SCIENCE PLAN

BASIN-SCALE EVENTS & COASTAL IMPACTS

Uniting the North Pacific to Better Understand the Ocean We Share

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EXECUTIVE SUMMARY

The North Pacific Ocean is experiencing unprecedented transformation driven by climate change, with impacts that transcend national boundaries and affect marine ecosystems, fisheries, and coastal communities across the basin. Marine heatwaves are growing more frequent and intense, ocean chemistry is changing rapidly, and species are shifting their distributions across political boundaries. These changes threaten fisheries valued at billions of dollars, cultural practices that have sustained communities for generations, and the ecological integrity of one of Earth's most productive marine regions.

Despite substantial investments in ocean research across the North Pacific, fragmented knowledge-sharing systems create critical bottlenecks that hinder comprehensive understanding of these changes and limit our collective ability to respond effectively. Research often remains siloed within organizations and across international boundaries, while critical information may not reach decision-makers in time to implement effective responses. This fragmentation can result in delayed recognition of emerging climate impacts, missed intervention windows for protecting vulnerable species, duplicated research efforts, and inefficient use of limited monitoring resources.

The Basin-scale Events to Coastal Impacts (BECI) project aims to establish a **North Pacific Ocean Knowledge Network** that works toward integrating climate, oceanographic, ecological, biological, socioeconomic, and traditional knowledge across national and disciplinary boundaries. This knowledge network seeks to:

- Connect diverse data sources on ocean conditions and climate impacts throughout the North Pacific basin
- Transform fragmented information into synthesized, actionable knowledge
- Deliver timely, accessible insights to support climate-informed decision making

The BECI Knowledge Network is being designed to serve as a connecting framework across North Pacific nations (*Figure 1*), working toward enhanced understanding, better coordination, management support, and resource optimization throughout the region.

The knowledge network being developed employs a four-layer architecture that aims to balance flexibility with scientific integrity:

- Data Layer: Connects distributed repositories while respecting data ownership and sovereignty
- Integration Layer: Provides standardized interfaces and semantic frameworks for cross-domain compatibility
- Analysis Layer: Combines built-in analytical capabilities with a dedicated team of specialists to transform integrated data into actionable insights
- User Layer: Delivers customized interfaces for researchers, managers, and policymakers

This architecture is guided by established principles to promote accessibility, inclusivity, and scientific integrity, including FAIR Data Principles (Findable, Accessible, Interoperable, Reusable) and OCAP Principles for Indigenous Knowledge (Ownership, Control, Access, Possession).

Strategic Approach and Implementation

BECI plans to focus initially on Pacific salmon as an exemplar species, then expand to other commercially and ecologically important transboundary species. By working to connect previously isolated research, monitoring efforts, and knowledge systems, BECI seeks to provide Regional Fisheries Management Organizations, national agencies, non-government organizations, and coastal communities with more comprehensive information on changing marine ecosystems across the North Pacific basin.

Our implementation is planned to follow three progressive phases, each building upon previous achievements while expanding capabilities over time to address emerging needs:

- Initial Phase (Years 1-2): Focuses on beginning to connect data sources and establishing core infrastructure
- Intermediate Phase (Years 2-3): Aims to enhance integration capabilities through standardized analysis frameworks
- Advanced Phase (Years 3+): Works toward delivering more comprehensive actionable knowledge through predictive modeling and synthesis

Through a series of targeted use cases addressing specific climate-related challenges, we aim to demonstrate how reducing barriers to knowledge integration and applying ecological modeling approaches may enhance our collective ability to respond more effectively to climate impacts.

Real-World Applications

Our knowledge network approach addresses management priorities through specific use cases that seek to translate research into more practical applications. Four use case examples are provided below and full use cases are presented in Appendix A:

Understanding Marine Heatwave Impacts: By systematically compiling existing research on marine heatwave impacts across the North Pacific, we aim to help fisheries managers better understand species vulnerabilities and identify potential strategies for preparing for future events.

Ecosystem-Based Approaches to Climate Change: Through the development of a collaborative framework cataloging diverse ecological models, we're working to help management organizations more effectively identify appropriate models for specific questions and regions and support the development of standardized scenarios for comparing model outputs.

Climate-Adaptive Spatial Conservation Planning: By synthesizing existing approaches and developing technical guidelines for incorporating climate projections into spatial planning, we're working to help conservation managers assess vulnerability and identify potential climate refugia for more adaptive approaches to spatial management.

Standardizing Ecosystem Monitoring: Our framework for ecosystem status reporting will harmonize core metrics across ecoregions while respecting regional priorities, improving our ability to detect basin-scale patterns and respond to emerging threats

Governance and Partnerships

BECI is being developed through a three-pillar structure to promote effective coordination across the North Pacific:

- Governance Bodies: Including a Steering Committee, Advisory Board, Scientific Panel, and Partnership Council

- Operational Units: Including the Project Office, Working Groups, Task Forces, and Regional Nodes
- Functional Teams: Specialized units focused on data management, knowledge synthesis, modeling, outreach, and capacity building

The project builds on collaborative relationships spanning the North Pacific Ocean, with PICES (North Pacific Marine Science Organization) and NPAFC (North Pacific Anadromous Fish Commission) serving as foundational partners. These organizations bring decades of experience fostering international scientific collaboration and working to overcome institutional barriers to knowledge sharing.

Our approach acknowledges the deep historical understanding of Indigenous peoples who have observed North Pacific Ocean changes since time immemorial. We are committed to respectful engagement that honors diverse values and ways of knowing, working to ensure that if Indigenous groups would like to collaborate, traditional knowledge is integrated appropriately while respecting knowledge sovereignty principles.

Expected Outcomes

By developing new pathways for cross-regional collaboration, information integration, and knowledge synthesis, BECI aims to help decision-makers access more integrated knowledge to support climate-resilient approaches to marine resource stewardship in a changing North Pacific Ocean. We hope our efforts will contribute to:

- Improved understanding of climate impacts on marine ecosystems at multiple spatial and temporal scales
- Enhanced capacity to detect and respond to emerging threats before critical thresholds are crossed
- More coordinated management approaches for transboundary species
- More efficient research and monitoring investments across the North Pacific basin
- Strengthened science-policy interfaces that support more effective climate adaptation

Through these outcomes, BECI seeks to improve how we collectively understand and respond to climate change in our shared North Pacific Ocean, recognizing that this ambitious work involves significant challenges and will develop progressively over time.

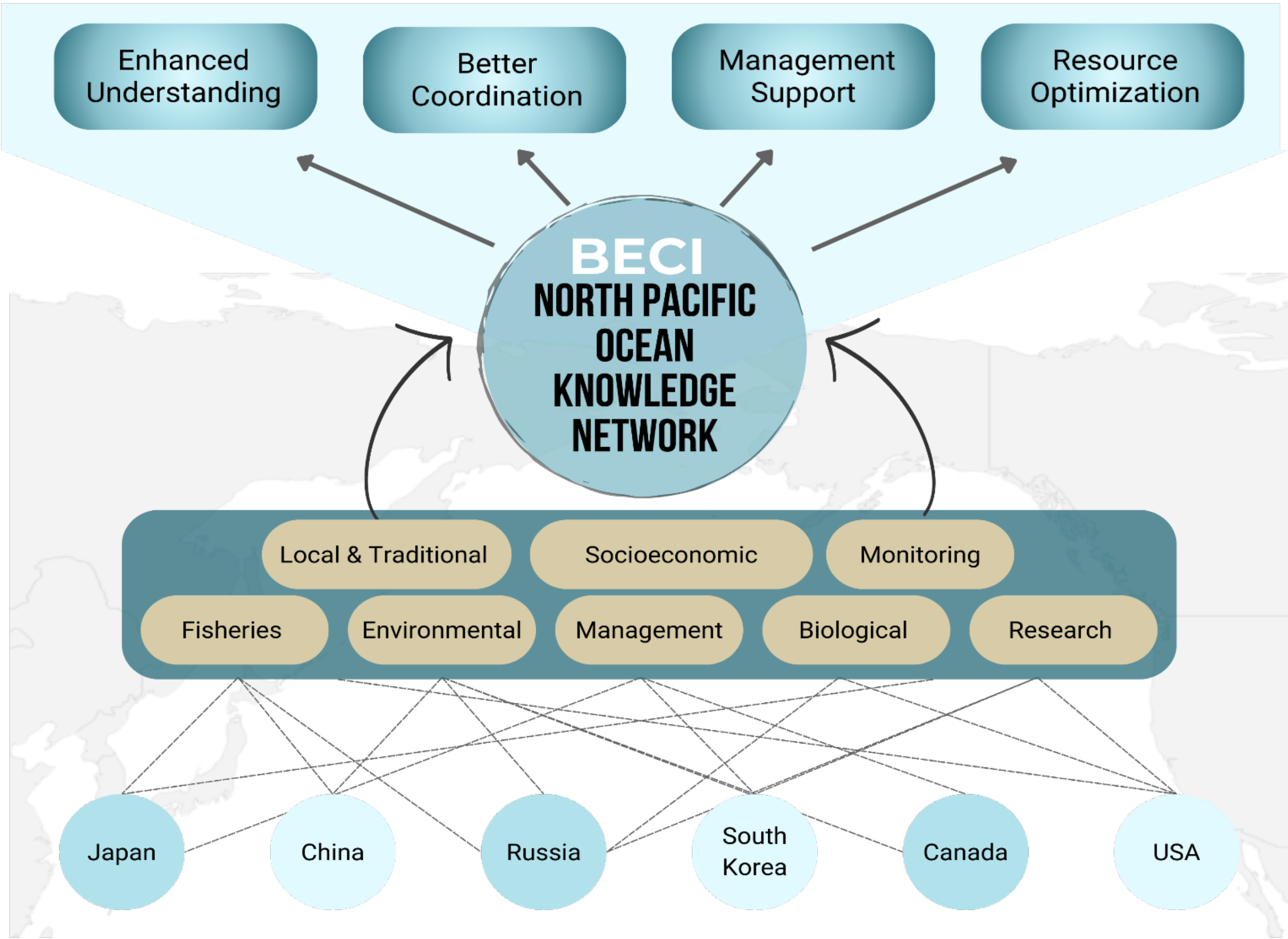

***Figure 1**. **The BECI North Pacific Ocean Knowledge Network** integrates diverse knowledge domains across North Pacific nations to deliver enhanced understanding, coordination, management support, and resource optimization throughout the region.*

By bringing together diverse knowledge systems and expertise from across the North Pacific, BECI seeks to help decision-makers develop more climate-resilient approaches to marine resource stewardship in our rapidly changing ocean.

BACKGROUND

Climate Change & Transboundary Challenges

The North Pacific Ocean is experiencing unprecedented transformation, driven by both progressive climate change and intensifying marine heatwave events (Holsman et al., 2020; Bograd et al., 2019; Yati et al., 2020). Ocean warming has accelerated markedly in recent decades, fundamentally altering marine environmental conditions (Cheng et al., 2022; Fox-Kemper et al., 2021; Watanabe et al., 2021). This warming, combined with increasing acidification and declining oxygen levels, creates complex challenges for marine organisms that must navigate changing conditions throughout their life cycles (Haigh et al., 2022; Ono et al., 2022). Marine heatwaves have grown more frequent and intense (Jacox et al., 2022; Holbrook et al., 2020; Yati et al., 2020), triggering catastrophic consequences including fisheries collapses (Sydeman et al., 2021; Suryan et al., 2021; Nishikawa et al., 2021). These combined pressures are transforming marine ecosystems and affecting coastal communities around the Pacific Rim (Free et al., 2019; Gao et al., 2020; Holsman et al., 2023).

Communities around the North Pacific rim are experiencing the frontline effects of climate change through multiple impacts. Coastal populations, from Indigenous communities to major fishing ports, face unprecedented challenges. Rising ocean temperatures and changing circulation patterns are reshaping species distributions, with cascading effects on fisheries-dependent livelihoods that have sustained communities for generations (Pinsky et al., 2018; Nakamura et al., 2021). Simultaneously, physical threats from intensifying storms, coastal erosion, and sea level rise directly endanger infrastructure and public safety (Overeem et al., 2011; Kimura et al., 2019). These impacts are not distributed equally, smaller communities and those with limited resources often face the greatest adaptation challenges despite contributing least to the climate crisis (Whitney et al., 2020). For many Indigenous peoples across the North Pacific, these changes threaten not only economic security but also cultural practices, traditional knowledge systems, and food sovereignty that have been maintained through centuries of careful observation and adaptation to local environments (Mustonen et al., 2018; Poe et al., 2022). As climate change continues, improved knowledge sharing across boundaries becomes increasingly important for effective adaptation strategies.

SHIFTING FISHERIES RESOURCES
As commercially valuable species move northward, traditional fishing communities face disruptions to livelihoods and food security. Some lose access to historically important species while others gain new fishing opportunities.

EXTREME WEATHER EVENTS
Increased frequency & intensity of these events damage coastal infrastructure, fishing vessels, & aquaculture facilities across Japan, Russia's Far East, Alaska, & the Pacific North West.

OCEAN ACIDIFICATION & MARINE ECOSYSTEM CHANGES
Rapid acidification threatens shellfish industries, while changing ocean conditions impact entire food webs that coastal communities depend on.

CULTURAL IMPACTS
Indigenous communities including Aleut, Ainu, Yupik, & coastal First Nations face threats to cultural practices & traditional knowledge systems tied to specific marine species & seasonal patterns.

ADAPTATION INEQUITIES
Remote communities relying on local seafood face nutrition challenges, while changing water conditions increase harmful algal blooms & introduce new marine pathogens.

FOOD SECURITY & HEALTH CONCERNS
Smaller or economically disadvantaged communities often have fewer resources to implement climate adaptation strategies compared to wealthier regions.

Impacts to Marine Species & Ecosystems

Climate change is affecting marine ecosystems through multiple interconnected pathways including increasing ocean temperatures, acidification, deoxygenation, and altered circulation patterns (Bindoff et al., 2019; Yasunaka et al., 2019). These changes create cascading effects throughout marine food webs, from primary producers to top predators, altering ecosystem structure, function, and resilience (Free et al., 2019; Yati et al., 2020; Ito et al., 2022). The transboundary nature of oceanographic processes and marine species further complicates these climate challenges, as organisms regularly cross jurisdictional boundaries throughout their life cycles (Pinsky et al., 2018; Miller et al., 2013; Furuichi et al., 2020).

Species of significant economic and cultural importance to North Pacific nations—including Pacific salmon, Pacific saury, Pacific sardine, Pacific mackerel, and tunas—are experiencing profound impacts including shifts in distribution, altered growth rates, changes in reproductive timing, and modified population dynamics (Hollowed et al., 2013; Cheung et al., 2015; Okunishi et al., 2021; Xu et al., 2023). Concurrently, ocean acidification threatens calcifying organisms fundamental to marine food webs, while deoxygenation compresses suitable habitat for many species (Breitburg et al., 2018; Ono et al., 2021).

These stressors do not operate in isolation but interact in complex ways that can amplify negative effects on marine ecosystems through cumulative impacts (Samhouri et al., 2017; Kanamori et al., 2022). As climate change accelerates, novel ecological communities are emerging, characterized by changing species interactions and disrupted predator-prey relationships (Pecl et al., 2017; Yati et al., 2020; Watanabe et al., 2021). Traditional single-nation management strategies are increasingly inadequate for addressing these complex, interconnected challenges, necessitating new frameworks for international collaboration and knowledge exchange that can effectively respond to rapidly changing ocean conditions across political boundaries (Makino & Sakurai, 2014; Hollowed et al., 2019).

SPECIES DISTRIBUTION SHIFTS

Commercially important fish stocks are moving northward or deeper as ocean temperatures rise, crossing established national boundaries & management zones. This includes species like Pacific cod, pollock, & various salmon species into Arctic waters.

EMERGING ARCTIC FISHERIES

As sea ice retreats in the Arctic portion of the North Pacific, new fishing opportunities emerge in areas lacking established management regimes, creating potential for unsustainable exploitation.

INDIGENOUS RIGHTS & KNOWLEDGE

Climate impacts affect indigenous communities with traditional fishing rights that span national boundaries, requiring management approaches that respect these rights while adapting to changing conditions.

DIVERGENT NATIONAL INTERESTS

Countries bordering the North Pacific have different economic dependencies on fisheries, management approaches, & climate policies, complicating coordinated action.

DATA SHARING CHALLENGES

Effective management requires transparent sharing of catch data, scientific research, & monitoring information across national boundaries, which faces political & practical barriers.

GOVERNANCE MISMATCHES

Existing management frameworks weren't designed to handle rapidly shifting fish stocks, creating jurisdictional gaps as species move across traditional management boundaries.

Fishery Management Issues

Effective fisheries management in the North Pacific faces mounting complexity as climate change transforms marine ecosystems and drives species across established jurisdictional boundaries (Pinsky et al., 2018; Fujimori et al., 2021). Traditional management frameworks were designed for relatively stable ecosystems with predictable species distributions—assumptions that no longer hold in today's rapidly changing ocean (Miller et al., 2013). As commercially important stocks shift, they create novel management challenges that no single nation can address independently (Cheung et al., 2015; Ito et al., 2022). The North Pacific's geopolitical landscape further complicates these challenges, with six major fishing nations (United States, Canada, Russia, Japan, China, and South Korea) possessing different management priorities, economic dependencies on fisheries, and approaches to climate policy (Oremus et al., 2020). Data and information sharing—essential for informed transboundary management—often encounters political barriers. Addressing these challenges requires better information sharing and coordination across international boundaries (Brattland & Mustonen, 2018).

Current Gaps & Needs

Despite substantial investments in ocean research and monitoring across the North Pacific, fragmented knowledge-sharing systems create critical bottlenecks (Hampton et al., 2013; Tenopir et al., 2020; Tanhua et al., 2021). Research remains siloed within organizations and across international boundaries, preventing comprehensive understanding of ocean changes (Pinsky et al., 2018; Watanabe et al., 2021).

Through engagement with scientists, fisheries managers, and Regional Fisheries Management Organizations, we have identified consistent needs across the region:

- Improved access to and integration of environmental data across jurisdictions
- Clear, standardized summaries of changing ocean conditions
- Tools to explore climate scenarios and their implications for managed species
- Support for understanding climate impacts on fish populations, especially for transboundary species
- More effective communication channels between research and management organizations
- Practical approaches to connect existing monitoring programs across borders

These challenges are particularly acute in the high seas—areas beyond national jurisdictions that serve as crucial migration corridors and feeding grounds for many commercially important species, yet remain understudied (Hazen et al., 2019; Morishita, 2018).

Our engagement with scientific experts has revealed several critical technical needs:

- Ecological forecasting on management-relevant timescales
- Approaches to prediction when ocean conditions exceed historical parameters
- Fisheries-relevant indicators that better connect environmental change to population dynamics
- Knowledge products designed for practical application rather than academic outputs alone

Additionally, ecosystem modeling techniques are increasingly needed to provide enhanced predictions of ecosystem dynamics, particularly for transboundary organisms and high seas areas where significant knowledge gaps exist (Link et al., 2024). Current ecological and oceanographic models are constrained by fragmented knowledge bases, spatial and temporal discontinuities, and methodological limitations that impede comprehensive ecosystem understanding (Cisneros-Montemayor et al., 2020; Pinto, 2012; Ruckelshaus et al., 2008).

Without coordinated international approaches to addressing these gaps, the North Pacific region will continue facing delayed recognition of emerging climate impacts, missed intervention windows, and inefficient use of limited monitoring resources (Lewison et al., 2016). BECI's knowledge network will directly address these challenges by creating innovative pathways for cross-regional collaboration, information integration, and knowledge synthesis to support climate-informed, science-based decision making across the region.

The Basin-scale Events to Coastal Impacts (BECI) project directly addresses key recommendations from the 2024 PICES External Review, particularly the critical call for PICES to "revise its role to provide actionable science information that is relevant to the Contracting Parties and facilitate actions towards science-based solutions." Through its focus on delivering integrated, actionable knowledge products, BECI represents a practical implementation of this strategic recommendation.

What We Aim to Do

The Basin-scale Events to Coastal Impacts (BECI) project will establish a **North Pacific Ocean Knowledge Network** that integrates environmental, ecological, fisheries, and socioeconomic information across national and disciplinary boundaries. This knowledge network will:

1. Connect diverse data sources on ocean conditions and climate impacts throughout the North Pacific basin, including oceanographic measurements, species distribution data, climate projections, and ecosystem monitoring from research institutions, government agencies, and Indigenous knowledge systems
2. Transform fragmented information into synthesized, actionable knowledge through standardized protocols, cross-disciplinary integration, and analytical tools that identify patterns, relationships, and thresholds in complex marine systems
3. Deliver timely, accessible insights to support climate-informed decision making through visualization platforms, status reports, forecasting products, and management-relevant frameworks

We will focus initially on Pacific salmon as an exemplar species, then expand to other commercially and ecologically important transboundary species including Pacific saury, halibut, squid, and tunas. Primary users will include fisheries managers, conservation planners, coastal communities, and resource agencies across NPAFC member nations.

Through this approach, we aim to provide practical tools that bridge the gap between scientific data and management needs, enabling more effective responses to climate-driven changes in North Pacific marine ecosystems.

The geographic scope of BECI is the North Pacific Ocean (north of 30°N latitude) and its marginal seas, which includes key regions such as the Gulf of Alaska, Bering Sea, Sea of Okhotsk, Yellow Sea, and East China Sea. This area is governed by six nations—Japan, Korea, China, Russia, United States, and Canada—as well as international treaties. The domain encompasses a complex marine ecosystem spanning 14 distinct ecoregions, including the Oyashio/Kuroshio Region, Western and Eastern Bering Sea, Aleutian Islands, Gulf of Alaska, and California Current regions. This expansive area captures fisheries that operate on the high seas and/or cross-national jurisdictions, making it subject to intricate international management arrangements. We will focus initially on Pacific salmon as an exemplar species, then expand to other commercially and ecologically important transboundary species including Pacific saury, halibut, squid, and tunas. By connecting previously isolated research, monitoring efforts, and knowledge systems, BECI will provide Regional Fisheries Management Organizations (RFMOs), national agencies, non-government organizations and coastal communities with integrated, actionable information on key climate-driven changes in marine ecosystems across the North Pacific basin.

Our approach emphasizes practicality and relevance—breaking down barriers between data sources, disciplines, and knowledge systems to deliver insights in formats that directly support management and conservation needs. We aim to equip decision-makers with the integrated knowledge necessary to develop climate-resilient approaches to marine resource stewardship.

Why BECI is Critical Now & the Cost of Inaction

The pace of climate change in the North Pacific requires improved approaches to understanding marine ecosystems and fisheries. The scale and complexity of these environmental shifts benefit from enhanced collaborative models for sharing ecological and oceanographic information. Without coordinated action, we risk overlooking critical patterns, duplicating efforts, and responding inadequately to emerging threats.

BECI aims to improve collaboration by establishing a **knowledge network** that connects diverse climate and ecosystem data across disciplinary and national boundaries to provide actionable information for decision-makers. This coordinated strategy will enable us to:

- Identify emerging patterns more rapidly
- Develop deeper, more nuanced understanding
- Respond more effectively and strategically to environmental challenges

Without a coordinated approach to understanding climate impacts, we face:

- Slower recognition of emerging climate change risks
- Lost opportunities to learn from shared experiences across regions
- Inefficient use of limited research and monitoring resources
- Gaps in our understanding of regional and basin-scale changes
- Reduced ability to support evidence-based management decisions

BUILDING OUR KNOWLEDGE NETWORK

Effectively addressing climate change in the North Pacific requires improved coordination of scientific information across different disciplines and regions. Our approach is to progressively build a comprehensive understanding of climate change in the North Pacific, starting with foundational data integration and evolving into sophisticated knowledge synthesis and advanced analytics specifically targeted to support management and conservation actions across the region.

A Systematic Approach to Knowledge Integration

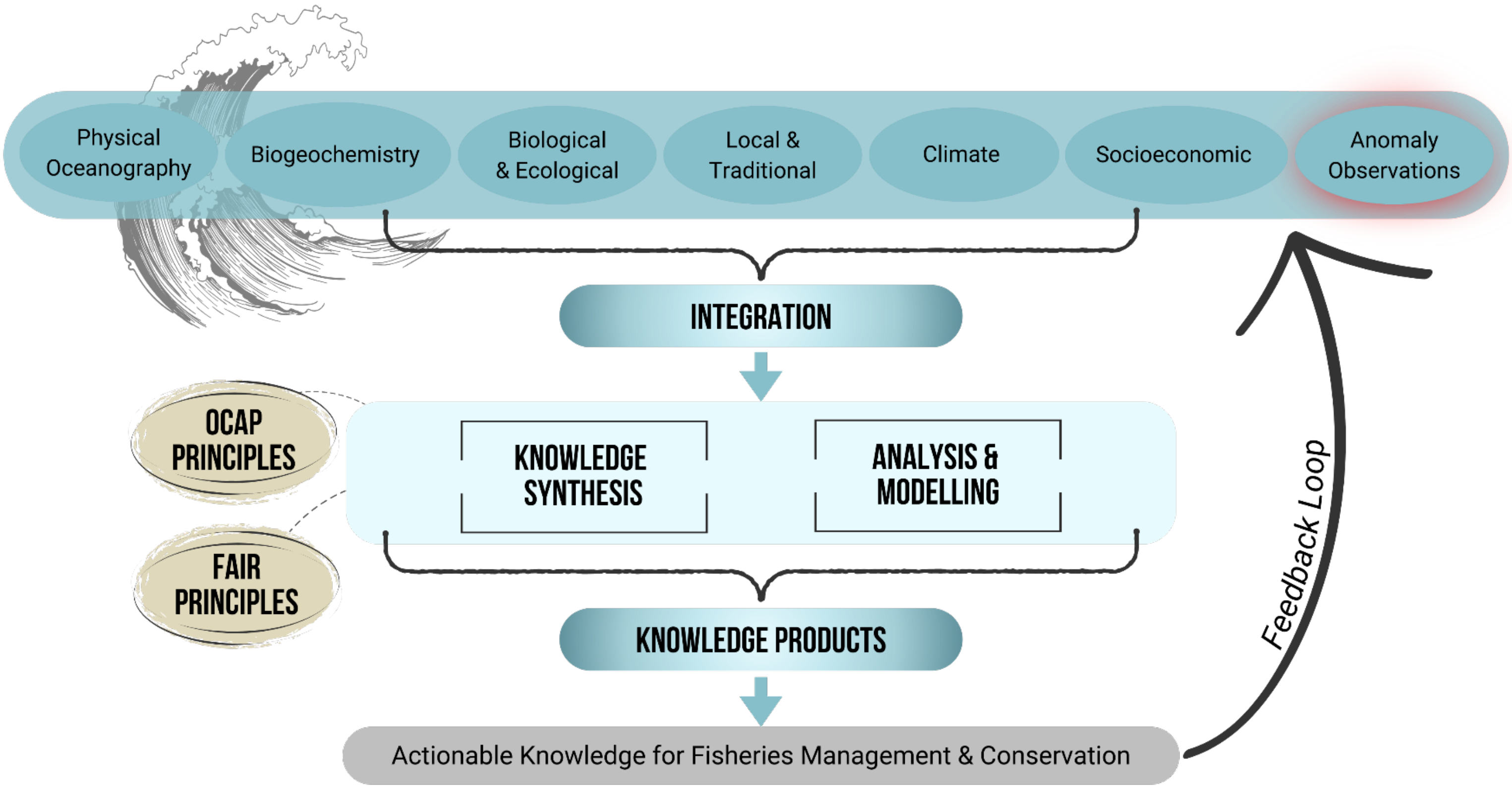

Figure 2. BECI Knowledge Network Visualization. *This diagram illustrates our integrated approach to knowledge production that combines diverse data sources from physical oceanography, biogeochemistry, biological & ecological, local & traditional, climate, socioeconomic perspectives, and anomaly observations. Through a systematic integration process, these multidisciplinary inputs are transformed into comprehensive knowledge synthesis and advanced analysis and modeling products. The knowledge products aim to generate actionable insights for ecosystem-based management in the North Pacific region. These approaches are developed in accordance with Ownership, Control, Access, Possession (OCAP) and Findable, Accessible, Interoperable, Reusable (FAIR) principles, ensuring ethical and effective knowledge management. A continuous feedback loop enables ongoing refinement, allowing the framework to adapt to new information and evolving user needs.*

As illustrated in *Figure 2*, BECI establishes a comprehensive knowledge network that facilitates the transformation of diverse data sources into actionable knowledge for decision-makers across the North Pacific. Within this network, scientists, analysts, and knowledge holders collaborate using standardized processes to integrate multiple types of information—from physical oceanography and biogeochemistry to local and traditional knowledge and socioeconomic data—while respecting both Findable, Accessible, Interoperable, Reusable (FAIR) and Ownership, Control, Access, and Possession (OCAP) principles. An essential component of our approach is the feedback loop that ensures products are continuously refined based on user input and emerging information. This adaptive system ensures that BECI remains responsive to the evolving needs of managers, researchers, and other stakeholders across the North Pacific.

The knowledge network consists of two core components:

1. The North Pacific Ocean Knowledge Network

This foundational infrastructure integrates data, information, and expertise across political and disciplinary boundaries. The network connects existing environmental information, research, and monitoring efforts through standardized protocols, enabling knowledge to flow more freely between regions and organizations.

Our integration approach employs multiple synthesis methodologies that incorporate both quantitative and qualitative approaches, such as:

- Data harmonization and standardization - Converting diverse datasets into compatible formats with consistent units, terminology, and quality standards
- Cross-disciplinary translation - Creating shared vocabularies and ontologies that enable meaningful communication across scientific fields and knowledge systems
- Temporal correlation analysis - Identifying relationships between historical events, current observations, and projected future conditions
- Spatial integration techniques - Combining information from different geographic regions to identify cross-boundary patterns
- Multi-model ensemble approaches - Integrating outputs from diverse ecological modelling frameworks to reduce uncertainty and identify robust patterns

The network focuses on informing ecosystem-based approaches that strategically consider the interconnectedness of biological, physical, and human components. Ecosystem modelling techniques are a crucial component, providing enhanced predictions of ecosystem dynamics, particularly for transboundary organisms and high seas areas.

2. Knowledge Products

Following the integration of diverse data sources, BECI transforms this information into practical knowledge products through two parallel, but complementary processes shown in *Figure 2*: knowledge synthesis and analysis and modelling. While these appear as separate processes in the diagram, in practice they function iteratively: synthesis efforts identify patterns that inform modeling parameters, while modeling results provide quantitative insights that require further synthesis. This cyclical exchange creates a more robust knowledge base than either approach alone.

These processes result in tangible outputs (*Figure 3*) that translate integrated data into actionable knowledge through:

- Cross-regional comparative analyses - Revealing common patterns and unique regional responses to similar climate drivers
- Cross-species response profiles -Identifying shared vulnerabilities and resilience factors across taxonomic groups
- Management strategy evaluations - Assessing potential outcomes of different approaches across varying climate scenarios
- Threshold identification - Pinpointing critical environmental thresholds where ecosystem responses may fundamentally change
- Adaptation pathway mapping - Developing decision trees that link current conditions to potential future states

Our knowledge products represent the synthesis of environmental data, ecological monitoring, traditional ecological knowledge, and ecological modelling insights. They range from environmental condition assessments and synthesis reports to analytical resources and visualization platforms, providing a holistic picture of ocean ecosystems and their responses to climate change.

Development Phases

Our implementation will follow three progressive phases, each building upon the achievements of previous work while expanding capabilities to meet emerging needs:

- Initial Phase (Years 1-2): Focuses on connecting data sources and establishing core infrastructure

- Intermediate Phase (Years 2-3): Enhances integration capabilities through standardized analysis frameworks and knowledge synthesis
- Advanced Phase (Years 3+): Delivers comprehensive actionable knowledge for decision makers through predictive modelling and advanced knowledge products

As BECI capabilities evolve, our ability to address complex challenges grows progressively more sophisticated—from basic data connection to integrated predictions and decision support.

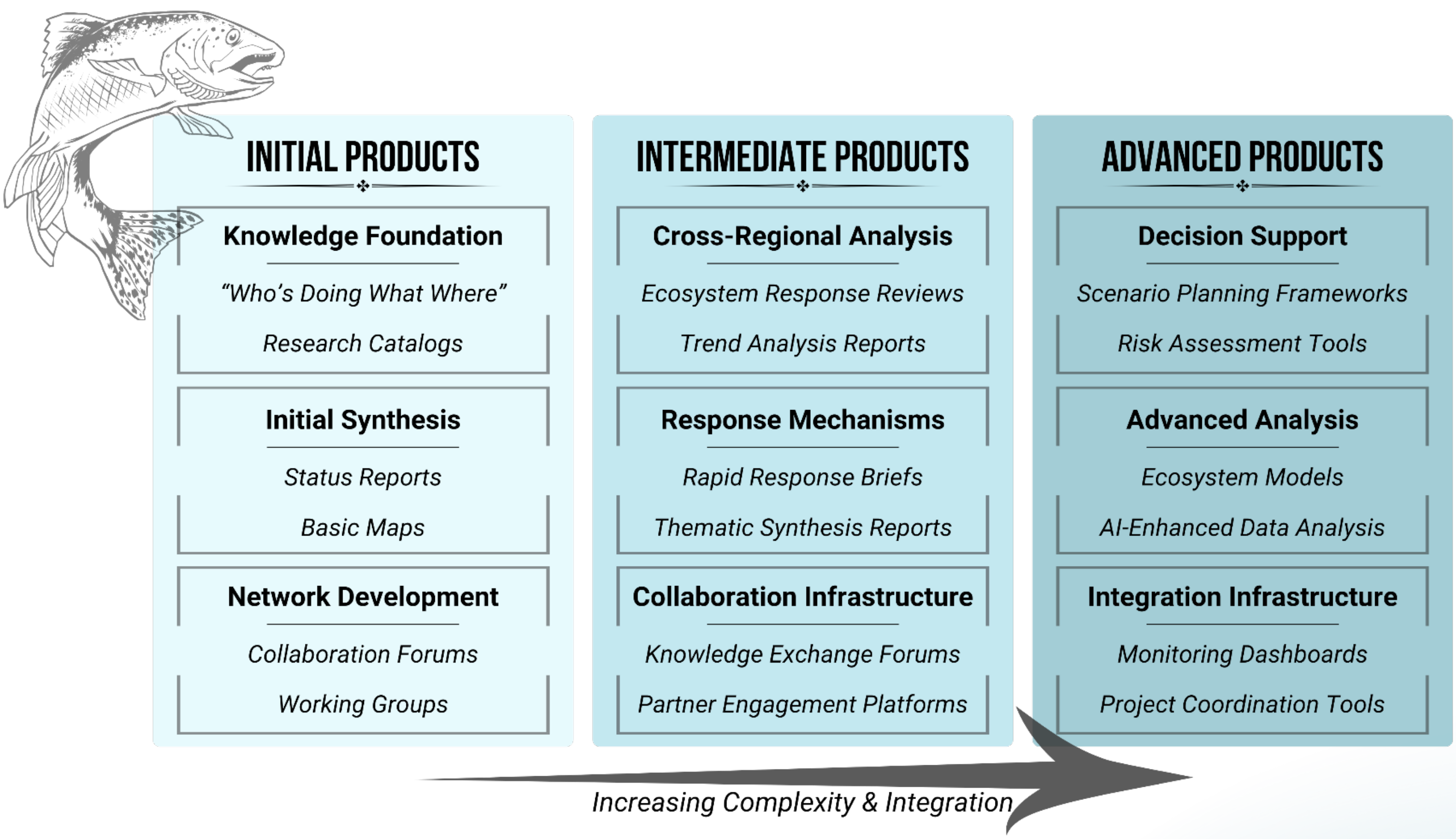

Figure 3. Knowledge Products. *BECI knowledge products will advance in complexity and integration as the network evolves. This figure provides examples of outputs across three development phases: initial, intermediate, and advanced. Each phase builds upon previous work while expanding capabilities to meet emerging needs across the North Pacific region.*

Use Cases

To demonstrate how our knowledge network and products deliver practical value, we have developed a series of use cases that address specific climate-related challenges identified by partners across the North Pacific. Each use case showcases how BECI transforms fragmented data and information into actionable insights that support evidence-based decision making for critical marine resource management and conservation.

List of Current Use Cases (full use cases are provided in Appendix A)

UC1: Learning From Marine Heatwave Impacts on Key Fisheries - Creating a comprehensive synthesis of marine heatwave impacts across the North Pacific to connect dispersed data on past events, identify response patterns across species and regions, and develop management strategies to improve resilience to future extreme events.

UC2: Ecosystem-based Approaches to Climate Change to Inform Decision Making - Building a collaborative platform to inventory, compare, and integrate diverse climate-related ecological models, supporting model comparisons and ensembles for better climate projections that translate scientific knowledge into actionable management strategies.

UC3: North Pacific Ocean Color-Salmon Productivity Initiative - Linking ocean primary productivity measurements to salmon survival across life stages and regions to develop improved forecasting tools and management approaches that better account for changing ocean conditions.

UC4: International Year of the Salmon Synthesis - Maximizing the value of this landmark research program through improved data integration, visualization, and synthesis to advance scientific understanding of salmon ecology in a changing North Pacific Ocean and support evidence-based management.

UC5/6: North Pacific Ocean Ecosystem Status Report Framework - Building on the PICES North Pacific Ecosystem Status Report and Ocean Health Index processes to create a standardized framework for ecosystem status assessments that harmonizes data analysis and reporting across ecoregions, starting with an Alaska Region pilot (UC5) and expanding to a multinational framework (UC6).

UC7: Climate-Adaptive Spatial Conservation Planning - Developing frameworks and decision-support resources that enable conservation managers to design more effective protected area networks that can adapt to changing ocean conditions across jurisdictional boundaries.

The BECI Knowledge Network will generate specific knowledge products across various use cases, including:

- BECI Knowledge Network interactive map (all use cases)
- Comprehensive synthesis report of MHW impacts organized by ecological mechanism, region, and species (UC1)
- Needs Assessment Report for climate-ready fisheries management in the North Pacific (UC2)
- Comprehensive multinational ecosystem status report framework with standardized core metrics and regional adaptations (UC6)
- Synthesis report on the state of climate-adaptive spatial conservation planning (UC7)

Several of our initial use cases focus on Pacific salmon to align with NPAFC priorities and the BC Salmon Restoration and Innovation Fund objectives. Others address broader ecosystem challenges that affect multiple commercially and ecologically important species across the North Pacific.

These use cases demonstrate how BECI addresses real-world challenges while guiding our development priorities. They illustrate how breaking down barriers to knowledge integration and applying ecosystem modelling approaches can enhance our collective ability to respond effectively to climate impacts, ultimately delivering the actionable knowledge for fisheries management and conservation that is the end goal of our knowledge flow process.

GUIDING PRINCIPLES & TECHNICAL IMPLEMENTATION

Our knowledge network is built on a four-layer technical architecture that allows us to connect diverse data sources while ensuring scientific integrity, ethical governance, and user accessibility (*Figure 4*).

Layered Architecture Overview

The BECI Knowledge Network uses a layered technical approach:

- Data Layer: Connects distributed repositories while respecting data ownership and sovereignty
- Integration Layer: Provides standardized interfaces and semantic frameworks for cross-domain compatibility
- Analysis Layer: Combines built-in analytical capabilities with a dedicated team of specialists to transform integrated data into actionable insights.
- User Layer: Delivers customized interfaces for researchers, managers, and policymakers

This architecture ensures both flexibility and interoperability, allowing BECI to progressively expand capabilities while maintaining core functionality and ethical data governance. Detailed technical specifications for each layer are provided in Appendix B.

Guiding Principles

Our implementation is guided by established principles that ensure accessibility, inclusivity, and scientific integrity:

FAIR Data Principles

- Findable - Easily discoverable through rich metadata and persistent identifiers
- Accessible - Available through standardized protocols with appropriate authentication
- Interoperable - Using common vocabularies and formats that enable integration
- Reusable - Well-documented with clear usage licenses and provenance information

OCAP Principles for Indigenous Knowledge

- Ownership - Recognizing that communities own their knowledge and cultural data
- Control - Ensuring Indigenous partners maintain control over data about their communities
- Access - Establishing appropriate protocols for accessing Indigenous knowledge
- Possession - Supporting Indigenous data sovereignty and stewardship

Open Science Approaches

- Promoting transparency in methods and analyses
- Encouraging reproducible research practices
- Creating accessible knowledge products for diverse audiences
- Supporting equitable participation across regions and institutions

Technical Implementation Strategy

Our technical implementation strategy leverages existing technologies while creating a flexible system that can evolve with changing needs:

- User-friendly, interactive platforms with multilingual support
- Prioritization of collaborative, cross-regional approaches
- AI-enhanced tools for knowledge discovery and synthesis
- Robust data security and responsible data sharing protocols
- Flexible infrastructure that can evolve with technological advancements

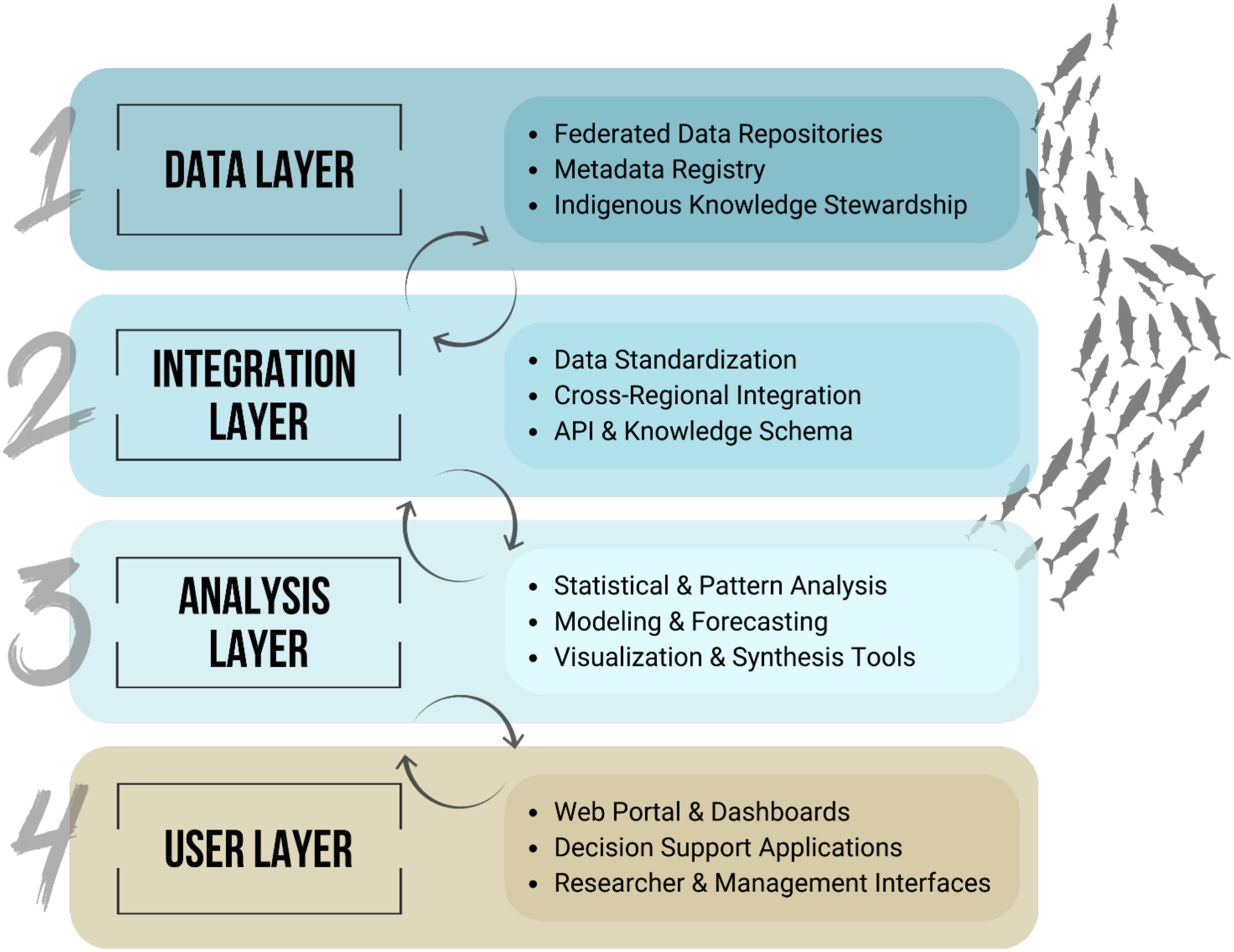

Figure 4. BECI Knowledge Network Layered Architecture. *A four-tiered system connecting distributed data repositories through standardized interfaces and analysis tools to customized user applications. Bidirectional arrows show information flow between layers, enabling flexibility and interoperability while maintaining ethical data governance through FAIR and OCAP principles.*

GOVERNANCE & STRUCTURE

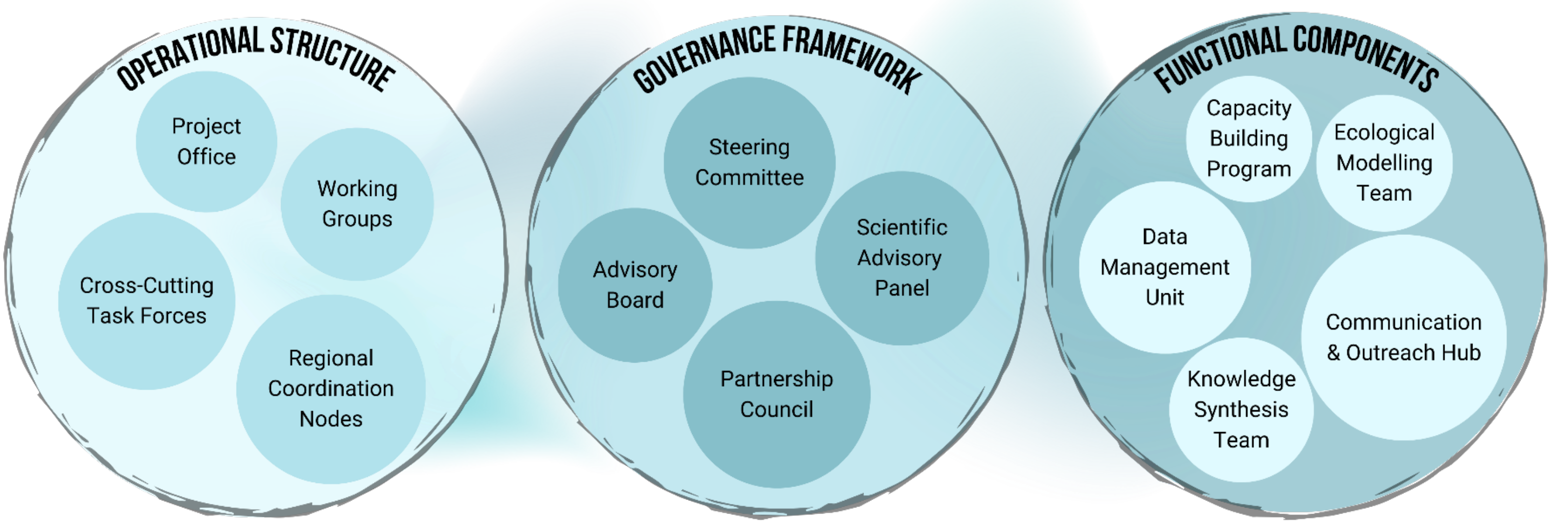

Figure 5. BECI Governance Structure. *The three-pillar framework shows the interconnected governance bodies, operational units, and functional teams that enable effective coordination across the North Pacific.*

While BECI is currently in its early planning and strategic development phase, we are systematically building toward a comprehensive governance and operational framework that will support our ambitious vision. *Figure 5* illustrates our three-pillar structure consisting of governance bodies, operational units, and functional teams that work together to ensure effective coordination across the North Pacific.

Operational Structure

Our operational units implement the network's activities and facilitate collaboration:

- Project Office: Based at PICES, providing administrative and scientific support in addition to coordination across all network activities
- Working Groups: Standing teams of experts focused on ongoing research priorities and knowledge synthesis within specific scientific areas
- Cross-Cutting Task Forces: Time-limited teams addressing urgent emerging issues or specific methodological challenges that require rapid, focused attention across regions
- Regional Coordination Nodes: Sub-networks focused on specific regions of the North Pacific to ensure local relevance and implementation

Governance Framework

Our governance bodies provide strategic direction and ensure diverse stakeholder representation:

- Steering Committee: Representatives from PICES and key partner organizations providing strategic direction and oversight
- Advisory Board: Distinguished representatives from policy, science, industry, and conservation sectors offering high-level guidance
- Scientific Advisory Panel: International experts who ensure scientific rigor across disciplines
- Partnership Council: Representatives from Indigenous communities, industry, NGOs, and management agencies providing input on practical needs

Functional Components

Our functional teams deliver specialized capabilities:

- Data Management Unit: Coordinates data sharing, standards, and integration across the network
- Knowledge Synthesis Team: Specialists in analyzing and synthesizing information from diverse sources
- Ecological Modelling Team: Develops and integrates models to simulate climate-ecosystem interactions, project future scenarios, and evaluate potential management strategies across the North Pacific basin
- Communication and Outreach Hub: Dedicated to translating scientific findings for various audiences
- Capacity Building Program: Supporting training and participation across the network, particularly for early-career scientists and underrepresented groups

Decision-Making Process

BECI employs a structured yet adaptive approach to decision-making that balances scientific rigor with operational flexibility. The process centers on an annual science planning meeting with key partners, implemented through quarterly steering committee meetings. For major initiatives, we follow an open consultation process that solicits input from diverse stakeholders. Throughout all activities, we maintain a commitment to regular review and adaptive management, allowing the network to respond effectively to emerging challenges while ensuring both scientific integrity and stakeholder responsiveness.

PARTNERSHIPS & ENGAGEMENT

BECI is built on collaborative relationships that span the North Pacific Ocean. Our approach recognizes that addressing complex climate challenges requires bringing together diverse perspectives, knowledge systems, and expertise that no single organization could achieve alone. Through strategic partnerships with researchers, managers, Indigenous communities, non-governmental organizations, and industry stakeholders, we create connections that strengthen our collective capacity to understand and respond to climate-driven changes in marine ecosystems.

Our Collaborative Network

BECI builds upon existing scientific frameworks while fostering new connections across the North Pacific. Our network encompasses major research institutions, universities throughout the Pacific Rim, Regional Fisheries Management Organizations, and national agencies with North Pacific interests. By integrating these scientific and management entities with non-government organizations, Indigenous knowledge holders, and industry stakeholders, we create pathways for multidisciplinary collaboration that transcend traditional boundaries, supporting climate-informed decision making across the entire North Pacific basin.

BECI will build on the existing international partnerships of both PICES and the NPAFC. PICES brings decades of experience in fostering international scientific collaboration and overcoming institutional barriers to knowledge sharing. Through its long-standing working groups, technical committees like the Technology and Data Exchange Committee (TCODE), and cross-cutting science programs, PICES has developed robust mechanisms for connecting researchers across national boundaries and creating platforms for interdisciplinary knowledge exchange. The organization has proven particularly adept at bridging differences between research institutions in countries around the North Pacific Rim, helping to break down historical barriers that have traditionally limited comprehensive ecosystem understanding. Similarly, NPAFC has developed specialized expertise in coordinating salmon-related research across international boundaries, with a proven track record of facilitating data sharing and collaborative research on anadromous fish populations. These existing institutional capacities provide a strong foundation for BECI's knowledge network, ensuring that we can leverage established relationships, trusted communication channels, and proven methodologies for scientific collaboration.

From international scientific initiatives like FishMIP to regional management organizations like PICES and NPAFC, our partners form a robust foundation for collaboration across scientific, governance, and community domains (*Figure 6*). By establishing these foundational data integration capabilities, BECI creates a sustainable framework for information sharing that extends beyond any single use case, supporting the full spectrum of research and management needs across the North Pacific. We continue to expand our network of supporting organizations to ensure broad representation of expertise and interests across the North Pacific basin.

Figure 6. *Examples of BECI's supporting partners and collaborators.*

Practical Benefits for Partners

The BECI knowledge network provides tangible value to diverse stakeholders and Indigenous communities (*Figure 7*):

For Management Agencies

- Enhanced understanding of climate impacts on managed species
- Access to synthesized research insights
- Cross-regional management insights
- Improved response coordination

For Research Organizations

- Improved access to cross-regional information
- Collaborative opportunities with multidisciplinary teams
- Enhanced visibility for research outcomes
- Connections to management and policy applications

For Indigenous Communities

- Platforms for knowledge co-production that respect Indigenous sovereignty
- Broader consideration of traditional ecological knowledge
- Opportunities to inform research priorities and approaches
- Access to information needed for resource management decisions

For Industry & NGOs

- Access to integrated climate and ecosystem information
- Improved understanding of ecosystem shifts affecting resources
- Enhanced risk assessment capabilities for climate impacts
- Connections to the broader North Pacific research community

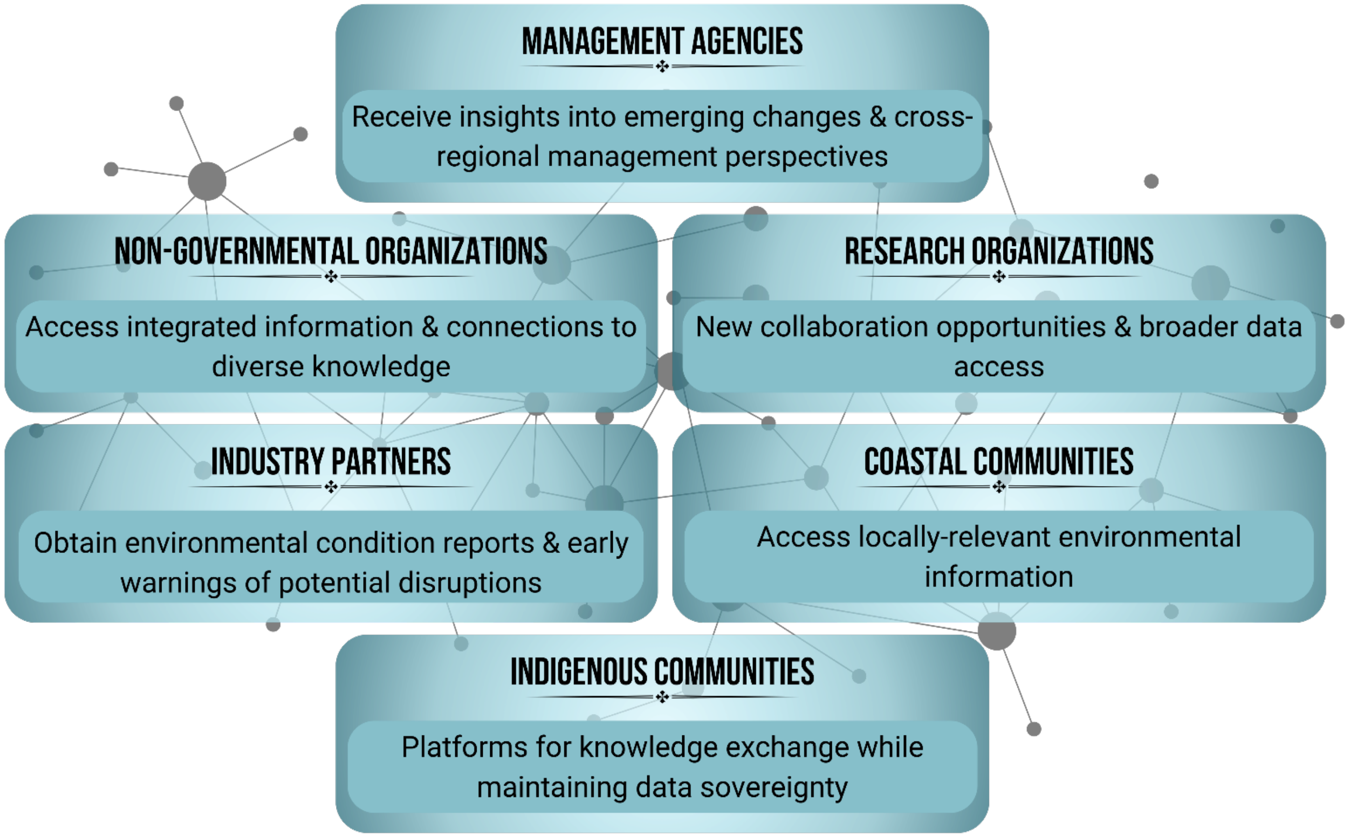

Figure 7. BECI Partner Benefits. *The network delivers specialized value to diverse user groups across the North Pacific, from management agencies and research organizations to Indigenous communities and industry partners. By bringing these diverse organizations together in a cohesive network, we create opportunities for knowledge exchange and collaboration that enhance marine research and management across the entire region.*

Engagement Approach

BECI will engage partners through:

- Regional working groups and task forces
- Workshops/ online platforms designed for collaborative exchange
- Cross-sector knowledge exchange forums
- Collaborative knowledge product development
- Regular communication and targeted outreach
- Co-designed research and monitoring initiatives

Indigenous Knowledge & Partnership

BECI recognizes the deep historical understanding of Indigenous peoples who have observed North Pacific Ocean changes since time immemorial. To ensure meaningful and ethical engagement, we have developed a dedicated Indigenous Engagement Strategy that guides our approach to working with coastal Indigenous communities.

Our approach is founded on key principles that prioritize:

- Moving at the speed of trust: Starting engagement early, before research agendas are finalized, and beginning with listening
- Reciprocity and balance: Ensuring that activities, contributions, and relationships provide mutual benefits and embody the principle of 'giving back'
- Respect and accountability: Creating ethical and safe spaces that honor diverse values, cultures, ways of knowing, and priorities
- Knowledge sovereignty: Upholding principles of Ownership, Control, Access, and Possession (OCAP) in how Indigenous knowledge is collected, stored, and shared
- Transparency: Providing clear, accessible, and timely communications with realistic expectations based on capacity and desired outcomes

This principled approach supports multiple forms of engagement including:

- Creating pathways for appropriate Indigenous knowledge integration
- Building community data stewardship capacity
- Developing collaborative knowledge production mechanisms

Our engagement strategy acknowledges historical challenges in research relationships and establishes processes to avoid extractive approaches. Instead, we seek to create meaningful partnerships where engagement is authentic, reciprocal, and relational—generating outcomes that advance trust and mutual benefits for all involved.

Funding & Project Support

BECI is currently funded by the British Columbia Salmon Restoration & Innovation Fund and is an endorsed project of the United Nations Decade of Ocean Science for Sustainable Development. The project is implemented through the collaborative efforts of PICES and NPAFC, with ongoing support from multiple international research and management organizations.

Future project sustainability will be pursued through continued institutional partnerships, targeted grant applications, and the demonstration of the project's scientific value in understanding North Pacific marine ecosystem changes.

If you are interested in exploring partnership opportunities, please contact us:

Email: **BECI@pices.int** **Website:** **www.beci.info**

ALIGNMENT WITH NPAFC RESEARCH PRIORITIES

The NPAFC Science Plan 2023-2027 aims to "establish a research framework to develop a mechanistic understanding of the impact of changing climate on salmon abundance and distribution trends in the North Pacific Ocean." BECI strategically advances this goal by building upon existing research and monitoring initiatives, creating pathways for knowledge exchange, enhancing collaboration across political boundaries, systematically integrating disparate information sources into cohesive knowledge products, and facilitating comprehensive synthesis across disciplines and regions, ultimately enhancing our understanding of how climate change is impacting salmon abundance and distribution.

Our knowledge network approach directly supports key NPAFC research themes (numbered below) through several proposed use cases:

1. Pacific Salmon in a Changing North Pacific Ocean

BECI will synthesize existing knowledge and facilitate new insights on climate-driven changes affecting salmon through multiple complementary use cases:

The "Learning from Marine Heat Wave Impacts on Key Fisheries" use case will compile and analyze impacts of extreme climate events on commercially important species across the North Pacific, providing important insights into how these increasingly frequent events affect salmon and their ecosystems.

The "North Pacific Ocean Color-Salmon Productivity Initiative" will enhance understanding of relationships between primary productivity and salmon survival across life stages and regions, addressing a fundamental link in the mechanistic understanding of climate impacts on salmon populations.

The "Ecosystem-based Approaches to Climate Change to Inform Decision Making" use case includes development of the North Pacific Ocean Marine Ecosystem Model Ensemble (NOMEME), which directly addresses the NPAFC call to "develop statistical models as well as ecosystem models coupled with biophysical models." By creating a collaborative framework for model comparison and integration across the Pacific Rim, NOMEME aims to reduce uncertainty in projections, identify critical ecological processes affecting salmon productivity, enable systematic comparison of alternative climate scenarios, and provide more robust scientific guidance for management decisions in a changing climate. This use case also includes the Pacific Ecosystem Changes under Climate Scenarios (PECCS) project, which will apply standardized approaches to assess climate impacts on marine ecosystems under different climate scenarios.

2. Integrated Information Systems

BECI itself embodies the NPAFC's goal of building integrated data systems that are Findable, Accessible, Interoperable, and Re-usable (FAIR). The North Pacific Ocean Knowledge Network is specifically designed as a federated information system that connects previously isolated data sources while maintaining data sovereignty and ownership. Through standardized protocols, metadata frameworks, and consistent integration approaches, BECI creates the infrastructure needed for comprehensive information sharing across the region. This system is implemented through:

The "International Year of the Salmon Synthesis" use case, which exemplifies our approach by supporting integration of new datasets and creating accessible synthesis products and visualization tools from this landmark research program.

Our "North Pacific Ecosystem Status Report Framework - Alaska Region Pilot and Multinational Framework" use cases enhance standardization of reporting on ecosystem monitoring and status assessments cross multiple nations in the North Pacific, creating a model for integrated information systems that can be expanded throughout the region.

By establishing these foundational data integration capabilities, BECI creates a sustainable framework for information sharing that extends beyond any single use case, supporting the full spectrum of research and management needs across the North Pacific.

3. Management Systems

BECI will bridge the gap between scientific knowledge and management action through use cases specifically designed to translate complex scientific information into management-relevant formats:

The "Ecosystem-based Approaches to Climate Change to Inform Decision Making" use case creates accessible tools for decision-makers to identify and apply appropriate models for climate-informed management. By connecting modelers with decision-makers across the North Pacific, this initiative works to establish pathways for scientific insights to directly inform management strategies.

The "Learning from Marine Heat Wave Impacts on Key Fisheries" use case includes compilation of management responses to past extreme events, synthesizing lessons learned and best practices to facilitate knowledge transfer between regions affected by similar climate challenges.

Both the "North Pacific Ecosystem Status Report Framework - Alaska Region Pilot" and its multinational expansion are designed to translate complex ecosystem data into standardized, management-relevant formats with consistent scoring approaches, enhancing the utility of scientific information for decision-makers throughout the North Pacific.

APPENDIX A: USE CASES

Use cases provided in Appendix A demonstrate how BECI's knowledge network will address specific climate challenges in the North Pacific and help work toward our goals of connecting knowledge across boundaries. These scenarios illustrate both current challenges faced by stakeholders and BECI's solutions, providing a roadmap for delivering tangible benefits to partners. These use cases will evolve as the project develops to address additional user group needs and expand focus to other priority species. Specific use cases will be prioritized for implementation.

UC1: Learning From Marine Heatwave Impacts on Key Fisheries - Creating a comprehensive synthesis of marine heatwave impacts across the North Pacific to connect dispersed data on past events, identify response patterns across species and regions, and develop management strategies to improve resilience to future extreme events.

UC2: Ecosystem-based Approaches to Climate Change to Inform Decision Making - Building a collaborative platform to inventory, compare, and integrate diverse climate-related ecological models, supporting model comparisons and ensembles for better climate projections that translate scientific knowledge into actionable management strategies.

UC3: North Pacific Ocean Color-Salmon Productivity Initiative - Linking ocean primary productivity measurements to salmon survival across life stages and regions to develop improved forecasting tools and management approaches that better account for changing ocean conditions.

UC4: International Year of the Salmon Synthesis - Maximizing the value of this landmark research program through improved data integration, visualization, and synthesis to advance scientific understanding of salmon ecology in a changing North Pacific Ocean and support evidence-based management.

UC5/6: North Pacific Ocean Ecosystem Status Report Framework - Building on the PICES North Pacific Ecosystem Status Report and Ocean Health Index processes to create a standardized framework for ecosystem status assessments that harmonizes data analysis and reporting across ecoregions, starting with an Alaska Region pilot (UC5) and expanding to a multinational framework (UC6).

UC7: Climate-Adaptive Spatial Conservation Planning - Developing frameworks and decision-support resources that enable conservation managers to design more effective protected area networks that can adapt to changing ocean conditions across jurisdictional boundaries.

UC1: Learning From Marine Heat Waves Impacts on Key Fisheries

Background

Marine heatwaves (MHWs) have emerged as a profound and increasingly frequent consequence of climate change in the North Pacific Ocean. These extreme events, defined as periods when daily sea surface temperature (SST) exceeds the 90th percentile of historical SST observations within a given region for at least 5 consecutive days (Oliver et al. 2018; Holbrook et al. 2019), have dramatically impacted marine ecosystems and fisheries across the basin. While large-scale events like "the Blob" (2013-2016) have received significant attention, smaller-scale MHWs occur frequently throughout the North Pacific, creating a complex mosaic of thermal stressors that marine ecosystems must contend with.

The North Pacific has experienced several notable MHWs in recent years. "The Blob," an unprecedented warm water mass that persisted from 2013-2016 in the Northeast Pacific, caused widespread ecological disruptions, including mass mortality events of seabirds, shifts in species distributions, and fisheries closures (Cavole et al. 2016). In 2019-2020, another major MHW developed in the Gulf of Alaska, reinvigorating concerns about vulnerable fish stocks that had not yet recovered from previous thermal stress. Simultaneously, the Northwest Pacific has experienced its own MHWs, with significant impacts on commercially important species like Pacific cod and anchovy (Liu et al. 2024).

These events have highlighted the economic vulnerability of fisheries to thermal extremes. A single MHW can result in approximately 800 million USD in direct losses, with cascading effects generating more than 3.1 billion USD in indirect losses that persist across multiple years (Smith et al. 2021). The Gulf of Alaska Pacific cod fishery collapse following the 2014-2016 MHW stands as a stark example, with a 71% reduction in allowable catch and estimated losses exceeding $100 million (Barbeaux et al. 2020).

While valuable research has documented MHW impacts on key North Pacific commercial species—including Gulf of Alaska walleye pollock (Rogers et al. 2021), Gulf of Alaska Pacific cod (Barbeaux et al. 2020), Northeast and Northwest Pacific cod (Liu et al. 2024), Pacific sardine (Cavole et al. 2016) and Northwest Pacific anchovy (Liu et al. 2024)—these findings remain fragmented across disparate studies, regions, and fisheries. This fragmentation creates a critical knowledge gap for decision-makers who need comprehensive understanding to develop effective response strategies.

The National Oceanic and Atmospheric Administration (NOAA) has made significant advances in forecasting and monitoring marine heatwaves through initiatives like their MHW Tracker and experimental seasonal prediction systems. This use case would build upon these existing operational frameworks, focusing on connecting physical forecasts to ecological and management responses rather than duplicating prediction efforts.

The urgency of addressing this gap is underscored by climate projections indicating that MHWs will increase substantially in frequency, intensity, and duration, becoming up to 20 times more frequent even under conservative climate scenarios (RCP2.6) (Collins et al. 2019). By synthesizing existing knowledge across the North Pacific into an integrated framework, this analysis provides fisheries managers and policymakers with the comprehensive understanding needed to anticipate, prepare for, and mitigate the complex impacts of future marine heatwaves on economically and ecologically vital fisheries.

Issues of Concern

- Increasing frequency, intensity, and duration of marine heat waves in the North Pacific, with projections indicating a 20-fold increase even under conservative climate scenarios
- Fragmented understanding of marine heatwave impacts on commercially important fish species and fisheries across the North Pacific hinders effective management responses
- Insufficient integration of marine heat waves into future fisheries projections and vulnerability assessments
- Insufficient capacity for anticipating and responding strategically to future marine heatwaves, leaving critical fisheries vulnerable to potentially avoidable impacts
- Prolonged and frequent recurrence of MHWs will likely exceed recovery windows for commercially important fish species, leading to compounding impacts

Objectives

Knowledge Synthesis

- Create a comprehensive synthesis of existing knowledge on MHW impacts on key commercial species throughout the North Pacific, integrating disparate regional studies into a basin-wide understanding
- Document, evaluate, and compare management responses to past MHW events across jurisdictions to identify best practices and adaptation strategies

Develop Knowledge Products

- Develop accessible visualization tools and knowledge products to enhance understanding of MHW patterns, ecological impacts, and management implications

Outreach & Collaboration

- Establish a collaborative network of researchers, managers, and stakeholders across the North Pacific to facilitate knowledge exchange and coordinate monitoring efforts
- Identify critical knowledge gaps and research priorities to improve forecasting and management of MHW impacts on fisheries

Focal Species

- Pacific Salmon
- Pacific Halibut
- Tuna and Tuna-Like Species
- Pacific Saury
- Pacific Herring
- Pacific Hake
- Squid

Information/Data

Physical Data

- Historical and real-time temperature data (satellite, buoy, and vessel-based) to characterize MHW events
- Spatial and temporal metrics of past marine heat waves in the North Pacific
- Oceanographic parameters (salinity, dissolved oxygen, productivity) associated with MHW events

- NOAA MHW forecasting products and prediction tools to serve as foundation for impact assessments

Biological/Ecological Data

- Systematic survey or catch data of key fish species before, during, and after marine heat wave events
- Physiological data (energetics, stomach contents, growth rates) on key fish species before, during, and after marine heat wave events
- Species-specific vulnerability assessments and thermal tolerance thresholds
- Ecosystem-wide impacts including prey availability and predator-prey relationships

Management Data

- Management responses (catch quotas, closures, etc.) implemented during past MHW events
- Economic impact assessments of MHWs on fisheries and coastal communities
- Traditional and local ecological knowledge of MHW impacts and adaptation strategies
- Policy frameworks and governance mechanisms available for MHW response

Proposed Activities & Outputs

Phase	Step	Action	Product(s)
Initial	Knowledge Synthesis	Comprehensive literature review of MHW impacts on fisheries across the North Pacific	Literature database with systematic categorization of impacts by species, region, and response type
	Visualization tool	Collation of spatial and temporal data on past MHWs in the North Pacific	BECI Knowledge Network Interactive map: • Historical MHW events • Intensity • Duration • Spatial extent metrics
	Network Development	Identify and connect with scientists throughout North Pacific working on MHW impacts on key species	Directory of ongoing MHW research and monitoring activities

	Management Review	Document management responses to past MHW events across jurisdictions	Database of Initial management response with preliminary assessment of effectiveness
Intermediate	Synthesis Development	Analyze patterns of species response across regions and events	Comprehensive synthesis report of MHW impacts organized by ecological mechanism, region, and species
	Visualization tool	Map species-specific impacts in relation to MHW characteristics	BECI Knowledge Network Interactive Map: Enhanced layers connecting MHW events to documented biological impacts
	Network Enhancement	Form a North Pacific working group on MHW impacts and management responses	Established working group with regular meetings and collaborative research agenda
	Management Assessment	Evaluate effectiveness of past management responses	Management response report with comparative analysis of strategies and outcomes
	Vulnerability Assessment	Develop framework to assess species and fisheries vulnerability to future MHWs	Vulnerability assessment methodology report and preliminary application to key species
	Forecast Integration	Integrate NOAA MHW forecasts with species distribution and biological response data	GIS-based decision support tool connecting predicted MHW patterns with vulnerable fisheries and ecosystems
Advanced	Stakeholder Engagement	Organize regional workshops with diverse stakeholders to develop MHW response strategies	Series of regional workshops and cross-regional knowledge exchange forums
	Best Practice Development	Synthesize lessons learned and identify effective management approaches	Best practice guidelines for proactive and reactive management responses to MHWs
	Decision Support Tool Creation	Develop tools to support management decision-making during MHW events	Web-based decision support platform with impact projection

			capabilities and management option evaluation
	Early Warning System Development	Create indicators to identify early biological responses to emerging MHWs and utilize NOAA's MHW forecasting systems	Early warning indicator framework integrated with existing monitoring systems
	Adaptive Management Integration	Work with RFMOs to incorporate MHW scenarios into Management Strategy Evaluations	MSE outputs and recommendations for adaptive fisheries management under MHW conditions

Expected Outcomes

This use case will produce a comprehensive understanding of marine heatwave impacts on key species across the North Pacific, leading to tangible improvements in management capacity and ecological resilience:

Scientific Outcomes

- Comprehensive synthesis of MHW impacts on commercially important species across the North Pacific
- Identification of common vulnerability factors and resilience characteristics across species and ecosystems
- Improved understanding of ecological mechanisms connecting physical MHW characteristics to biological responses
- Clear articulation of critical knowledge gaps to guide future research priorities

Management Applications

- Evidence-based best practices for management responses to MHWs at different stages (preparation, during-event, recovery)
- Enhanced capacity to incorporate MHW scenarios into fisheries forecasting and quota-setting processes
- Early warning indicators of potential fisheries impacts from emerging MHW conditions
- Decision-support tools tailored to different management contexts and jurisdictions

Collaboration Benefits

- Established Pan-Pacific network of researchers and managers focused on MHW impacts and responses
- Improved knowledge transfer between regions that have experienced severe MHWs and those preparing for future events
- Enhanced coordination of monitoring efforts across jurisdictions to capture basin-wide patterns
- Strengthened science-policy interface for addressing extreme climate events in marine systems

Stakeholder Benefits

- Improved industry understanding of potential MHW impacts and preparation strategies
- Enhanced coastal community resilience through proactive planning for MHW events
- Documented traditional and local ecological knowledge contributions to understanding and managing MHW impacts
- Clearer communication of MHW science to non-technical audiences through visualization tools and knowledge products

Challenges/Limitations

Cross-Cultural & Cross-Jurisdictional Collaboration

- Nature: Building effective collaboration between diverse stakeholder groups, nations, and cultures across the North Pacific presents significant coordination challenges
- Impact: Insufficient collaboration would fragment knowledge synthesis and limit the effectiveness of basin-wide understanding
- Mitigation: Employ experienced facilitators with cultural competency; establish clear communication protocols; develop multi-lingual resources; leverage existing international frameworks (e.g., PICES) to build on established relationships

Data Heterogeneity & Compatibility

- Nature: Data on MHW impacts comes from diverse sources with different methodologies, temporal and spatial scales, and accessibility constraints
- Impact: Challenges in integrating and comparing datasets could limit comprehensive analysis and hide important patterns

- Mitigation: Develop standardized metadata frameworks; focus on relative changes rather than absolute values where methodologies differ; employ statistical approaches designed for heterogeneous datasets

Knowledge Gaps & Monitoring Limitations

- Nature: Existing literature on MHW impacts may be incomplete, inconsistent, or regionally biased, with significant gaps for certain species and regions
- Impact: Synthesis products may misrepresent the state of knowledge and overlook critical impacts or vulnerabilities
- Mitigation: Clearly document knowledge limitations; leverage expert judgment to identify and prioritize critical gaps; design monitoring frameworks to address key uncertainties

Management Implementation Barriers

- Nature: Even with improved knowledge, institutional barriers, resource limitations, and competing priorities may impede implementation of recommended management responses
- Impact: Scientific insights might not translate to improved outcomes for fisheries and ecosystems
- Mitigation: Engage management agencies from the outset; align recommendations with existing management frameworks; provide implementation options at different resource levels; demonstrate economic benefits of proactive management

Sustaining Long-Term Collaboration

- Nature: Maintaining momentum and engagement in collaborative networks requires ongoing coordination, funding, and demonstrated value to participants
- Impact: Initial progress could stall without sustained commitment to the network
- Mitigation: Establish clear governance structures for the working group; secure multi-year funding commitments; regularly demonstrate value to participants through tangible products; integrate activities with existing organizational priorities

Key Partners

Research Organizations

- NOAA Pacific Marine Environmental Laboratory & Alaska Fisheries Science Center
- NOAA Climate Prediction Center and MHW forecasting teams
- Fisheries and Oceans Canada (DFO) Science Branch
- Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
- University research laboratories specializing in climate impacts and fisheries
- PICES Working Groups on Climate Change and Ecosystem Effects
- Climate modelling centers (global and regional)

Management Bodies

- North Pacific Fishery Management Council
- Pacific Fishery Management Council
- Regional Fisheries Management Organizations
- National and sub-national fisheries agencies
- Coastal resource management authorities

Monitoring Networks

- Integrated Ocean Observing Systems
- Distributed Biological Observatory
- Research vessel programs and surveys
- Satellite monitoring programs (NOAA, NASA, JAXA)

Industry Partners

- Commercial fishing organizations and associations
- Seafood processing companies
- Aquaculture operations in affected regions
- Marine recreation and tourism sectors

Indigenous and Community Partners

- Coastal communities affected by MHWs
- Traditional knowledge holders and Indigenous fishing organizations
- Community-based monitoring networks
- Local conservation organizations

UC2: Ecosystem-based Approaches to Climate Change to Inform Decision

Background

Climate change is profoundly altering marine ecosystems in the North Pacific, impacting fisheries productivity, species distributions, and ecosystem function. Despite the proliferation of climate and ecological models that could inform management decisions, there remains a significant disconnect between model development and practical application in fisheries management. Numerous models exist—ranging from single species population models to species distribution models (SDMs), to food web models and ecosystem assessments—but they are often underutilized in decision-making processes. This gap stems from several factors: the conservative nature of fisheries science, high levels of uncertainty in model predictions, and the absence of effective knowledge brokers who can translate complex modelling outputs into actionable management strategies. The North Pacific region, with its ecological and economic importance (particularly for salmon fisheries), presents an ideal case study for developing a coordinated approach to connect existing models with management needs in a changing climate.

Issues of Concern

The key challenge is the limited integration of climate-informed ecological models into fisheries management decision processes in the North Pacific. Despite thousands of existing models, there is no centralized system to identify which models are most suitable for specific management questions, geographic regions, or species of interest. Conservation and fisheries managers often lack awareness of available tools or are hesitant to adopt models with high uncertainty. Additionally, there is limited understanding of which models are being used in practice versus those that remain purely academic. Without effective knowledge brokering between modelers and decision-makers, valuable scientific information fails to influence management strategies for climate adaptation in fisheries.

Objectives

1. Develop a comprehensive inventory of climate-related ecological models relevant to North Pacific fisheries management
2. Create accessible tools for decision-makers to identify and apply appropriate models for climate-informed decision-making
3. Bridge the gap between model developers and management practitioners through effective knowledge brokering
4. Demonstrate successful applications of models for climate adaptation in fisheries management through case studies
5. Establish a collaborative platform for model comparison and integration in the North Pacific region

Information/Data

- Published ecological, biological, and species distribution models for the North Pacific
- Documentation of models currently used in fisheries management decisions
- Climate projection data relevant to marine ecosystems
- Species-specific data with emphasis on salmon and other commercially important species
- Geographic information on model coverage and application areas
- Case studies of successful model applications in management contexts

Sources & Organizations

- NOAA Fisheries
- Department of Fisheries and Oceans Canada (DFO)
- North Pacific Marine Science Organization (PICES)
- North Pacific Anadromous Fish Commission (NPAFC)
- FishMIP (Fisheries Model Intercomparison Project)
- University research laboratories developing marine ecosystem models
- Regional Fisheries Management Organizations

Proposed Activities & Outputs

Phase	Step	Action	Product(s)
Initial	Stakeholder Engagement	Conduct interviews with fisheries managers and conservation agencies to understand model usage and needs	Needs Assessment Report for climate-ready fisheries management in the North Pacific
	Model and data identification	Identify existing models that could contribute to the project goals	Preliminary inventory of models
	Engagement	Engage with modelling groups across the North Pacific	Inventory of modelling groups across the North Pacific
Intermediate	Model Inventory	Identify and catalog existing climate-related ecological models used or applicable in North Pacific fisheries management	Comprehensive Model Inventory and Assessment report
	Establish Working Groups	Form an ecosystem modelling focused working group to collaborate on ensemble model knowledge and protocols to inform decisions – link with corresponding climate modelling working groups	Active working group with regular meetings and communication channels
	Case Study Development	Document successful applications of climate models in fisheries management decisions	"Models in Action" Case Studies Report
	Visualization Tool	Create GIS-based visualization of model coverage and applications in the North Pacific	North Pacific Ecosystem Visualization Tool
Advanced	Model Ensembles	Form an ecosystem modelling working group to collaborate on ensemble model knowledge and protocols to inform decisions – link with corresponding climate modelling working groups	Active working group with regular meetings and communication channels
	Model Ensembles	Develop a protocol to run comparative scenarios across divergent models for standardised comparisons (NOMEME)	North Pacific Ocean Marine Ecosystem Model Ensemble (NOMEME) protocol developed
	Model Integration	Develop a platform for comparing outputs from diverse	Model Intercomparison Platform for the North Pacific

		model types, with disparate structures and climate inputs	
	Decision Framework	Create protocols for integrating model outputs into management decisions	Climate-Ready Fisheries Management Framework
	Capacity Building	Conduct training workshops for managers on model applications	Training materials and workshop series

Expected Outcomes

1. Improved awareness among fisheries managers of available modelling tools for climate adaptation
2. Enhanced capacity to select appropriate models for specific management questions
3. More effective integration of climate considerations into fisheries management decisions
4. Stronger collaboration between model developers and management practitioners
5. Identification of critical knowledge gaps requiring further model development
6. Development of best practices for applying models in climate-informed fisheries management
7. Creation of a sustainable knowledge network connecting modelling expertise with management needs
8. New ensemble models created to address uncertainty and inform adaptive management across the North Pacific

Challenges/Limitations

Data Accessibility & Model Reproducibility

- Nature: Many models rely on proprietary data or have restrictions on sharing outputs
- Impact: Limited ability to compare or integrate models across institutions
- Mitigation: Develop data-sharing agreements and focus on metadata rather than raw data where necessary

Institutional Resistance to Model Adoption

- Nature: Conservative approach in fisheries management limits adoption of models with high uncertainty
- Impact: Continued reliance on historical data rather than forward-looking projections
- Mitigation: Document case studies showing successful model applications and develop uncertainty communication frameworks

Technical Complexity Barrier

- Nature: Advanced modelling approaches require specialized expertise to interpret and apply
- Impact: Underutilization of available models by management practitioners
- Mitigation: Create simplified interfaces and decision support tools that translate model outputs into management-relevant information

Technical Resources & Capacity Limitations

- Nature: Running new modelling approaches and calibrating with new inputs can be time consuming – some modellers might not be able to implement new standardised approaches and scenarios in their existing models.
- Impact: Ensemble model does not get buy in
- Mitigation: Facilitate pathways for modellers to obtain new climate data inputs, similar to FishMIP, and ensure there is technical troubleshooting capacity to help modellers implement new scenarios; approach modellers who have yet to finalise their model scenarios and runs, to ensure they implement a standardised scenario as well.

Geographic & Taxonomic Gaps

- Nature: Uneven coverage of models across the North Pacific region and focal species
- Impact: Inability to address management needs in underrepresented areas or species
- Mitigation: Identify priority gaps and develop targeted modelling efforts to address them

Coordination Challenges Across International Boundaries

- Nature: Different management structures and priorities across countries in the North Pacific
- Impact: Fragmented approach to model development and application
- Mitigation: Leverage existing international organizations (PICES, NPAFC) to facilitate collaboration

Key Partners

Data Providers

- NOAA Fisheries (climate and ecosystem data, stock assessment models)
- Department of Fisheries and Oceans Canada (Canadian fisheries and ecosystem monitoring)
- North Pacific Anadromous Fish Commission (salmon data across the North Pacific)
- Pacific Fishery Management Council (fisheries management data)
- PICES (integrated ecosystem assessment data)

Knowledge Contributors

- University research laboratories developing climate-ecological models
- NOAA's Integrated Ecosystem Assessment program
- Climate modelling centers (e.g., NCAR, Environment Canada)
- FishMIP participants working in the North Pacific
- Independent researchers with specialized expertise in marine SDMs

Implementation Partners

- GIS and data visualization specialists
- Knowledge brokers with experience in fisheries-management interfaces
- Software developers for platform creation
- Organizations with experience in model intercomparison (e.g., FishMIP)

End Users

- Regional Fisheries Management Organizations
- National fisheries management agencies
- Tribal/First Nations fisheries managers
- Commercial fishing industry representatives
- Conservation organizations focused on marine ecosystems

UC3: North Pacific Ocean Color-Salmon Productivity Initiative (NPOCPI)

Background

The relationship between primary productivity and fisheries yield has been widely demonstrated, particularly for resident fish. Determining the relationship between primary productivity (as measured through ocean color and chlorophyll-a) and Pacific salmon productivity represents a critical ecological linkage that can inform fisheries management. Satellite-derived ocean color data provides synoptic measurements of surface chlorophyll-a concentrations, which serve as a proxy for phytoplankton biomass and primary productivity in the marine environment. Global climate and earth systems models also provide marine environmental outputs such as sea surface temperature and chlorophyll-a, which can be used as valuable data sources for assessing long-term trends and variability in ocean productivity, and can be easily linked to lower- and upper- trophic fish biomass metrics (e.g., through the Fisheries and Marine Ecosystem Ensemble Intercomparison Project (FishMIP), Blanchard et al. 2024), offering opportunities to improve predictions of salmon biomass under changing climate conditions. Some efforts have already been made to make climate projections relating to fish biomass publicly available, with key examples the FishMIP Shiny App (https://rstudio.global-ecosystem-model.cloud.edu.au/shiny/FAO_report_shiny/), which visualises spatially aggregated data of projected changes in potential fish biomass under alternative climate emission scenarios, and the Climate, Ecosystems, and Fisheries Initiative (CEFI) (https://psl.noaa.gov/cefi_portal/), which provides spatio-temporal information about past and future climatic conditions for US marine regions based on state-of-the-art, high-resolution ocean models and decision-support systems.

Characterizing spatial and temporal changes in phytoplankton phenology and composition at the base of the food web in the North Pacific is an important step toward estimating potential environmental pressures on fish stocks, including Pacific salmon (Myers et al., 2016). Pacific salmon are migratory species that traverse vast oceanic regions during different life stages, encountering variable ocean conditions that influence their growth, survival, and recruitment. Given the increasing impacts of climate change on ocean ecosystems, integrating large-scale ocean productivity datasets with salmon productivity metrics is essential for predicting future stock dynamics and informing adaptive fisheries management. However, a key challenge lies in effectively synthesizing diverse and complex datasets across spatial and temporal scales to establish meaningful ecological relationships. A knowledge network and data-sharing platform that links ocean primary productivity data to Pacific salmon productivity and survival can facilitate interdisciplinary collaboration, enhance predictive modelling capabilities, and ultimately support sustainable fisheries management.

Issues of Concern

- Data Integration and Compatibility: The availability of ocean primary productivity data from various sources, including satellite observations, in situ measurements, oceanographic models and biogeochemical models, presents challenges related to data standardization, resolution, and compatibility with salmon population datasets.
- Spatiotemporal Variability: Primary productivity and salmon productivity vary across multiple scales, requiring robust methods to assess their dynamic interactions and capture regional and seasonal differences.
- Uncertainty in Ecological Linkages: While primary productivity is a fundamental driver of marine food webs, the strength and nature of its relationship with salmon survival and productivity may be influenced by intermediate trophic interactions, oceanographic conditions, and climate variability.
- Data Accessibility and Sharing: Effective collaboration across institutions, agencies, and researchers depends on the development of transparent data-sharing protocols that balance open access with data ownership considerations.
- Predictive Model Development: Linking primary productivity to salmon productivity requires advanced modelling approaches that incorporate environmental drivers, species interactions, and uncertainty assessments to generate reliable forecasts for fisheries management.

Objectives

Develop a Collaborative Knowledge Network

Establish a working group focused on linking climate change metrics to Pacific salmon productivity, starting with ocean primary productivity and expanding to additional variables such as temperature, salinity, and ocean acidification.

Compile & Standardize Data

Aggregate existing empirical and modeled primary productivity datasets alongside Pacific salmon population data (e.g., stock-recruit relationships) to ensure consistency and comparability across studies.

Quantify Spatiotemporal Relationships

Analyze the spatial and temporal linkages between primary productivity patterns and Pacific salmon population dynamics across the North Pacific Ocean to inform predictive models that support fisheries management decisions.

a. Assess Productivity and Fisheries Yield Relationships: Examine how ocean primary productivity influences fisheries yields based on existing literature and data (e.g., Conti et al. 2010, Ware et al. 2005).

b. Evaluate Salmon-Specific Productivity Relationships: Investigate the relationship between ocean primary productivity and Pacific salmon survival and recruitment (e.g., Rosengard et al. 2019, Malick et al. 2015).

Understand Oceanographic Mechanisms

Identify key oceanographic drivers (e.g., upwelling, mixed-layer depth, thermal stratification) that influence primary productivity patterns and their effects on salmon foraging conditions and overall survival.

Develop Predictive Models

Integrate ocean productivity data with salmon population dynamics to create predictive models that assess potential future changes in salmon productivity under different climate scenarios.

Enhance Data Accessibility & Sharing

Establish an open-access platform that enables researchers, fisheries managers, and policymakers to access, share, and visualize ocean primary productivity and salmon productivity data.

Support Fisheries Management & Policy

Provide actionable insights for fisheries management by linking environmental variability to salmon population trends, enabling more adaptive and resilient fisheries policies in the face of climate change

Focal Species

- Chinook salmon (Oncorhynchus tshawytscha)
- Sockeye salmon (O. nerka)
- Coho salmon (O. kisutch)
- Pink salmon (O. gorbuscha)
- Chum salmon (O. keta)

Information/Data

Ocean productivity data (also see Yu et al. 2023), and other climate information

- NASA's MODIS-Aqua and VIIRS chlorophyll-a data (2002-present)
- NOAA CoastWatch VIIRS *Chl*-a anomoly
- ESA's Sentinel-3 OLCI data (2016-present)
- Historical SeaWiFS data (1997-2010)
- Zooplankton composition and abundance surveys
- Global climate/Earth System models (VGPNN, VGPM, GFDL)
- World Ocean Atlas 2023 (WOA23)
- Regional climate projections and downscaled models (CMIP6 downscaled models, ROM/MOM)
- Global ecosystem models with *Chl*-a/productivity indices (e.g., FishMIP, Blanchard et al. 2024)

Salmon productivity data (spawner/recruit indices, etc.)

- North Pacific Anadromous Fish Commission (NPAFC)
- Pacific Salmon Commission (PSC)
- National agencies (NOAA, DFO Canada, NPAFC member countries)
- State/provincial fisheries departments
- Indigenous/traditional knowledge

Proposed Activities & Outputs

Phase	Step	Action	Product(s)
Initial	Knowledge synthesis	Literature review assessing: Scope and scale, available data, existing analyses	Review paper of state of knowledge for the North Pacific and salmon
	Knowledge Network development	1. Establish governance structure (steering committee, technical working groups) 2. Establish expertise network	Directory of researchers, managers, and knowledge holders Initial knowledge exchange webinars and workshops (already established via FishScore)
	Data collation – primary productivity data	1. Acquire satellite-derived ocean color products 2. Acquire modeled productivity and climate data (historical and future projections)	Regional comparison summary reports (e.g., Pacific Ecosystem Changes under Climate Scenarios (PECCS))
Intermediate	Data collation – salmon data	Compile salmon productivity data: • Spawner-recruit relationships • Stock-specific returns • Age composition • Size-at-age metrics • Marine survival rates • Abundances, catches Stakeholder and rightsholder workshops to obtain additional unpublished and traditional knowledge	Plain language summary reports of elicited information
	Data integration and management	1. Establish a centralized database	BECI Dashboard: • Interactive data portal for stakeholder use

		2. Establish a collaborative workspace for project partners • Build data-sharing protocols • Document uncertainty and limitations • Integrate into BECI dashboard using BECI databases and visualization tools	• Data usage policy reports
	Productivity data visualization tool	1. Process productivity data 2. Develop ocean indices • Regional and basin-scale productivity metrics • Winter and spring bloom timing, magnitude, and duration • *Chl*-a anomalies • Summer stratification patterns • Upwelling intensity indices • Mixed layer depth estimates (from auxiliary oceanographic data)	BECI Knowledge Network Interactive map: Initial mapping products of productivity and climate indices
	Analysis and Model Development	1. Exploratory analyses: • Time series decomposition of chlorophyll-a and productivity patterns • Identification of critical spatial domains for each salmon species	Visualization tools (map, trends, etc..): Time series of *Chl*-a/primary productivity patterns for the North Pacific (map and trends, as per FishMIP Shiny App) Predictive models of salmon returns based on ocean productivity indices

		• Investigation of climate-driven productivity regime shifts 2. Statistical modelling • Relate productivity indices to salmon metrics • Historical and future correlative approaches 3. Hypothesis testing: • Match-mismatch hypothesis between salmon ocean entry and spring bloom • Critical size-critical period hypothesis linking early marine growth to survival • Bottom-up trophic dynamics across ocean basin scales	Report on identification of early warning indicators for poor ocean conditions Report on cross-species/cross-regional assessments and comparison of vulnerability to productivity changes Report on identification of critical thresholds and tipping points
	Data management and sharing	1. Develop knowledge synthesis and data sharing protocols 2. Data provenance protocols and documentation 3. Processing algorithms and parameters – open source	Opensource database of synthesised data and algorithms Steering committee reports on engagement with end users and knowledge holders
Advanced	Product development and dissemination	1. Develop outreach and scientific products 2. Decision-support and management tool development	Peer-reviewed publication on findings Technical report detailing methodologies Decision-support tools for management

		• Pre-season forecasting tool for salmon returns • Scenario planning for adaptation strategies • Risk assessment framework for fisheries planning • Integrated ecosystem and vulnerability assessment	• Framework document for salmon productivity forecasting with climate scenarios • Interactive web-based app with climate impact visualizations • Operational forecasting system with regular updates
	Data management and sharing	1. Build on integrated database to include spatial and temporal components, metadata	BECI Dashboard Integrated database that includes: 1. Spatial layers: • Chlorophyll-a concentration grids (monthly composites) OR links to these data • Primary productivity estimates (monthly and seasonal) OR links to these data • Oceanographic features (fronts, eddies, gyres) • Migration corridors and feeding grounds (species-specific) 2. Temporal components: • Time series of productivity indices • Seasonal and interannual variability metrics • Historical salmon abundance records

			• Recruitment time series Open-source code repositories for data processing and analysis

Expected Outcomes

Scientific Outcomes

- Quantification of bottom-up control on salmon productivity
- Identification of critical periods and regions influencing salmon survival
- Understanding of climate-mediated changes in productivity-salmon relationships

Management Applications

- Pre-season forecasting tools for salmon returns
- Early warning system for poor ocean productivity conditions
- Risk assessment framework for fisheries planning

Technical Deliverables

- Open-source code repositories for data processing and analysis
- Interactive data portal and visualization tools for stakeholder use
- Operational forecasting system with regular updates

Challenges/Limitations

Data Accessibility & Continuity

- Challenge: Many oceanographic datasets are housed by federal agencies (particularly US agencies like NOAA and NASA). While some are currently freely available, there is a high risk these data may become inaccessible due to political climate changes, funding cuts, or policy shifts.
- Impact: Loss of access would severely compromise the initiative's ability to maintain real-time monitoring and forecasting capabilities.
- Mitigation: Develop redundant data sources by incorporating global climate models (e.g., GFDL); establish formal data-sharing agreements with multiple international agencies; create local data archives where permissible; develop relationships with alternative data providers including academic institutions.

Data Shareability & Intellectual Property Constraints

- Challenge: Legal restrictions may prevent sharing certain oceanographic or proprietary fisheries data on public platforms.
- Impact: Limited data sharing would hamper collaborative analysis and reduce transparency for stakeholders.
- Mitigation: Implement tiered access systems with different permission levels; develop data anonymization protocols; create summary products that can be shared publicly while protecting sensitive information; establish clear data governance frameworks with input from all contributors.

Technical & Computational Resource Limitations

- Challenge: Processing and analyzing large-scale remote sensing data and climate models requires substantial computational infrastructure and specialized expertise.
- Impact: Resource constraints could limit analytical capabilities and delay product development.
- Mitigation: Leverage existing computational infrastructure through partnerships with universities and research institutions; pursue shared computing resources; prioritize efficient code development; consider cloud-based solutions with scalable capacity.

Integrating Disparate Data Types

- Challenge: Merging satellite data, oceanographic measurements, fisheries statistics, and traditional knowledge involves reconciling different spatial and temporal scales, formats, and collection methodologies.
- Impact: Integration difficulties could lead to inconsistent analyses and reduce confidence in results.
- Mitigation: Develop robust data harmonization protocols; create metadata standards specific to the initiative; invest in methodological research to address scale mismatches; document limitations transparently.

Ecological Complexity & Model Uncertainty

- Challenge: The relationship between primary productivity and salmon survival involves complex trophic interactions and non-linear dynamics that are difficult to model accurately.
- Impact: Oversimplification could lead to unreliable predictions and management advice.

- Mitigation: Embrace ensemble modelling approaches; implement rigorous validation protocols; clearly communicate uncertainty in all products; continuously refine models with new data; consider Bayesian frameworks that can incorporate multiple knowledge sources.

Knowledge Translation & Implementation

- Challenge: Bridging scientific findings with practical fisheries management decisions requires effective knowledge translation.
- Impact: Scientific insights might not influence management decisions without proper integration pathways.
- Mitigation: Include managers early in project design; develop decision-support tools tailored to management frameworks; create regular communication channels; provide training for managers on interpreting products.

Funding Sustainability

- Challenge: Long-term ecological monitoring requires sustained funding beyond typical grant cycles.
- Impact: Inconsistent funding could create data gaps and disrupt operational products.
- Mitigation: Develop diversified funding portfolio; create value-added products that could generate support; demonstrate economic value to commercial fisheries; align with major climate adaptation initiatives.

Key Partners

This will require collaboration and successful engagement with:

- Government research institutions (NOAA, DFO, others)
- Researchers and university partners
- Fisheries management agencies (NPAFC)
- Indigenous communities and organizations
- Commercial and recreational fishing representatives
- Environmental NGOs and conservation groups

Partners Include

- Data Providers: oceanography datasets – NOAA (incl. CEFI), NASA, PICES; salmon productivity data – NPAFC, PSC, DFO, NOAA, external salmon experts, PSF
- Knowledge Contributors: University research labs studying oceanography linkages with fish; PSC; Indigenous knowledge holders; salmon experts from government (NOAA, DFO) and NGOs; oceanography experts; Fisheries agencies (DFO, NOAA Fisheries, NFSC, AFSC, NMFS, Fisheries Agency of the Russian Federation, NPAFC)
- Implementation Partners: Oceanography experts, data analysts/scientists, ecosystem modellers, GIS specialists, data visualization experts, communications specialists and facilitators
- End Users: Scientists, RFMOs, decision makers

UC4: International Year of the Salmon Synthesis

Background

The International Year of the Salmon (IYS) (https://yearofthesalmon.org) was a 5-year collaborative initiative spanning 2018–2022 organized by the North Pacific Anadromous Fish Commission (NPAFC) and the North Atlantic Salmon Conservation Organization (NASCO). The IYS was the largest international research initiative to date focused on the resilience of salmon throughout the Northern Hemisphere.

A major component of the initiative was three High Seas Expeditions in the North Pacific Ocean coordinated between Canada, Japan, the Republic of South Korea, the Russian Federation and the United States. Single-vessel expeditions into the Gulf of Alaska took place in the winter of 2019 and 2020 and a multi-vessel Pan-Pacific expedition in the winter of 2022. The IYS High Seas Expeditions built on international collaborative capacity to collect critical field data to better understand the factors influencing salmon survival in the North Pacific in winter.

Findings from the IYS cruises and associated IYS projects have been compiled into several reports (e.g. NPAFC Technical Reports 18, 20, 22) and publications, although the latter have not been tracked on the IYS website. The final 2022 IYS Synthesis Symposium: 'Salmon in a Rapidly Changing World: Synthesis of the International Year of the Salmon and a Roadmap to 2030' brought together participants from academia, government, industry, NGOs and Indigenous organizations to consider the progress made by the IYS, to discuss its legacy, and to provide recommendations for the future. Although there were 106 presentations at the conference, only 6 synthesis papers were included in the resultant synthesis product (NPAFC Bulletin 7).

Two key IYS data products include: 1) the International Pacific Salmon Data Legacy (IPSDL), a database of high seas salmon catches and biological characteristics (McKinnell & Langan, 2024); and 2) the IYS Data Catalogue, which includes data generated from the IYS High Seas Expeditions, aligned with the technical standards and networks recommended by the Global Ocean Observing System (Johnson & van der Stap, 2024). Continued development of these products has generally stalled since IYS ended, despite clear direction for valuable expansion, for example, a suggestion by McKinnell and Langan (2024) to include salmon scale data in the IPSDL. This inclusion would enable a retrospective spatial analysis of marine growth, allowing tracking of individual growth trajectories in a changing environment.

Since 2022, many IYS scientists have worked on additional data products, for example: the compilation and meta-analysis of salmon diet data from the North Pacific Ocean (Graham et al., 2019); assimilation of eDNA data products (C. Deeg, DFO, pers. comm), enabling characterization of NE Pacific ecosystem structure, salmon spatiotemporal distribution, killer whale ecotype distribution etc.; and assimilation of IYS Fit-Chip data (K. Miller, DFO, pers. comm), providing valuable insights into pathogens and stressors (including starvation) of salmon throughout the NE Pacific. Additionally, there were several excellent map-based products generated: the NPAFC High-Seas Salmonid Tag Recoveries and Expedition Application includes a map termed "IYS High Seas Expeditions" which allows a user to access and explore IYS high seas expedition data in an interactive mapping environment. There are many opportunities to collate, synthesize, and expand upon these initiatives.

Finally, at the time of the IYS wrap-up in 2022, a significant amount of analytical work, data assimilation and publication of information was ongoing; results generated by many teams have not yet been combined into study-wide datasets, nor have many of the findings been assimilated into broader syntheses. Many questions remain related to dietary overlap, intra- and inter-specific competition, productivity, migration and distribution patterns of Pacific salmon, food web dynamics, and ultimately, how ocean warming may affect these factors.

The IYS provided a major opportunity to better understand high seas ecology and to provide insight into factors affecting salmon survival in the ocean. A full synthesis of scientific findings and outputs from this landmark program would be extremely valuable to further our understanding of the mechanisms regulating high seas salmon production and the effects of climate change on high seas salmon and steelhead.

Issues of Concern

The International Year of the Salmon program wrapped up in 2022. Since that time, many of the key researchers have assimilated further findings, are in the process of publication (either primary or technical reports), and/or have been involved in the creation of other outputs including databases and visual products. Several major data and visualization products were created during IYS, which could be updated with new data, findings and knowledge. There is a key need to assimilate and synthesize this critical knowledge and these scientific findings into meaningful scientific inputs, allowing for better assessment, forecasting and management of salmon.

The synthesis of the International Year of the Salmon (IYS) program could generate several valuable products that will help translate the research into practical and accessible resources for scientists, policymakers, and the public. By creating a diverse range of outputs, the program can ensure that its findings reach multiple audiences and serve various purposes—from rigorous scientific research to public education and policy development.

Objectives

The key objectives are as follows:

Knowledge Synthesis

Synthesize key IYS findings to integrate the diverse research findings from multiple geographic regions, to create more a comprehensive overview of IYS outcomes and allow us to better identify enduring gaps, lessons learned, and potential next steps. This will be achieved through the following:

- Literature Review to collate scientific findings from IYS projects and to integrate findings across the entire North Pacific.
- Interviews with all IYS PIs (and all speakers at the IYS final synthesis symposium) to provide an overview on outcomes/data & visual products/ next steps/ ongoing gaps.
- Creation of a report on the value of coordinated research, lessons learned, gaps identified and potential next steps.

Data Management & Visualization

Through BECI, continued collation of North Pacific datasets will enhance the existing IYS data platforms. BECI-led workshops with IYS researchers will invigorate continued consolidation of data and data products, and result in the creation of new, accessible visual products. This will be achieved through the following:

- Contribute to updates to the International Pacific Salmon Data Legacy e.g. possible addition of new datasets such as scale growth data.
- Contribute to updates to the IYS Data Catalogue with new datasets.
- Creation of advanced visualization tools to represent complex salmon ecosystem data on the BECI website through the BECI Ocean Knowledge Network Interactive Map.

Outreach & Communication

Create resources and products that help translate the scientific research into practical, engaging and accessible resources for scientists, policymakers, and the public. This will be achieved through the following:

- Creation of website resources.
- Creation of accessible newsletter style reports.
- Creation of visual informative products e.g. ArcGIS story maps.

Information/Data

The information to be collated as part of the IYS synthesis includes the following:

- Research vessel survey information (2019-2022)
- Oceanographic data from each survey
- Biological sampling conducted and results
- Stock identification results
- Publications from IYS
- Collation of databases/data products created by IYS scientists
- Collation of spatial data layers created by IYS scientists
- Data and reports created through the other IYS component projects

Implementation Plan

Phase	Step	Action	Product(s)
Initial	Literature review	Literature review of primary and technical literature	Review paper on key findings and products from the IYS program
	Interviews	Interview IYS research community	Database with identified data sets, analytical products and visual products that are not part of the current IYS data catalogue Within database highlight information on outcomes/data & visual products/ next steps/ ongoing gaps

			Final product is a report on the value of coordinated research, lessons learned, gaps identified and potential next steps
	Data collation	Contribute to the collation of IYS datasets that are not part of the current IYS Data Catalogue e.g. • Scale data (marine growth) • eDNA • Salmon diet data • Genomics/Genetics • Fit-Chip information	Continued collation of IYS datasets and creation of IYS metadata
	Knowledge Network: IYS synthesis working group	Biannual online webinar/workshop for IYS program leads/community	Definition of an IYS synthesis working group and establish collaborative workspace for project partners Finalize database of IYS data sets, analytical products and spatial layers Outreach about BECI and ongoing IYS synthesis
	Knowledge Product: IYS database	Continued contribution to data and metadata compilation	Collation of IYS datasets into IYS data catalogue Creation of IYS metadata
Intermediate	Data transformation, standardization and integration	Build on the federated system developed for the IYS Data Catalogue Follow existing protocols for data transformation, standardization, metadata creation etc.	Standardization of the initial IYS Data Catalogue

	Visualization Tool	Link to data layers in the International Pacific Salmon Data Legacy and build on the BECI Knowledge Network Interactive Map	BECI Knowledge Network Interactive Map: • Basic distribution maps (potentially linked with historic NPAFC data) • Migration routes • Marine growth (scale data) • Species distribution model outputs • Oceanographic data • eDNA ecosystem data • FitChip fish health information etc.
	Genomic and Population Database	Identify and compile genomic and genetic data from IYS	Database of a genetic diversity data
Advanced	Interactive Ecological Data Visualization tools	Compile new data and data layers from the IYS data catalogue and the ISPDL.	BECI Knowledge Network Interactive Map: • Ecosystem characterization; Salmon distribution etc. BECI dashboard: • Environmental summaries from survey areas
	Analytical and Scientific Products	Work with external partners to create synthesized and analytical products and summaries.	Potential products may include: • Environmental summaries for different survey areas • Detailed scientific analysis of salmon

			populations, migration patterns, and ecosystem interactions

Expected Outcomes

The information collated during IYS provides a crucial opportunity to synthesize scientific knowledge about salmon and their ecosystems across their entire life cycle and transboundary ecosystems. The synthesis process will:

- Integrate diverse research findings from multiple geographic regions
- Provide more comprehensive insights into salmon populations and ecosystems
- Provide more comprehensive insights into climate change impacts on salmon growth, migration and survival
- Identify critical knowledge gaps
- Guide future research priorities
- Inform long-term monitoring and conservation efforts
- Create accessible scientific resources for researchers, policymakers, and conservation professionals
- Support evidence-based policy development

Challenges/Limitations

Data Sharing Impediments

Protected data, lack of interest or fear of sharing, data in fragmented or inaccessible media, privacy and IP restrictions. Possible mitigation may be the creation of protected datasets or data layers, collation of metadata only, as well as clear communication about benefits of sharing and open access.

Knowledge Transfer Impediments

concerns about releasing information prior to publication, protected or traditional knowledge, language constraints. Potential mitigation would be information protection until post-publication, creation of restricted data layers, clear communication about the potential benefits of sharing/products, use of translators, working with key partners and collaborators involved in IYS, PICES and NPAFC to build trust and facilitate collaboration.

Key Partners

Data Providers

Relevant datasets will be provided by NPAFC, NPAFC member country organizations, the past IYS working group members and cruise scientists.

Knowledge Contributors

Knowledge on lessons learned, ongoing gaps will be gathered through an interview process with the past IYS working group members and cruise scientists, Indigenous communities and organizations involved in IYS, and broader government and university research teams working on projects affiliated or derived from IYS.

Implementation Partners

Implementation and creation of key products through the IYS Synthesis will include partners with essential skills such scientific writers, GIS specialists, data visualization experts, software developers, and data scientists.

End Users

will include government and university research facilities, Indigenous fisheries organizations, NGOs working on marine ecosystems and fisheries, and Fisheries management agencies.

UC5: North Pacific Ocean Ecosystem Status Report Framework Phase 1 (Alaska Ecoregion Pilot)

Background

The North Pacific Ocean is experiencing unprecedented climate-driven changes affecting marine ecosystems and fisheries across national boundaries (Hollowed et al., 2013; Hazen et al., 2019). While significant monitoring efforts exist, they often remain fragmented across countries, resulting in inconsistent metrics, methodologies, and lengthy reporting processes (Beamish et al., 2009; Duffy et al., 2019).

The North Pacific Ecosystem Status Reports (NPESR) produced by PICES (North Pacific Marine Science Organization) represent important collaborative efforts to synthesize ecosystem information across 14 distinct ecoregions spanning the North Pacific (PICES, 2010; McKinnell & Dagg, 2010). These ecoregions include the Oyashio/Kuroshio, Sea of Okhotsk, Yellow Sea, East China Sea, South China Sea, Western Bering Sea, Northern Bering–Chukchi Seas, Eastern Bering Sea, Aleutian Islands, Western Gulf of Alaska, Eastern Gulf of Alaska, Northern California Current, and Southern California Current. Each ecoregion has unique ecological characteristics, monitoring capacities, and management priorities, creating significant challenges for standardized reporting and cross-regional comparisons (Megrey et al., 2009; Zador et al., 2016).

Despite this comprehensive geographic coverage, the NPESR process is limited by voluntary, non-standardized contributions from member countries. This results in inconsistent reporting across ecoregions, with significant variations in data availability, parameter selection, and analytical approaches. There is a clear need to create a more coordinated framework for the NPESR process that will not only increase efficiency but also provide significant benefits including enhanced comparability across regions, improved detection of ecosystem-wide patterns, reduced duplication of effort, and better integration of findings into management decisions.

The Ocean Health Index (OHI), introduced by Halpern et al. (2012), offers a complementary approach that could strengthen the NPESR framework. Unlike NPESR's primarily descriptive approach focusing on ecological status and inconsistent human dimension metrics, OHI provides a quantitative, goal-oriented framework that integrates ecological, social, and economic dimensions of ocean health into standardized scores (Halpern et al., 2015; Lowndes et al., 2015). OHI uses reference points to assess status relative to targets, employs standardized scoring methodologies, and focuses on sustainability outcomes. By integrating elements of OHI with NPESR, we can create a framework that maintains NPESR's ecological depth while adding standardized scoring, human dimensions with consistent metrics, and outcome-oriented metrics (Samhouri et al., 2012; Koehn et al., 2020).

NPESR typically includes:

- Physical and oceanographic conditions (temperature, salinity, currents)
- Chemical parameters (nutrients, oxygen, acidification)
- Lower trophic level productivity (phytoplankton, zooplankton)
- Fish stock abundance and distribution
- Seabird and marine mammal populations
- Notable ecosystem events (e.g., harmful algal blooms)
- Human activities (fisheries, shipping, coastal development)
- Socioeconomic indicators (when available)

OHI's distinguishing features include:

- A consistent framework of 10 standardized goal metrics applied uniformly across regions
- Quantitative scoring against reference points (0-100 scale)
- Explicit integration of human benefits from marine ecosystems
- Calculation of both status and likely future state
- Incorporation of pressures and resilience factors into scoring
- Standardized methodology allowing direct cross-regional comparisons
- Open-source, repeatable assessment process

By combining elements of the NPESR approach with the structured goal-oriented methodology of OHI, we can create a more standardized, comparable framework that maintains essential flexibility for regional priorities while ensuring consistent core metrics.

This hybrid approach will demonstrate how standardized ecosystem monitoring, assessment, and reporting frameworks can enhance knowledge sharing, support ecosystem-based management decisions, and improve understanding of climate impacts across the North Pacific, directly supporting BECI's mission to connect knowledge and enhance science-based decision making across political boundaries.

The Alaska region, encompassing multiple PICES ecoregions (Eastern Bering Sea, Aleutian Islands, and Western Gulf of Alaska), represents an ideal focal point for advancing this integrated ecosystem status reporting approach due to several factors. First, it has well-established monitoring programs with long-term datasets. Second, it spans multiple ecologically distinct areas with transboundary significance. Third, it supports valuable fisheries resources that migrate across international boundaries. Finally, it has experienced pronounced climate impacts, including marine heatwaves, sea ice loss, and shifting species distributions, making it a critical area for understanding climate-ecosystem interactions (Bond et al., 2015; Duffy-Anderson et al., 2017; Holsman et al., 2020). Using Alaska's multiple ecoregions as a testing ground provides an opportunity to demonstrate how standardized approaches can work across ecologically diverse areas while respecting their unique characteristics. Once validated in the Alaska region, this framework can be systematically expanded to all 14 PICES ecoregions, ultimately enabling a comprehensive, standardized assessment of the entire North Pacific ecosystem that maintains regional nuance while allowing meaningful cross-regional comparisons and basin-wide synthesis.

Issues of Concern

Current ecosystem status reporting in the North Pacific faces several critical challenges:

- Inconsistent monitoring and reporting metrics across PICES member countries
- Lack of standardized core parameters that all countries agree to monitor and report
- Fragmented data collection impeding transboundary understanding of ecosystem changes
- Limited integration between conventional ecological monitoring and human dimensions
- Insufficient data standardization hampering comparative analyses across regions
- Need for more efficient reporting processes that reduce redundancy and enhance accessibility

Objectives

1. Develop a hybrid NPESR-OHI framework for Alaska ecoregions that integrates standardized core metrics with flexible regional indicators
2. Create data submission protocols and templates to facilitate consistent reporting across participating organizations
3. Establish a digital platform for collating, analyzing, and visualizing ecosystem status data
4. Demonstrate how standardized ecosystem monitoring can enhance transboundary understanding of climate impacts
5. Support ecosystem-based management and conservation approaches through accessible, comparable ecosystem status information
6. Create a model framework that can be expanded to other PICES ecoregions and member countries

Information/Data

Core Physical/Oceanographic Parameters

- Sea surface temperature (seasonal means and anomalies)
- Major climate indices (PDO, ENSO) relevant to Alaska region
- Sea ice extent and timing (for applicable areas)
- Ocean acidification metrics
- Dissolved oxygen levels

Core Biological Parameters

- Chlorophyll-a concentrations
- Zooplankton biomass indices
- Harmful algal bloom occurrence
- Key forage fish abundance
- Groundfish/demersal fish community indicators

Commercial Species Data

- Stock assessment data for key commercial species
- Distribution shifts
- Size structure changes
- Recruitment indices

Human Dimensions

- Commercial fishing effort and landings
- Subsistence harvest levels
- Coastal community well-being indicators
- Marine transport activity
- Marine Pollution

Sources and Organizations

- NOAA Alaska Fisheries Science Center
- NOAA Pacific Marine Environmental Laboratory
- Alaska Department of Fish and Game
- North Pacific Research Board
- University of Alaska research programs
- Tribal and First Nations monitoring programs
- PICES databases and working groups
- Commercial fisheries observer programs

Implementation Plan

Phase	Step	Action	Product(s)
Initial	Framework Development	Create hybrid NPESR-OHI framework specifying core and flexible indicators for Alaska ecoregions	Comprehensive framework document detailing required metrics, methodologies, and reporting formats
	Stakeholder Engagement	Convene workshops with Alaska region monitoring agencies, tribal organizations, and management bodies	Stakeholder needs assessment and engagement report
	Data Inventory	Catalog existing monitoring programs and datasets in Alaska region relevant to ecosystem status reporting	Directory of available datasets, responsible organizations, and metadata
Intermediate	Template Creation	Develop standardized data submission templates and protocols	Data submission documents including templates, quality control procedures, and metadata requirements

	Digital Platform Development	Create beta version of digital platform for collating, analyzing, and visualizing ecosystem indicators	Web-based interactive ecosystem status platform for Alaska ecoregions
	Pilot Implementation	Implement the framework with participating organizations in Alaska region	First standardized Alaska ecoregion ecosystem status report using the hybrid framework
	Data Visualization Tools	Develop interactive visualization tools for ecosystem indicators	BECI dashboard with time series, data visualization on maps, and anomaly tracking
Advanced	Cross-Regional Analysis	Conduct comparative analyses across Alaska ecoregions	Cross-regional synthesis report identifying common patterns and key differences in ecosystem status
	Framework Expansion	Work with PICES to expand framework to other North Pacific ecoregions	Expanded framework documentation with region-specific adaptations
	Enhanced Decision Support	Develop tools for translating ecosystem status information into management-relevant formats	Decision support documents linking ecosystem indicators to management thresholds and reference points
	Forecast Integration	Incorporate predictive ecosystem forecasts into the status reporting system	Integrated forecast/status reporting system with uncertainty estimates

Expected Outcomes

1. Improved standardization of ecosystem monitoring and reporting across Alaska ecoregions
2. Enhanced data integration across multiple organizations and monitoring programs
3. More efficient ecosystem status reporting processes with reduced duplication of effort
4. Better understanding of climate impacts on ecosystem structure and function
5. Increased comparability of ecosystem indicators across regions and time periods

6. More accessible ecosystem information for managers, policymakers, and stakeholders
7. Stronger scientific foundation for ecosystem-based management decisions
8. Creation of a model framework that can be expanded to other PICES ecoregions
9. Enhanced transboundary collaboration on ecosystem monitoring and assessment

Challenges/Limitations

Institutional Inertia & Established Practices

- Nature: Organizations have existing monitoring programs and reporting formats
- Impact: Resistance to adopting new standardized approaches
- Mitigation: Emphasize compatibility with existing programs, include organizations in development and decision-making process, demonstrate added value, and provide transition support

Resource & Capacity Constraints

- Nature: Limited funding and staff for data acquisition, management and reporting
- Impact: Incomplete implementation of the framework
- Mitigation: Focus on core metrics that are already widely monitored, create efficient data submission processes, and seek dedicated funding

Data Sharing Impediments

- Nature: Institutional barriers to data sharing, proprietary concerns
- Impact: Incomplete ecosystem status information
- Mitigation: Develop strong working relationships and trust with data holders, create data sharing agreements, emphasize metadata when raw data cannot be shared, create protected data layers when necessary

Methodological Differences

- Nature: Varying sampling methods, analytical approaches, and quality control
- Impact: Limited comparability of data across sources
- Mitigation: Develop clear methodological guidelines, cross-calibration procedures, and quality assurance protocols

Scale Mismatches

- Nature: Different temporal and spatial scales of monitoring programs
- Impact: Challenges in integration and synthesis
- Mitigation: Define standardized reporting units and time periods, develop interpolation methods for different scales

Key Partners

Data Providers

- NOAA Alaska Fisheries Science Center (ecosystem monitoring, stock assessments)
- NOAA Pacific Marine Environmental Laboratory (oceanographic monitoring)
- Alaska Department of Fish and Game (state fisheries monitoring)
- University of Alaska research programs (various ecosystem components)
- North Pacific Research Board funded projects (focused studies)
- U.S. Fish and Wildlife Service (seabird and marine mammal monitoring)
- Tribal and First Nations monitoring programs (local ecological knowledge, subsistence harvest)
- Alaska Ocean Observing System (oceanographic monitoring)
- Global Ocean Observation System
- NASA (satellite data)

Knowledge Contributors

- PICES Working Groups and Expert Groups
- North Pacific Anadromous Fish Commission (salmon expertise)
- Ocean Health Index research team
- Ecosystem modelling groups
- Climate science centers
- Alaska Climate Science Center
- Indigenous knowledge holders
- Commercial fisheries organizations

Implementation Partners

- Data scientists and database specialists
- GIS and visualization experts
- Software developers for digital platform
- Science communicators
- Project management specialists
- Ecological statisticians
- Workshop facilitators

End Users

- North Pacific Fishery Management Council
- Alaska fisheries management agencies
- Coastal communities and Indigenous organizations
- Conservation organizations
- Commercial fishing industry
- Other PICES member countries (for potential expansion)
- Marine spatial planning initiatives
- Climate adaptation planning groups
- Marine protected area managers

UC6: North Pacific Ocean Ecosystem Status Report Framework Phase 2 (Multinational Pilot)

Background

The North Pacific Ocean functions as an interconnected ecosystem spanning multiple national boundaries, where climate-driven changes increasingly impact marine resources and ecosystem services across the entire basin (Hazen et al., 2019; Hollowed et al., 2013). While individual country monitoring efforts provide valuable insights within national waters, true understanding of ecosystem dynamics requires coordinated transboundary approaches that can capture basin-scale patterns and processes (Pinsky et al., 2018; Bograd et al., 2019).

The North Pacific Ecosystem Status Reports (NPESR) produced by PICES (North Pacific Marine Science Organization) represent important collaborative efforts to synthesize ecosystem information across 14 distinct ecoregions spanning the North Pacific (PICES, 2010; McKinnell & Dagg, 2010). These ecoregions include the Oyashio/Kuroshio, Sea of Okhotsk, Yellow Sea, East China Sea, South China Sea, Western Bering Sea, Northern Bering–Chukchi Seas, Eastern Bering Sea, Aleutian Islands, Western Gulf of Alaska, Eastern Gulf of Alaska, Northern California Current, and Southern California Current. Each ecoregion has unique ecological characteristics, monitoring capacities, and management priorities, creating significant challenges for standardized reporting and cross-regional comparisons (Megrey et al., 2009; Zador et al., 2016).

Despite this comprehensive geographic coverage, the NPESR process is limited by voluntary, non-standardized contributions from member countries. This results in inconsistent reporting across ecoregions, with significant variations in data availability, parameter selection, and analytical approaches. There is a clear need to create a more coordinated framework for the NPESR process that will not only increase efficiency but also provide significant benefits including enhanced comparability across regions, improved detection of ecosystem-wide patterns, reduced duplication of effort, and better integration of findings into management decisions.

The Ocean Health Index (OHI), introduced by Halpern et al. (2012), offers a complementary approach that could strengthen the NPESR framework. Unlike NPESR's primarily descriptive approach focusing on ecological status and inconsistent human dimension metrics, OHI provides a quantitative, goal-oriented framework that integrates ecological, social, and economic dimensions of ocean health into standardized scores (Halpern et al., 2015; Lowndes et al., 2015). OHI uses reference points to assess status relative to targets, employs standardized scoring methodologies, and focuses on sustainability outcomes. By integrating elements of OHI with NPESR, we can create a framework that maintains NPESR's ecological depth while adding standardized scoring, human dimensions with consistent metrics, and outcome-oriented metrics (Samhouri et al., 2012; Koehn et al., 2020).

NPESR typically includes:

- Physical and oceanographic conditions (temperature, salinity, currents)
- Chemical parameters (nutrients, oxygen, acidification)
- Lower trophic level productivity (phytoplankton, zooplankton)
- Fish stock abundance and distribution
- Seabird and marine mammal populations
- Notable ecosystem events (e.g., harmful algal blooms)
- Human activities (fisheries, shipping, coastal development)
- Socioeconomic indicators (when available)

OHI's distinguishing features include:

- A consistent framework of 10 standardized goal metrics applied uniformly across regions
- Quantitative scoring against reference points (0-100 scale)
- Explicit integration of human benefits from marine ecosystems
- Calculation of both status and likely future state
- Incorporation of pressures and resilience factors into scoring
- Standardized methodology allowing direct cross-regional comparisons
- Open-source, repeatable assessment process

By combining elements of the NPESR approach with the structured goal-oriented methodology of OHI, we can create a more standardized, comparable framework that maintains essential flexibility for regional priorities while ensuring consistent core metrics.

This hybrid approach will demonstrate how standardized ecosystem monitoring, assessment, and reporting frameworks can enhance knowledge sharing, support ecosystem-based management decisions, and improve understanding of climate impacts across the North Pacific, directly supporting BECI's mission to connect knowledge and enhance science-based decision making across political boundaries.

The United States (Alaska regions), Canada (Eastern Gulf of Alaska), and Japan (Oyashio/Kuroshio systems) represent ideal partners for a multinational framework pilot project due to their strong scientific capacities, established monitoring programs, and history of successful collaboration through PICES. These countries span critical migratory corridors for shared species including Pacific salmon, albacore tuna, marine mammals, and seabirds (Sydeman et al., 2015; Woodworth-Jefcoats et al., 2017). Climate impacts occurring in one nation's waters directly affect the abundance, distribution, and health of species in another's, creating an inherent need for coordinated monitoring and assessment (Di Lorenzo et al., 2013).

The multinational framework would leverage each country's monitoring strengths while addressing their limitations. The United States offers comprehensive fisheries monitoring and ecosystem reporting systems with strong benthic and pelagic fish assessments. Canada provides sophisticated integrated ocean observing networks and salmon management expertise. Japan contributes exceptional oceanographic monitoring capabilities and long-term time series for western Pacific species. Together, they create a powerful collaborative network spanning the eastern and western reaches of the North Pacific (Murawski et al., 2010).

This multinational approach will demonstrate how standardized ecosystem monitoring, assessment, and reporting frameworks can enhance knowledge sharing across political boundaries, support coordinated ecosystem-based management for shared species and improve understanding of basin-scale climate impacts across the North Pacific. By connecting these regions through a common framework, we can better detect, understand, and respond to ecosystem-wide changes that no single nation could effectively address alone (Levin et al., 2014; Samhouri et al., 2014).

Objectives

1. Develop a multinational NPESR-OHI framework that integrates standardized monitoring across Alaska, Canada, and Japan
2. Create multilingual data submission protocols that facilitate consistent reporting while respecting national data policies
3. Demonstrate how standardized transboundary monitoring can enhance understanding of basin-scale climate impacts
4. Support coordinated ecosystem-based management approaches for shared migratory species
5. Create a scalable model that can be expanded to include additional PICES member countries

Proposed Activities & Outputs

Phase	Step	Action	Product(s)
Initial	Framework Development	Create hybrid NPESR-OHI framework specifying core and flexible parameters across USA, Canada, and Japan ecoregions	Comprehensive multilingual framework document detailing required metrics, methodologies, and reporting formats
	Multinational Working Group	Establish coordination team with representatives from each country and ecoregion	Governance structure document with clear roles, responsibilities, and decision-making protocols
	Data collation	Catalog existing monitoring programs and datasets across the three countries relevant to ecosystem status reporting	Directory of available datasets, responsible organizations, and metadata with cross-regional mapping
	Stakeholder Engagement	Convene international workshops with monitoring agencies, indigenous organizations, and management bodies from all three countries	Multinational stakeholder needs assessment and engagement report
Interme diate	Data Sharing Protocols	Develop multilingual data sharing agreements that address national regulatory constraints	Tiered data sharing framework document with metadata standards and access control specifications

	Template Creation	Create standardized multilingual data submission templates and quality control procedures	Multilingual data submission documents including templates, quality control procedures, and metadata requirements
	Digital Platform Development	Create beta version of cross-basin digital platform for collating, analyzing, and visualizing ecosystem indicators	Web-based interactive multinational ecosystem status platform
	Pilot Implementation	Implement the framework starting with core physical and biological parameters across selected ecoregions	First standardized multinational ecosystem status report using the hybrid framework
	Collaborative Analysis	Conduct joint analysis of shared climate-driven ecosystem patterns across participating ecoregions	Cross-basin synthesis identifying teleconnections and shared response patterns
Advanced	Full Integration	Incorporate complete suite of indicators including human dimensions across all participating ecoregions	Comprehensive multinational ecosystem status report with standardized core metrics and regional adaptations
	Management Translation	Develop tools for translating ecosystem status information into management-relevant formats for shared species	Decision support documents linking ecosystem indicators to management thresholds and reference points for transboundary resources
	Forecast Integration	Incorporate predictive ecosystem forecasts into the status reporting system across all participating regions	Integrated multinational forecast/status reporting system with uncertainty estimates
	Framework Expansion	Work with remaining PICES member countries to expand the framework to additional ecoregions	Expanded framework documentation with additional PICES member country-specific adaptations
	Knowledge Exchange Platform	Create permanent infrastructure for ongoing data sharing, analysis, and visualization	North Pacific Ocean Knowledge Network with sustainable governance and funding model

Implementation Strategy

Initial Phase: Foundation Building (Years 1-2)

- Investigate each countries desire to participate in NPESR-OHI framework building and develop relationships with representatives for each ecoregion
- Form a Multinational Working Group with representatives from each country
- Identify shared priority indicators across all seven ecoregions
- Create data sharing protocols that address each country's regulatory constraints
- Develop trilingual templates and metadata standards

Intermediate Phase: Pilot Implementation (Years 2-3)

- Launch initial data integration for core physical and biological parameters
- Create beta (pre-release) version of multinational data dashboard
- Produce first coordinated ecosystem status assessment report
- Identify shared climate-driven ecosystem patterns across ecoregions

Advanced Phase: Expansion & Refinement (Years 3-5+)

- Incorporate full suite of indicators including human dimensions
- Develop management-relevant products including early warning indicators
- Create coordinated forecasting capability across ecoregions
- Incorporate remaining ecoregions within Canada, USA and Japan (if we go with 1 each to start)
- Engage additional PICES countries for future expansion

Advantages of Multinational Approach

- Enhanced Scientific Value: Connecting eastern and western Pacific ecoregions allows detection of basin-scale patterns and teleconnections
- Improved Management of Shared Resources: Better coordination for species that migrate across these ecoregions
- Complementary Expertise: Each country brings unique monitoring strengths and analytical approaches
- Diplomatic Benefits: Strengthens scientific cooperation across nations with significant geopolitical importance
- Increased Efficiency: Shared data standards and analysis approaches reduce redundant efforts

Challenges & Mitigation Strategies

Language Barriers

- Create multilingual platforms and metadata standards
- Establish translation protocols for key documents
- Leverage bilingual scientists as knowledge brokers

Different Data Policies

- Develop tiered data sharing agreements
- Create metadata sharing options when raw data cannot be shared
- Implement harmonized access controls respecting national regulations

Varied Monitoring Approaches

- Focus initially on most comparable indicators
- Develop cross-calibration methodologies
- Create standardized data transformations to common formats

Coordination Complexity

- Building a trusting relationship with national coordinators
- Establish clear governance with national coordinators
- Create regular coordination meeting schedule
- Develop project management tools with multilingual interfaces

Key Partners

United States

- NOAA Alaska Fisheries Science Center
- Alaska Department of Fish and Game
- University of Alaska
- North Pacific Fishery Management Council
- Alaska Observing System
- U.S. Integrated Ocean Observation System

Canada

- Fisheries and Oceans Canada (DFO)
- Ocean Networks Canada
- University of British Columbia
- Pacific Salmon Commission
- Canadian Integrated Ocean Observing System

Japan

- Japan Fisheries Research and Education Agency
- Japan Meteorological Agency
- Fisheries Technology Institute
- University of Tokyo

International Organizations

- PICES Secretariat
- North Pacific Anadromous Fish Commission
- Pacific Salmon Commission
- Ocean Health Index team
- Global Observation System

This multinational framework would provide a powerful demonstration of how standardized approaches can work across different national systems while respecting their unique characteristics. It would create a model for eventual expansion to include all PICES member countries in a truly integrated North Pacific ecosystem assessment framework.

UC7: Climate-Adaptive Spatial Conservation Planning in the North Pacific Ocean

Background

The North Pacific Ocean is experiencing significant changes due to climate change, including shifting species distributions, changing productivity patterns, and altered ecosystem dynamics. These changes pose major challenges for effective conservation planning, particularly in Areas Beyond National Jurisdiction (ABNJ), which comprise approximately 64% of the global ocean surface. Traditional static spatial approaches to conservation using Marine Protected Areas (MPAs) and other Area-Based Management Tools (ABMTs) are increasingly insufficient as marine ecosystems undergo rapid transformation under climate change (Bruno et al. 2018). The fixed boundaries of conventional protected areas fail to accommodate the dynamic nature of ocean systems where species distributions are rapidly shifting poleward and into deeper waters in response to warming temperatures (Hobday 2011, Cashion et al. 2020). This spatial mismatch is exacerbated by changes in ocean chemistry, including acidification and deoxygenation, which alter habitat suitability across broad geographic ranges regardless of protection status. Marine species facing these stressors are exhibiting accelerated phenological shifts in migration timing, breeding cycles, and feeding patterns that transcend the temporal management frameworks of static reserves. This ineffectiveness is compounded by extreme climatic events, changing oceanographic conditions, and institutional barriers to adaptive management, necessitating more flexible, anticipatory conservation strategies that respond to ongoing marine ecosystem change rather than attempting to preserve historical conditions.

Frameworks are needed to make marine conservation and management more robust under the increasing pressures of global change and resource needs (Fulton et al. 2015). To date, the MPA planning process considers only a few, if any, aspects of climate change (Jones et al. 2020). Conservation planning in the North Pacific requires consideration of multiple temporal scales—from seasonal variations to multidecadal climate change impacts—and must adapt to ephemeral oceanographic features, climate oscillations, and long-term shifts in ecosystem productivity (Brown et al. 2015, Crespo et al. 2020). Forward-looking protected areas and adaptive or dynamic marine spatial management can help maintain ecological connectivity and provide critical protection and refugia from climate impacts for commercially valuable fish stocks as their ranges shift, ultimately contributing to both biodiversity protection and fisheries sustainability (Arafeh-Dalmau et al. 2023). Existing climate-adaptive MPAs that have demonstrated effectiveness include the Pacific Remote Islands Marine National Monument, which preserves pelagic habitats and migration corridors for commercially valuable tuna and other migratory fish, while safeguarding critical feeding grounds that become increasingly important as climate change alters oceanic productivity. In California, the network of MPAs along the coast was strategically designed to protect larval dispersal pathways, helping marine populations adapt as ocean conditions change (Carr et al. 2017). The integration of robust climate projections from dynamic Earth System Models, climate models, biological/ecological models, and ensemble modelling approaches like the Fisheries and Marine Ecosystem Model Intercomparison Project (FishMIP) offer a promising avenue to develop more climate-adaptive spatial conservation strategies that can account for future ocean conditions when designing protected areas and other spatial conservation measures (Fulton et al. 2015). Some initial efforts have begun to progress this work, with focus on the North Atlantic oceanic regions (e.g., Palacios-Abrantes et al. 2023), but a focused initiative is needed for the North Pacific region to contribute to the BECI knowledge network.

Issues of Concern

Several key challenges hamper effective climate-adaptive conservation planning in the North Pacific:

- Knowledge gaps in climate impacts on pelagic and deep-sea habitats: Most research on climate adaptation for marine conservation has focused on coastal ecosystems, particularly coral reefs, with insufficient attention to open ocean and deep-sea environments that dominate the North Pacific (Wilson et al., 2020).
- Inadequate consideration of multiple climate stressors: Conservation planning typically considers temperature changes, but often fails to address other stressors such as ocean acidification, deoxygenation, and changes in productivity regimes that will have synergistic impacts.
- Conflicting adaptation strategies: The scientific literature presents polarizing advice between protecting only climate refugia versus protecting a diversity of habitats to increase resilience, creating confusion for conservation planners.
- Limited empirical evidence for adaptation effectiveness: Few existing MPAs have incorporated climate adaptation strategies, resulting in uncertainty about

which approaches will be most effective in protecting biodiversity under changing conditions.

- Governance challenges for dynamic management: Current governance structures for ABNJ lack mechanisms to implement and monitor dynamic MPAs that can shift boundaries as ocean conditions change.

Objectives

1. Develop a comprehensive framework for climate-adaptive spatial conservation planning in the North Pacific that integrates dynamic oceanographic, ecological and ensemble model projections
2. Create decision-support tools that enable conservation planners to incorporate multiple climate stressors and temporal scales into MPA network design
3. Identify potential climate refugia and high-vulnerability areas in the North Pacific based on ensemble modelling outputs
4. Establish protocols for dynamic and flexible ABMTs that can adapt to changing ocean conditions
5. Build capacity among conservation practitioners and governance bodies to implement climate-adaptive spatial planning approaches

Information/Data

The following types of data and information would contribute to this use case:

Climate Projections

FishMIP ensemble model outputs for the North Pacific under multiple emissions scenarios (SSP1-RCP2.6, SSP2-RCP4.5, SSP3-RCP6.0, SSP5-RCP8.5)

- Sources: ISIMIP, FishMIP contributors, NOMEME (North Pacific Ocean Marine Ecosystem Model Ensemble)

Oceanographic Data

Historical and current data on temperature, salinity, oxygen, pH, productivity patterns

- Sources: NOAA, World Ocean Database, Argo float program, OOI (Ocean Observatories Initiative), Earth System Models (e.g., GFDL)

Species Distribution Data

Current and projected distributions of key North Pacific species

- Sources: OBIS, GBIF, national fisheries research institutions, International Year of the Salmon datasets

Biodiversity Hotspot Information

Locations of ecologically significant areas

- Sources: CBD EBSAs, VME databases, IUCN Red List, migratory species tracking data

Ecosystem Connectivity Data

Larval dispersal pathways, animal migration corridors

- Sources: Animal tracking networks, oceanographic particle tracking models

Existing Protected Area Information

Current MPAs, fishery closures, and other spatial management measures

- Sources: World Database on Protected Areas, Regional Fisheries Management Organizations

Governance Frameworks

Institutional arrangements for ABMTs in the North Pacific

- Sources: BBNJ Treaty, RFMOs, ISA, IMO, regional seas organizations

Proposed Activities & Outputs

Phase	Step	Action	Product(s)
Initial	Data collation and integration	Compile and standardize available FishMIP and other climate model outputs for the North Pacific	BECI Dashbard interactive database of climate projections relevant to conservation planning
	Knowledge network development	Identify and connect key partners across the Pan-Pacific region working on climate-adaptive conservation	Working group on Climate-Adaptive Spatial Conservation Planning with regular webinar series
	Gap analysis	Review existing literature and practice in climate-adaptive MPAs in the North Pacific	Synthesis report on the state of climate-adaptive spatial conservation planning
Interme diate	Methodology development	Develop approaches for incorporating temporal variability at multiple scales into spatial planning	Technical guidelines for multi-scale temporal analysis in conservation planning

	Vulnerability assessment	Assess vulnerability of key ecosystems and species to multiple climate stressors	BECI Knowledge Network Interactive Map: Vulnerability layers for North Pacific ecosystems under different climate scenarios
	Decision support tool development	Create planning tools that incorporate FishMIP outputs into spatial prioritization	BECI Dashboard: Interactive conservation planning platform with climate projection layers
	Case study implementation	Apply framework to selected pilot areas in the North Pacific ABNJ	Case study reports demonstrating application of climate-adaptive planning approaches
Advanced	Dynamic MPA protocol development	Establish protocols for implementing and monitoring dynamic protected areas	Dynamic MPA implementation handbook and governance framework
	Performance evaluation	Monitor and evaluate effectiveness of different climate adaptation strategies	Report on comparative analysis of adaptation strategy effectiveness
	Policy integration	Work with governance bodies to incorporate climate-adaptive approaches into policy frameworks	Policy briefs and recommendations for North Pacific regional bodies and BBNJ process

Expected Outcomes

Implementation of this use case will lead to:

1. Enhanced understanding of climate change impacts on North Pacific marine ecosystems at multiple temporal and spatial scales
2. Improved capacity among conservation practitioners to incorporate climate projections into spatial planning processes
3. More robust and climate-adaptive MPA networks in the North Pacific, particularly in ABNJ
4. Development of innovative approaches to dynamic spatial management that can respond to changing ocean conditions
5. Strengthened science-policy interface for marine conservation governance in the region
6. Greater resilience of protected areas to climate change impacts
7. More effective conservation of biodiversity under changing climate conditions

Challenges/Limitations

Data Uncertainty & Resolution Issues

- Nature: Climate models have inherent uncertainties and may lack the spatial resolution needed for local conservation planning
- Impact: Could lead to inappropriate conservation priorities or misplaced protected areas
- Mitigation: Use ensemble approaches that quantify uncertainty, focus on robust trends across models, and downscale where appropriate

Governance Complexity for Dynamic Management

- Nature: Current legal frameworks for ABNJ may lack mechanisms for implementing and enforcing dynamic protected areas
- Impact: Could prevent implementation of innovative adaptation approaches
- Mitigation: Engage early with relevant governance bodies and develop approaches compatible with existing frameworks while advocating for necessary reforms

Cross-Jurisdictional Coordination

- Nature: The North Pacific spans multiple national jurisdictions and areas beyond national jurisdiction
- Impact: Could impede coherent region-wide conservation planning
- Mitigation: Establish strong coordination mechanisms between national and international bodies, potentially through regional working groups

Limited Empirical Evidence for Effectiveness

- Nature: Few climate-adaptive MPAs exist to provide evidence on which approaches work best
- Impact: Could lead to ineffective conservation investments
- Mitigation: Implement experimental approaches with robust monitoring to generate evidence while learning from terrestrial protected area experiences

Key Partners

Data Providers

- FishMIP contributors (global marine ecosystem models)
- NOMEME (North Pacific Ocean Marine Ecosystem Model Ensemble)
- PICES (North Pacific Marine Science Organization)
- NOAA (oceanographic and fisheries data)
- OBIS/GBIF (biodiversity data repositories)
- National fisheries research institutions around the North Pacific
- International Year of the Salmon program

Knowledge Contributors

- University research labs studying climate impacts on marine systems
- IPCC Working Group II contributors
- NGOs focused on marine conservation (e.g., Ocean Conservancy, WWF)
- Indigenous knowledge holders around the North Pacific

Implementation Partners

- GIS specialists and spatial conservation planning experts
- Regional Fisheries Management Organizations in the North Pacific
- UN Environment Programme Regional Seas Programme
- BBNJ Secretariat (once established)
- Software developers for conservation planning tools

End Users

- Regional Fisheries Management Organizations
- National conservation and fisheries management agencies
- BBNJ Conference of Parties (once treaty enters into force)
- Conservation NGOs implementing protected area projects
- Marine spatial planners in North Pacific nations

APPENDIX B: KNOWLEDGE NETWORK TECHNICAL FRAMEWORK

This appendix provides technical specifications for the knowledge network infrastructure that will integrate environmental, ecological, and socioeconomic data across the North Pacific region. It expands upon the layered architecture described in the main document, offering comprehensive information on data standards, integration protocols, analytical methods, and user interface approaches. This technical framework ensures that our knowledge network can effectively connect diverse information sources while maintaining flexibility to evolve with changing needs and technologies.

Our knowledge network infrastructure is built on a layered architecture that enables flexibility while ensuring interoperability:

Data Layer

- Federated Repository System: Connects existing data / information systems while respecting ownership and data sovereignty
- Metadata Registry: Central catalog of available data with standardized descriptors
- Data Processing Pipeline: Standardization, quality control, and transformation services
- Storage Infrastructure: Combination of distributed and centralized systems for efficiency

Integration Layer

- Semantic Framework: Ontologies and knowledge models that enable cross-domain integration
- API Management: Standardized interfaces for programmatic data access
- Authentication System: Unified access control respecting data sharing agreements
- Workflow Engine: Tools for creating reproducible analysis processes

Analysis Layer

- Statistical Tools: Standard and specialized analytical capabilities
- Modeling Framework: Support for multiple model types with standardized inputs/outputs
- Machine Learning Platform: Pattern recognition and predictive capabilities
- Visualization Engine: Interactive data exploration and presentation tools

User Layer

- Web Portal: Primary interface for users with role-based views
- Decision Support Applications: Specialized tools for management applications
- Mobile Access: Field-accessible capabilities for researchers and managers
- Collaboration Tools: Forums, workshops, and co-creation spaces

Conceptual Foundations

The technical architecture is supported by conceptual frameworks that ensure meaningful integration of diverse knowledge:

1. Data Integration Model - Defines relationships between diverse data / information types using unified schema and domain-specific ontologies
2. Quality Control Framework - Establishes protocols for data validation, standardization, and uncertainty quantification
3. Methodological Approach - Defines statistical and analytical methods for integrating and analyzing diverse data types across domains and scales
4. Predictive Modeling Guidelines - Establishes best practices for model selection, training, validation, and ensemble approaches

This multi-layered approach ensures the knowledge network can evolve over time while maintaining core functionality and accessibility for diverse users across the North Pacific region. The infrastructure will support integration of data across multiple domains, including oceanographic conditions, climate patterns, ecological interactions, fisheries dynamics, and human dimensions.

The knowledge network will prioritize key environmental data and transboundary species and ecosystems information, including but not limited to Pacific salmon, small pelagics, groundfish, highly migratory species, and cephalopods. This broad approach enables comprehensive ecosystem understanding while recognizing the interconnected nature of marine systems.

For comprehensive technical specifications, implementation strategies, and governance framework details, please refer to the "North Pacific Ocean Knowledge Network: A Framework for Integrated Ocean Knowledge" document.

APPENDIX C: BUILDING BECI

BECI has undertaken strategic engagement activities to build the foundation for our knowledge network. These efforts have focused on establishing key partnerships and identifying priority knowledge needs across the North Pacific region.

Scientific and Technical Workshops

We have conducted multiple targeted workshops bringing together experts from across disciplines and national boundaries:

- Salmon Knowledge Modelling Workshop (March 2025, Vancouver, BC) – Gathered 60 professionals to develop knowledge modelling approaches for integrating salmon escapement data, creating shared ontologies for cross-organizational data sharing.
- Multinational Ecosystem Model Ensemble Workshop (October 2024, Hawaii) – Convened 28 ecosystem modelling specialists and Regional Fisheries Management Organization members to discuss ecosystem model ensembles in the North Pacific region and potential protocol development.
- BECI Knowledge Network Planning Workshop (March 2023, Victoria, BC) - Convened 30 scientists in climate and fisheries modelling, ocean monitoring, fish ecology, and data systems from Canada, United States, Russia, South Korea and Japan to develop a draft Science Plan Outline and establish the framework for cross-regional knowledge integration.
- BECI Knowledge Network Introductory Workshop Series (Spring 2022, Virtual) – Engaged 35 experts from across the Pacific Rim to identify knowledge gaps in ocean monitoring, modelling, and data integration and to establish priority areas for the BECI initiative's focus.

Stakeholder Consultations & Partnerships

To ensure our knowledge network meets diverse stakeholder needs, we have:

- Conducted engagement with fisheries management representatives from Canada, United States, Japan, Korea, and Russia
- Initiated engagement with Indigenous organizations in Alaska, British Columbia, and Washington
- Established relationships with key organizations including PICES, NPAFC, GOOS, IOOS, NASA, NOAA, and PSMFC

Network Development Achievements

Building on these engagement activities, we have:

- Created an initial "Who's Doing What Where" database for the North Pacific
- Joined multiple PICES working groups to leverage existing structures
- Drafted a framework for diverse data source integration
- Established working relationships with data providers across multiple countries
- Developed an Indigenous Engagement Strategy
- Developed seven strategic use cases that operationalize BECI's core objectives of integrated knowledge synthesis, transdisciplinary collaboration, and adaptive ecosystem management, demonstrating the network's approach to bridging scientific, traditional, and local knowledge systems

These activities have directly informed our strategic planning, ensuring BECI addresses real-world priorities while building on existing capabilities. Moving forward, we will continue expanding engagement with particular emphasis on deepening relationships with Indigenous partners and industry stakeholders.

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