this Strategy balances the need for being prescriptive with the ability to be proactive and agile.

The Strategy outlines a three-part approach, with:

1. Critical, high-priority, immediately actionable recovery science themes that are mostly ongoing and scalable based on resourcing (Themes 1 through 8)—i.e., short-term goals.
2. A recommended action to guide a flexible and responsive salmon recovery science portfolio at the Center that we should initiate now and could be fully implemented in 3–5 years (Strategies 1 and 2)—i.e., mid-term goals.
3. An enduring effort that will ensure the ongoing relevance of Center salmon recovery science under a changing climate (Strategies 3, 4, and 5)—i.e., long-term goals.

Salmon Recovery Science

Goal statement

Our salmon recovery science must be intentional and relevant. The Center should develop and maintain a relevant research portfolio for salmon recovery science that identifies and communicates the themes that a) are most important to support recovery, and b) the Center is uniquely positioned to address.

Goal summary

Here, we identify and describe the highest-priority, most critical salmon recovery science themes to better inform salmon recovery actions region-wide. We initiated the long-term recovery science planning process specified in Strategies 1 and 3 by identifying eight "must-do-now" themes.

These critical research themes form the near-term core of the Center's salmon recovery science enterprise. They should also be regularly reassessed and evaluated as part of the ongoing salmon recovery science planning process (Strategies 1 and 2). We should implement these eight high-priority themes to the extent practical given the resources available to the Center. A suite of Strategies (1 through 5) will ensure that the Center's salmon recovery science remains relevant and intentional.

Our salmon science portfolio will inevitably be broader than these eight critical research themes. Nevertheless, we recommend that the Center ensures these eight are always adequately resourced to address our salmon recovery mission.

Salmon recovery science themes

The SRS Strategy was motivated and bounded by the reality that Center resources are limited. The Center cannot engage with all current and future issues limiting salmon recovery. We need to narrow the scope to the most urgent science needs. We estimate that the scientific endeavors described below would generate the most progress in our salmon recovery efforts.

Theme 1: Life-cycle models

The larger goal of salmon recovery requires moving beyond a piecemeal approach where we consider individual drivers in isolation from the rest of the life cycle. Life-cycle models are valuable for collating the impacts of diverse pressures, opportunities, and management actions on salmon population viability.

Problem Statement: There are many cumulative impacts on salmon population status and viability—management actions, the pressures salmon face over various spatial and temporal scales, and climate change. The larger goal of salmon recovery requires moving beyond a piecemeal approach where we consider individual drivers in isolation from the rest of the life cycle.

We can set up life-cycle models (LCMs) in many different ways. However, life stages are typically spatially explicit, and can compare risks, identify knowledge gaps, quantify inherent uncertainties, and evaluate relative recovery potentials associated with alternative scenarios across the full salmon life cycle. Especially when combined with insights from social science, LCMs have the potential to help identify the most impactful actions that can move the needle toward recovery.

Management Implications: We use LCM results throughout the region—for WCR Biological Opinions, NEPA determinations, and decisions that involve harvest and hatchery operations. In addition, local partners such as watershed managers use them to allocate resources toward more beneficial projects. However, we often develop LCMs in response to specific requests by partners and tailor them for particular management applications. For LCMs to make a difference in salmon recovery more broadly, their development must be proactive, generalized, and coordinated at a larger scale.

Research Focus: LCMs can examine which aspects of a model are most responsible for driving population dynamics and model uncertainty. With a well-grounded model, we can conduct systematic sensitivity/gap analyses to identify which aspects of the salmon life cycle could respond to new actions with the largest benefit for population recovery. Structured appropriately, LCMs can account for the life-history variability underlying portfolio effects and sublethal effects that carry over from one habitat to another, thus fully addressing the cumulative impacts of different stressors.

A full data-gap analysis would include both quantitative and qualitative components:

- The quantitative analysis would account for multiple model structures, influencing our ability to pinpoint particular gaps. We must compare model outcomes from

alternative mathematical formulations to clarify what we can and cannot assess for a given population.
- The qualitative component would consider each theme's potential roles, particularly to identify how large data gaps could influence our results.

We need to study the implications of various choices made in the model building to apply the life-cycle modeling approach more proactively and equitably across a larger cross-section of the populations we manage. In the future, we should communicate clearly and effectively what questions we can and cannot answer with available data for a given population and how that answer varies with model structure and additional data.

Theme 2: Freshwater restoration

Restoration planning needs to integrate projected changes (e.g., climate and human population growth, increasing stream temperature, changes in seasonal flow patterns, increasing wildfires) into models of future habitat to design stream restoration and naturalization scenarios that maximize biological and physical potential in light of global climate change.

Problem Statement: All salmon spawn in freshwater habitats, but many critically impaired populations also spend much of their lives in freshwater. Consequently, since their inception, freshwater habitat conservation (i.e., both protection and restoration) has been an integral part of ESA Recovery Plans and is a critical element in ESA Status Reviews. Climate and human population growth models predict continued change in freshwater habitats. Changing habitat leads to increasing stream temperatures, changes in seasonal flow patterns, increases in wildfire frequency and intensity, and additional human demands on water resources.

Management Implications: Freshwater habitat restoration remains one of our best opportunities to improve the capacity, survival, and condition at multiple life stages. WCR and other managers need new information about the most effective restoration options for freshwater habitat. Restoration alternatives that will a) promote recovery at the population and ESU levels, and b) provide resilience against projected climate change should be evaluated in the context of a changing climate using a life-cycle modeling framework.

Research Focus: We need to identify where, how much, and what kinds of restoration, improved access, or habitat protection would most benefit populations to inform salmon recovery in the face of changing habitat conditions. To do this at spatial scales relevant to population persistence, we need to answer three questions at the population scale:

1. How will freshwater habitat change as the climate shifts, and how will these changes interact with current and future anthropogenic modification of streams?
2. How will fish respond to these projected future conditions?
3. What type and quantity of restoration will benefit salmon carrying capacities and productivity the most, given this changing environment?

Theme 3: Toxics

Salmon need cool, clean water to survive and thrive. The sheer number of potentially toxic chemical contaminants in freshwater, estuarine, and ocean habitats challenge NOAA's clean water mission.

Problem Statement: Toxics threaten many managed salmon habitats (freshwater, estuarine, and marine), with risks to food webs and salmon health. Salmon are affected by both immediate and sublethal effects; the latter may be delayed in space and time, including trans-generation effects. The consequences of chemical exposures on wild population growth and abundance are still poorly understood.

Management Implications: ESA-listed salmonids migrate through habitats degraded or under threat of degradation by agricultural runoff, municipal and industrial wastewater discharges, stormwater runoff from urbanized areas and transportation corridors, mining, and historically contaminated industrial manufacturing sites.WCR and HQ (Offices of Protected Resources and Habitat) rely heavily on NWFSC's toxics expertise for the day-to-day implementation of the ESA, for reviewing federal actions under Section 7, and for recovery planning at the population and ESU scales.

Research Focus: Given current constraints, our research should prioritize two main categories of human land use as they affect water quality and salmon recovery:

1. Urban stormwater runoff, as representative of ongoing urbanization across the landscape, at present, and with future climate-driven human migration.
2. Modern pesticides, primarily as permitted by federal agencies for crop protection or invasive species management on forested, range, and agricultural lands in the West.

In both cases, the science should emphasize conceptual and quantitative linkages between human impacts at the sublethal scale and higher biological scales more directly relevant to the agency's conservation mission.

Theme 4: Social and economic dimensions

Developing effective salmon conservation strategies requires integrating insights from the natural and social sciences. The resulting strategies efficiently use limited recovery resources and account for the human behaviors and institutions that affect how well recovery interventions succeed.

Problem Statement: Effective salmon conservation requires judicious use of limited financial resources and the agreement and cooperation of diverse management entities, tribal nations, and stakeholder groups. Salmon conservation requires trade-offs in how and where we allocate scarce resources.

Management Implications: The research questions pursued within this theme can help inform the design of cost-effective conservation strategies that:

- Leverage stakeholder incentives.
- Account for the non-salmon benefits and costs of recovery actions.
- Minimize institutional impediments to effective recovery.
- Align recovery efforts with cultural values.
- Inform the development of complementary natural science research efforts.

The Center should integrate our social science research with LCM results before the results are interpreted as management and policy guidance.

Research Focus: Research within this theme investigates linkages between the human and natural systems associated with salmon recovery, especially:

1. Which recovery investments yield the greatest salmon conservation returns?
2. How do changes in ecosystem services resulting from salmon recovery policies affect stakeholders? How are these impacts distributed across space and time, and among communities?
3. How do current institutions and systems of governance related to salmon recovery, both formal and informal, promote or inhibit the effectiveness of salmon recovery actions?
4. To what degree are salmon recovery strategies aligned with non-economic social values, including equity, justice, and regard for indigenous sovereignty, culture, and traditional ecological knowledge?

Theme 5: Hatchery effects

Most adult salmon in the Pacific Northwest come from hatcheries that support sustainable fisheries, tribal treaty trust responsibilities, and the conservation of imperiled stocks. As such, hatchery science is fundamental to salmon recovery science.

Problem Statement: Based on their genetic similarity to natural-origin fish, over 50 hatchery populations are also ESA-listed, emphasizing the issues associated with differing and perhaps overlapping management goals for natural-origin, hatchery-origin, and listed fish. Throughout the Pacific Northwest, the challenge of operating consistently with recovery confronts traditional hatcheries (to augment harvest) and supplementation programs (for critical stocks). In the future, reliance on hatcheries may grow, including for Southern Resident killer whales (SRKW) and climate impacts.

Management Implications: To ensure compliance with the ESA, WCR staff review hatchery and genetic management plans (HGMP), consult with federal partners, co-managing states, and tribes for all hatchery operations, and periodically assess the impacts through the ESA Status Reviews.

Research Focus: A major issue highlighted in HGMPs and Status Reviews is the loss of fitness—the ability to produce adult offspring in nature—when salmon are artificially spawned and reared. The severity of fitness loss affects subsequent generations for each species; this, in turn, influences the recovery of ESA-listed salmon. Key questions include:

1. How do hatchery spawning practices, rearing environments, growth rates, and release strategies alter selection and change the expression of traits important in determining fitness, and what are the consequences for ecological interactions with wild fish?
2. How might alternative strategies reduce domestication selection?
3. Do such mechanisms persist (or how might they differ) in salmon species for which we have not documented heritable fitness loss but where a long and substantial history of hatchery influence may have ongoing effects?

We should evaluate outcomes under laboratory and natural conditions. Quantitative genetics frameworks, partnered with genomics tools to identify genes of major effect, would provide a robust platform for detecting and reducing domesticating mechanisms and fitness loss.

Theme 6: Climate change

Increasingly frequent population bottlenecks and declining abundance due to extreme climate events threaten salmon populations' long-term evolutionary potential.

Problem Statement: Signs indicate that salmon may already be under strong climate-induced selection. For example, recent freshwater and marine heatwaves have exposed populations across the U.S. West Coast to record-high temperatures. The productivity of interior Columbia River basin populations over the last five years was the lowest since the 1990s.

Management Implications: Declines in population productivity and abundance due to climate change could result in major management actions to avoid extinctions, including:

- Widespread collections for captive rearing.
- New introductions into potentially productive habitats that are currently unoccupied.
- Harvest restrictions to promote rapid adaptation to new conditions.
- Genetic engineering.
- Hydropower dam removal or operational changes.

Managers should be prepared for increasing genetic problems associated with small population sizes (e.g., inbreeding depression). The Center should evaluate the potential for unintended evolutionary consequences of proposed recovery management actions. Hatcheries will substantially impact the evolutionary responses of salmon to climate change.

Research Focus: We should expand our use of emerging genomic approaches to understand the genetic basis and evolutionary potential of salmon life-history traits. Further, we should use these tools to determine how the potential for adaptation corresponds to projected rates of environmental change and the strength of selection. By identifying the genetic basis and constraints for important traits, we can incorporate information on evolutionary responses into population-level demographic projections to improve understanding of population viability and the impact of proposed management actions on recovery.

Theme 7: Predators and alternative prey

We currently lack precise estimates of predation on juvenile salmon. We have only begun recognizing how alternative prey species' spatiotemporal patterns and abundances influence salmonid predation rates.

Problem Statement: Predation is assumed to be the primary cause of mortality for salmon. The impact of this predation by some predators (e.g., orcas, Caspian terns, double-crested cormorants) has been well quantified and, in many cases, resulted in effective management actions. However, we know very little about predation on salmon by most other predators. In particular, predation by seals and sea lions is of concern because their abundance has dramatically increased since the passage of the Marine Mammal Protection Act. Importantly, we have only begun to recognize how alternative prey species' spatiotemporal patterns and abundances influence predation rates on salmonids.

Management Implications: Multiple management actions can be taken to address predation, including:

- Removal of "problem" animals or deterrents to predation.
- Increasing alternative prey abundance.
- Decreasing piscine predator abundances through fisheries regulations.
- Altering the timing or location of hatchery releases.

Most avian and marine mammal predators also receive legal protections under the MMPA, the ESA, or the Migratory Bird Treaty Act (MBTA), limiting the range of potential actions.

Research Focus: Our current understanding of predation, or the role of alternative prey in mediating that predation, for some predators and life stages, needs to be revised to provide sound, science-based management advice. For example, avian predation in the nearshore and ocean has the potential to reduce survival dramatically, yet we know very little about it. We need to answer key questions, including:

1. At what life stage does most predation on salmon occur, and what predators are involved?
2. Are all salmon equally vulnerable to predators, or are some species, stocks, or individuals more susceptible?
3. How do alternative prey composition/distribution/abundance mediate predation?
4. How might rates of predation, types of predators, and vulnerable stocks change due to climate change?

Theme 8: Ocean survival

Climate change will produce much warmer oceans than anything we have seen in the past. This factor alone could drive many salmon populations extinct.

Problem Statement: Warmer marine waters have many impacts on salmon. In addition to the direct effects of increased temperature, physical stressors include ocean acidification, expanding hypoxic zones, and more pervasive harmful algal blooms. We can only mitigate negative outcomes once we understand the direct and indirect consequences of these ecosystem interactions.

Management Implications: Different salmon species and life-history types use the marine environment. Their responses to climate change will vary. Fishery management decisions are often stock-specific, so expanding our research capacity to account for crucial differences in stock sensitivities is essential. NOAA Fisheries will also face spatial planning decisions for new infrastructure and activities related to mitigation for carbon releases on land, increased long-term carbon storage in the ocean, and wind-based energy development. Biological opinions on these actions will involve salmon and their predators and prey because they all migrate through areas under consideration.

Research Focus: A coordinated data collection and ecosystem modeling effort is needed to identify:

1. The most important constraints on salmon marine survival under climate change.
2. Management actions that could improve survival.
3. Whether there are unidentified carryover effects that could inform freshwater management.

Salmon interactions with competitors and higher trophic levels need to be more fully explored, including in offshore areas, especially in the context of climate change. Data collection should focus on understanding climate effects on species interactions. We also need to anticipate range shifts and major changes in species composition.

Salmon Recovery Science Integration

Goal statement

Our science efforts should be driven by a cohesive, Center-wide approach that holistically addresses impacts on salmon across their entire life cycle. We strive to do that through an inclusive, transparent process that ensures people and projects work collaboratively toward a common goal and seamlessly integrate new science efforts into the Center's portfolio.

Goal summary

The Center should conduct ongoing strategic evaluations of the science we perform to effectively support salmon recovery as a recurring practice. We should maintain a full-life-cycle perspective in our science, incorporating cross-habitat and cumulative impacts of research and management advice. This holistic approach should foster communication and integration across our salmon science efforts, including SWFSC and WCR, and most importantly, within our co-manager community. Our success should be gauged by:

- The degree to which our salmon recovery science portfolio adopts a strategic planning stance.
- The extent to which our co-manager community understands and utilizes our recovery-based decision support tools.
- The level of resource investment NWFSC allocates to the goals and strategies identified in this Strategy.
- Whether we—the community of researchers, restoration practitioners, resource managers, and residents of the Pacific Northwest—move the needle on salmon recovery.

Strategy 1: Salmon recovery science coordination

Through existing and new cross-organizational teams, we will strive to improve coordination and communication within the NWFSC and between the NWFSC, WCR, NOAA Restoration Center (RC), and SWFSC. Initially, the focus should be on the eight research themes identified above. The goal of this effort would be to:

- Maintain synergies across our salmon recovery science portfolio.
- Incorporate whole-life-cycle perspectives to better identify data and knowledge gaps and opportunities for collaboration.
- Use existing and new cross-divisional teams to provide input on salmon recovery themes.
- Provide input on salmon recovery science prioritization to the NWFSC Leadership Team in the context of resource availability.

Activities across these teams may include:

- Coordinating salmon recovery science evaluations, in particular, relative to ESA Recovery Plans and Status Reviews.

- Organizing opportunities for communication and cross-pollination throughout the Center, such as workshops with topical presentations, open discussion, and a strong push for engagement from all Center researchers.
- Team-developed charters for standing teams across various salmon recovery topics, which may include other deliverables.

Strategy 2: Promote salmon recovery science themes

Concise evaluations of each current (and potentially new) salmon recovery science theme should be conducted regularly. These evaluations may ask:

- What are the outcomes?
- What research needs to be done?
- How informative would a proposed line of research be?
- Where are we falling short?
- What would help make our work in this area more successful?

These evaluations form a communication and knowledge base around which we integrate current and future salmon recovery science.

Embracing Climate, Ecological, and Social Change

Goal statement

The Center should account for the impacts of climate change across all habitats in our assessments of salmon viability, and should develop appropriate freshwater, estuarine, and marine management advice in the face of substantial uncertainty.

Goal summary

The Center should invest in a framework to incorporate change, especially climate-driven change, into our management advice and research. Specifically, we should:

1. Generate risk projections incorporating climate, environmental, biological, and socioeconomic forecasts for use by NOAA Fisheries and others to underscore the validity of our management advice.
2. Integrate and enhance our capacity for model validation and innovation through field observations and research in marine, estuarine, and freshwater environments.
3. Support social and economic research to increase our capability to use climate-informed advice to a) reduce risks due to resource variability and b) increase the resilience of communities that depend on these resources.
4. Develop a decision support system based on precautionary principles and recognize significant uncertainty regarding future conditions.

Strategy 3: Generate intentional research products

Our research products must be consistent with, and consumable by, the regional natural resource management and salmon recovery communities. We should therefore become more intentional in generating risk assessments around our projections of salmonid population processes. Moreover, we should undertake no Center salmon recovery science efforts in isolation. Each of our efforts contributes to the greater whole.

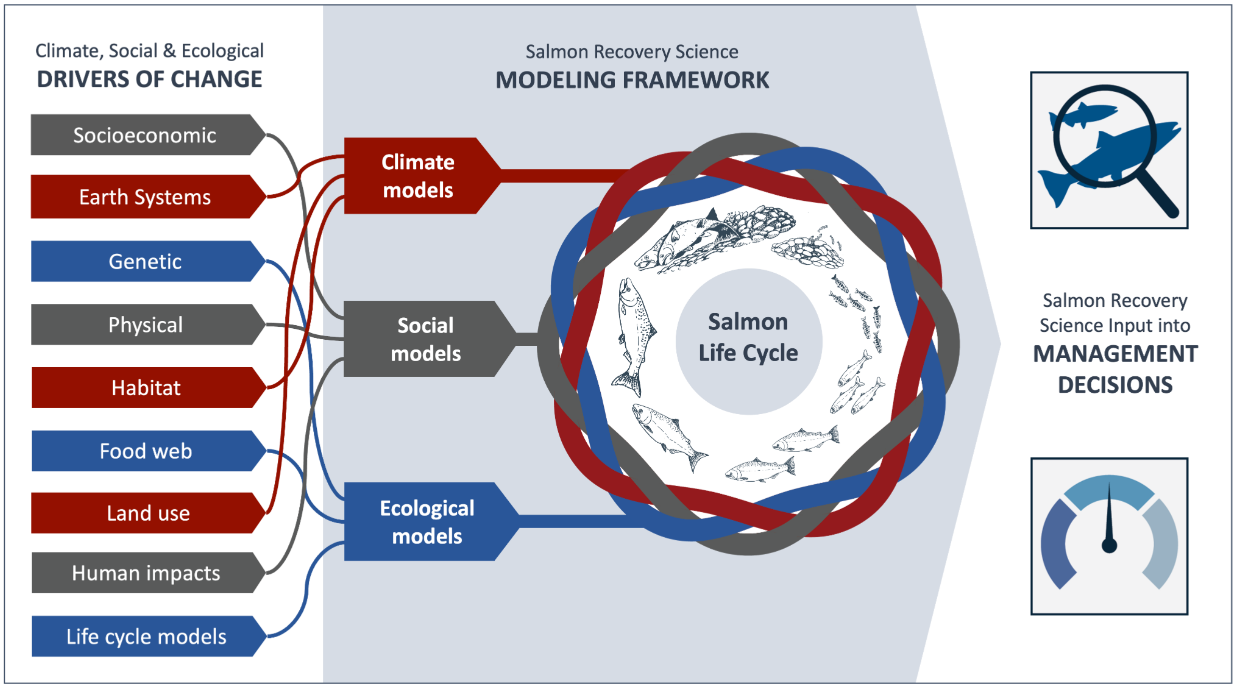

Figure 2. Effectively addressing climate impacts requires a framework for understanding and incorporating multiple drivers of change (left) into salmon forecasts. This multi-model ensemble approach begins with coordination across all research groups, including empirical and modeling teams that either study climate and other sources of change, or incorporate drivers of change into their work. The combined influence of climate, social, and ecological models should be fully integrated across the entire salmon life cycle (middle), and output from this framework should be tailored to directly inform management decisions across all habitats that salmon use (right).

Strategy 4: Adopt a multi-model basis to forecasting

The Center should invest in creating a framework for incorporating climate and other sources of change (e.g., land-use, socioeconomic, oceanographic, genetic) into salmon forecasts. This would require the multi-model ensemble approach shown graphically in Figure 2. There are three initial steps for establishing this framework:

1. The Center has strength in most areas in Figure 2, except for earth systems models and downscaling. We need additional collaboration with expertise in these areas.
2. Coordination across all research groups is necessary, including empirical and modeling teams that either study climate and other sources of change or incorporate drivers of change into their work. Initially, this could be a "Change and Salmon" in-house working group or a task of the SRST. This is a first step to identifying opportunities for integration/collaboration across the different research areas in Figure 2, and could be aided by implementing Strategies 1 and 2.
3. Long-term projections and near-term forecasts for salmon management across the Pacific Northwest region should require a formal ensemble (multiple models) methodology and integration with life-cycle models.

Strategy 5: Link modeling and data collection

Data collected under historical conditions may no longer define the parameter space for current and future climate states. While historical data allows the construction of trends and forecasts, its use also assumes some unknown degree of stationarity, creating the potential for biased or structurally unsound models that will fail in their intended purposes. Therefore, empirical and modeling programs must co-evolve to account for climate-driven changes in the ecosystem.

We propose regular (e.g., annual) meetings between empirical and modeling teams. The collaborations should, at a minimum, address:

- Science needs.
- Logistics and capabilities required to meet those needs.
- Communication/coordination with Center leadership, WCR partners, and other partners and dependencies.
- Periodic review of the meetings to ensure they are effective in content, timing, format, and outcomes.

Operational Goals and Strategies

The operational goals and strategies described below build on elements of the NWFSC Vivid Description of the Future (VDoF) and Implementation Plan, focusing on salmon recovery science. Progress toward these goals is being and will be made as part of overall new and ongoing NWFSC organizational improvements.

Valuing our people and their expertise

Scientists at the Center whose research focuses on Pacific salmon do their work because they appreciate Pacific salmon, including salmon's biological diversity and adaptations to the spectrum of ecosystems along the West Coast. The Center's striking diversity of salmonid research reflects a deep and broad understanding of ecosystem structure. We need an organizational design that fosters more collaborative and cross-discipline teams, including a productive mix of field observations, quantitative laboratory studies, and experiments to provide multiple perspectives on salmon recovery's complex scientific challenges (Figure 2).

Goal statement

Our success depends on our people. The Center must value the people tasked with salmon recovery science and science-support missions and encourage them to reach their full potential in individual areas of strength and expertise.

Goal summary

We support balancing innovation and the uptake of new technology and scientific approaches with the need to manage long-term data continuity and analyses necessary to reveal key patterns and processes.

Strategy 6: Ensuring continuity of capabilities

To ensure the effective continuity of data series and analyses, we should facilitate the transfer of institutional knowledge to future scientists and partners. The Center is uniquely suited to conducting long-term data collection. This is critical to increasing our understanding of salmonid productivity under the influence of biotic and abiotic factors across timescales well beyond individuals' careers.

Equally important to the continuity of data generation is the continuity of operations for analytical tools and applications. An open and documented work environment is critical for robust flexibility in staffing. Such an environment would also incubate innovation through internal knowledge transfer. Therefore, to best protect the Center's investment in its people and their work, we should:

1. Ensure continuity of key long-term datasets. This would require a) consideration of which personnel and resources to support continued data collection, and b) succession planning for transferring institutional knowledge.
2. Adopt an open data (e.g., Openscapes) working framework for documenting and communicating our salmon recovery science analyses, data, and decision support tools.
3. Implement succession planning for data to be well documented, accessible, and preserved when people retire.
4. Work with our partners to plan for the transfer of institutional knowledge.
5. Target new funding opportunities to accelerate the transfer of information and expertise to partners to fill expertise gaps.

Strategy 7: Innovation and training

Innovation is crucial to our salmon science missions. We support research and development, strategic hiring, staff training, internal and external workshops, collaborations, and comprehensive internal communication. To continue playing a leading role in the development and uptake of creative new approaches to salmon science, we should:

1. Develop a balanced portfolio of staff conducting field, laboratory, and analytical work to address key data gaps in salmon science and recovery plans.
2. Promote cross-disciplinary salmon work by enabling individual scientists to work more fluidly across divisions or programs when an individual's expertise benefits a project that may not be in their "home" administrative unit.
3. Encouraging innovation and thoughtful risk-taking for staff who want to try something new by allowing staff to use existing time or resources or seek additional resources for proof-of-concept projects.

Strategy 8: Fostering cross-team collaboration and communication

Throughout this plan, we have highlighted the importance of communication and collaboration across research teams; supporting this requires intentional efforts, such as:

1. Organized and regular cross-divisional and cross-team meetings (i.e., those discussed in Strategies 1, 4, and 5).
2. Team training in collaborative workflows and working effectively across teams.

Encouraging and Supporting Partnerships

Goal statement

Salmon recovery science is a shared responsibility. The Center should actively cultivate and participate in partnerships with other nations, federal agencies within and outside of NOAA, state and local governments, tribes, academic institutions, NGOs, private organizations, and private citizens.

Goal summary

Healthy partnerships are fundamental to achieving successful salmon recovery. Mutually beneficial partnerships combine resources to accomplish high-quality science, promote unified messaging, realize cost-savings, and implement effective management actions that would be impossible for any single entity to accomplish alone. These alliances would provide new sources for collaborations, technology, and broad opportunities that mesh with the Center's mission and strategic initiatives on salmon recovery.

Strategy 9: Foster innovative partnerships

We should continue to foster partnerships that address our salmon recovery science mandates, while also seeking to innovate and expand the potential for new partnerships through intentional and directed action. Specifically, we should:

1. Summarize the function and benefits of existing partnerships to the Center regarding real or potential access to leveraged resources, including but not limited to staff/expertise, infrastructure (e.g., labs, vessels, field sites), and external funding.
2. Proactively identify co-management-based partnerships within the sovereign tribal natural resource management community, focusing on opportunities to advance environmental justice.
3. Proactively identify educational and research partnerships with minority-serving institutions to expand diversity and inclusion within the fisheries science sector.
4. Develop more holistic science by incorporating ecosystem-based data collection and principles.
5. Encourage and support new partners in collaborations, technology, and other initiatives aligned with specific Center strategic goals.
6. Collaborate with science partners to optimize data sharing and shared science approaches.

Strategy 10: Recognize and reward partnership

The Center should be intentional and proactive in fostering robust partnerships that advance salmon recovery science tools, technology, and staff expertise, and should recognize and reward current efforts that exemplify the additive benefit of partnership-based work. This strategy should include elements such as:

1. Internal and external communication and social media call-outs to highlight innovative partnership-based work.
2. Encouraging partnership-based work by explicitly prioritizing such projects via the APP.

Evaluating Our Funding Situation

Goal statement

We regularly and proactively set realistic expectations about the scope and magnitude of our work, enabling strategic planning over the next 5–10 years.

Goal summary

An effective salmon science strategy requires understanding existing funding resources, estimates of future funding, and new and existing avenues to acquire the funding resources needed to effectively implement the short- and long-term science goals we have outlined.

Strategy 11: Develop an informed and empowered community

Base funds are limited and do not sufficiently cover the costs of addressing our mandates. External funds increase flexibility and broaden our financial portfolio. Multiple funding sources will add complexity; we should proactively provide our scientists with reliable guidance and assistance for finding, obtaining, and administering external funds.

Strategy 12: Prioritize targeted opportunities

We must be able to take advantage of new opportunities or emerging threats by rapidly mobilizing people and resources. We recommend short-term task forces to tackle specific issues. For example, if we needed to summarize the interactions between salmon and hake, we could draw from expertise in multiple Divisions, creating interactions between people that would otherwise not have worked together.

Prioritizing Facilities and Infrastructure

Goal statement

We should optimize the coordinated use of the Center's central laboratory and field station capabilities to support all eight research themes.

Goal summary

The Montlake facility has historically served as the Center's hub in the Pacific Northwest, supporting extensive laboratory research, aquatic facilities for empirical research on live fish, small boat staging and storage, archival and gear storage, and maintenance support areas. The transition from Montlake to a new leased facility will invariably impact multiple aspects of the Center's salmon recovery science portfolio. We must relocate some of the "wet" laboratory and field research capabilities to the four field stations. The strategy is to "open up" field stations by facilitating the free flow of projects and staff among all Center laboratories to optimally and efficiently leverage the attributes of all Center facilities.

Improving Outreach Effectiveness

Goal statement

To effectively communicate salmon recovery science, we should ensure that past, present, and future salmon recovery science data are being effectively shared within the salmon science community and to all salmon recovery partners and stakeholders, and that their feedback is incorporated into our practices.

Goal summary

We strive for effective outreach to disseminate important findings, combat misinformation, and foster trust and mutual understanding of our science. The messaging of our salmon science should be clear, concise, and tailored to the specific audience we are trying to reach. It is our responsibility to ensure that natural resource managers understand the meaning of a spectrum of scientific research-based advice if they are to make the best management decisions for salmon recovery.

Strategy 13: Promote communication and outreach practices

We encourage our scientists to attend and participate in workshops, international/national/regional technical committees, conferences, guest lectures, and forums. To increase the effectiveness of our communication and outreach efforts, we should:

1. Develop and share broadly a list of communication best practices, training, tactics, and lessons learned to help staff better communicate with peers and stakeholders.
2. Identify and prioritize critical stakeholders.
3. Review and, if necessary, revise current Center policies regarding travel and funding for travel to participate in outreach activities.
4. Integrate communications planning into developing proposed research projects.
5. Work with the NOAA Central Library to provide video archiving to Center seminars, to allow future access to and promotion of our seminar series and research talks.

Strategy 14: Expand the role and scope of outreach practices

The Center should continue supporting activities that have successfully engaged students and the general public with Center science in the past. These include:

1. Hosting onsite public outreach events at all Center facilities.
2. Providing lectures or seminars to community groups, museums, educational institutions, or other organizations.
3. Encouraging young people to take an interest in STEM activities or careers through direct offsite activities with K–12, college, and graduate students, especially with those groups who are under-represented in marine science.
4. Supporting student participation in Center science through formal and informal programs, and encouraging and rewarding staff who participate as mentors.
5. Fostering volunteer engagement through a rapid and more efficient process for onboarding volunteers and citizen scientists.

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