DFO Climate Change Science Community Needs Evaluation 2025

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Fisheries and Oceans Canada
National Capital Region
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Science Branch
National Capital Region
Climate Change and Aquatic Conservation Division
Fisheries and Oceans Canada
200 Kent St.
Ottawa, Ontario, K2P 2J8

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Table of Contents

ABSTRACT

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Demand is increasing for science advice to support the inclusion of climate change considerations in decision making at Fisheries and Oceans Canada (DFO). In response, DFO's Climate Change Science community gathered on March 19, 2025, to discuss science and cross-sectoral needs related to departmental climate change risks stemming from changes such as shifting species distributions, ecosystem degradation, and sea level rise. The needs identified were further discussed and refined in subsequent discussions. Key needs identified include stabilizing, strengthening, and increasing efficiency of observations and documenting climate change trajectories, extremes, and impacts; advancing high-resolution climate models; advancing research to support the understanding of climate change impacts; developing species distribution models, ecosystem models, and interdisciplinary assessments (vulnerability, risk, and cumulative impacts); synthesizing existing tools; and translating science into accessible, and easy-to-use formats for decision makers. While the majority of needs (n = 56) fall within the purview of the Ecosystems and Oceans Science Sector, 43 (including strengthening the science-policy-management interface and leverage partnerships to tackle cross-cutting climate issues) necessitate cross-sectoral (n = 29) or interdepartmental (n = 14) collaboration. This report provides a foundation for strategizing and prioritizing science activities and their mobilization into decision making to build a more climate-resilient DFO, allowing better support for Canadian aquatic ecosystems, species, communities, infrastructure, and industries through ongoing environmental change.

RÉSUMÉ

Stortini, C.H., Lamarche, M.-C., Ong, J.Y., Capelle, D., Chassé, J., Chu, C., Dauphin, G.J.R., Greenan, B., Gurney-Smith, H., Lavoie, D., Lizotte, M., Maillet, G., Mckindsey, C., Niemi, A., Pearce, C., Peña, A., Penney, J., Shackell, N., Small, D., Steiner, N., Sutton-Pande, V., and Wan, D. 2025. DFO Climate Change Science Community Needs Evaluation 2025. Can. Tech. Rep. Fish. Aquat. Sci. 3734: v + 49 p. https://doi.org/10.60825/ne61-zj14

La demande en matière de science liée aux changements climatiques pour soutenir la prise de décision au ministère de Pêches et Océans Canada (MPO) est en pleine expansion. En réponse à cela, la communauté scientifique du MPO spécialisée dans le changement climatique s'est réunie le 19 mars 2025 pour discuter des besoins scientifiques et intersectoriels liés aux risques que posent les changements climatiques pour le ministère, notamment la modification de la répartition des espèces, la dégradation des écosystèmes et l'élévation du niveau de la mer. Les besoins identifiés ont été examinés plus en détail et affinés lors de discussions ultérieures. Les principaux besoins identifiés sont les suivants: stabiliser, renforcer et accroître l'efficacité de l'observation et de la documentation des trajectoires, des phénomènes extrêmes et des impacts du changement climatique; faire progresser les modèles climatiques en haute résolution; faire avancer la recherche afin de mieux comprendre les impacts du changement climatique; développer des modèles de répartition des espèces, des modèles écosystémiques et des évaluations interdisciplinaires (ex, vulnérabilité, risques et impacts cumulatifs); synthétiser les outils existants; et traduire les données scientifiques en formats accessibles et faciles à utiliser pour les décideurs. Si la majorité des besoins (n = 56) relèvent du secteur des sciences des écosystèmes et des océans, 43 d'entre eux (notamment pour renforcer l'interface entre la science, la politique et la gestion ainsi que de tirer profit des partenariats afin de s’attaquer aux enjeux climatiques transversaux) nécessitent une collaboration intersectorielle (n = 29) ou interministérielle (n = 14). Ce rapport fournit une base pour élaborer des stratégies et établir des priorités en matière d'activités scientifiques et leur mobilisation dans la prise de décisions afin de rendre le MPO plus résilient aux changements climatiques. Cela permettra de mieux soutenir les écosystèmes aquatiques, les espèces, les communautés, les infrastructures et les industries canadiennes dans un contexte de changement environnemental continu.

1. Introduction

In response to the increasing requests for climate change-related science information to support decision making in Fisheries and Oceans Canada (DFO), the Climate Change Science community met on March 19, 2025 to examine key science needs to address previously identified and presently relevant departmental climate change risks (see Table 1), with the aim of guiding strategic direction in climate change science and its use across sectors. The process builds on previous departmental assessments linked to climate change (see section 2.1 Building on the Past).

This report summarizes the meeting outcomes and the extensive discussions that followed. To provide context for the reader, section 1 introduces the issue of climate change in the oceans and other aquatic environments, how DFO has invested in understanding and responding to it to date, and the context that drove the need for the work documented in this report. Past work (Interis Consulting Inc. 2005; DFO 2013a,b,c,d) to characterize the risks climate change poses to the success of DFO's regulation and ocean management activities, and the science needed to address those risks are summarized in section 2, followed by an in-depth overview of the outcomes of the March 19th meeting and follow-up discussions, during which previously identified needs (to address risks) were refined and expanded upon. The report concludes by framing these needs within the context of strategic climate change science planning and cross-sectoral collaboration for enhanced departmental climate change resilience.

1.1 Background

Canada's marine and freshwater ecosystems are already changing due to a combination of climate change and other human pressures (Greenan et al. 2019a). Climate change is manifesting in many ways including warmer water temperatures, acidification, oxygen depletion, rising sea levels, reduced sea ice cover, and increased frequency and severity of extreme events such as coastal flooding and marine heat waves (Fox-Kemper et al. 2021; IPCC 2023). Higher water temperatures and reduced dissolved oxygen are impacting aquatic species survival, metabolism, growth, and reproduction (Pörtner & Knust 2007; Pörtner & Farrell 2008; Pörtner & Peck 2010), distributions (Cheung et al. 2009; Pinsky et al. 2013; Shackell et al. 2014), productivity (e.g., Szuwalski et al. 2023), timing of life-cycle events (Brickman & Shackell 2024), interactions (Lord et al. 2017), and the overall structure and function of ecosystems (Hastings et al. 2020; Irvine et al. 2025). Ocean acidification is changing ocean carbonate chemistry, making it more difficult for many marine organisms to maintain metabolism (Lannig et al. 2010; Thor et al. 2022), regulate physiological processes (Esbaugh 2018; Reid et al. 2019; Shi & Li 2024), and perform energetically demanding processes such as calcification (Hofmann et al. 2010; Gurney-Smith et al. 2018). Rising sea levels contribute to an increase in extreme water levels during storms (Zhai et al. 2019), leading to more damage to shorelines and coastal infrastructure (Greenan et al. 2015; Greenan et al. 2018), and harm to coastal ecosystems (Feagin et al. 2005; Von Holle et al. 2019). Reduced sea ice cover affects transportation (Pizzolato et al. 2014; Aksenov et al. 2017), vessel safety (Eiken & Mahoney 2015; Bitner-Gregersen et al. 2018; Gudmestad & Bai 2020), sea ice habitat, and ecosystem dynamics. These changes are expected to continue to at least 2050 if current global greenhouse gas emissions are significantly reduced, or to intensify if global emissions increase or remain constant (Turner et al. 2020; Talukder et al. 2022; IPCC 2023; Hodapp et al. 2023). Climate change mitigation and adaptation actions within marine and freshwater environments are necessary to protect the health and resilience of aquatic ecosystems, fisheries/aquaculture, and coastal communities, and these actions must be informed by sound science.

DFO's Aquatic Climate Change Adaptation Services Program (ACCASP) was originally established in 2011 with funding set to end in 2017. Since 2017, an ongoing annual budget of $3.5 million has been allocated for the continuation of ACCASP. Since its inception, the program has aimed to support research on the multifaceted impacts of climate change on fisheries/aquaculture, ecosystems, and coastal infrastructure, guided by three areas of focus:

- **Changing ocean chemistry (previously (2011-2016) focused solely on Ocean Acidification):** This priority involves collection of ocean chemistry data to assess the current extent and projected expansion of ocean acidification and hypoxia, and research to improve understanding of the interaction of ocean acidification and hypoxia with other climate stressors and conditions (temperature, ocean circulation, freshwater input) and their impacts on marine organisms.
- **Vulnerability of fisheries, aquatic ecosystems, and coastal infrastructure:** ACCASP dedicates resources to study the vulnerability of fisheries, aquatic species and ecosystems, and coastal infrastructure to climate change.
- **Applied ocean models:** This priority involves refining ocean-climate models to enhance the accuracy and reliability of forecasting future ocean conditions, facilitating a nuanced understanding of possible future changes in key parameters such as temperature, water currents, oxygen, carbon compounds, and pH.

Through ACCASP, several climate change adaptation tools and frameworks have been produced, including, but not limited to the Canadian Extreme Water Level Adaptation Tool (CAN-EWLAT); Large Aquatic Basins (LABs) Risk Assessment in Pacific, Arctic, Atlantic, and Inland Freshwater (DFO 2013a,b,c,d); Risk Equivalency Decision-support Framework (Roux et al. 2022); Coastal

Infrastructure Vulnerability Index (Greenan et al. 2018); and Lobster Vulnerability Assessment (Greenan et al. 2019b).

Outside of ACCASP, DFO Science also produces "State of the Ocean" reports that describe the current status and trends in one of Canada's three oceans per year, relying on insights from climate change research, monitoring, and modelling activities. Similarly, several other science programs (*e.g.*, Marine Conservation Targets, Species At Risk, Freshwater Habitat Initiative) are exploring the complexities of considering climate change in their work. Overall, DFO is experiencing a growing interest and requests for support from various sectors (*e.g.*, Strategic Policy), programs (*e.g.*, Marine Conservation Targets), stakeholders (*e.g.*, fisheries), and rights holders (*e.g.*, Indigenous communities) in integrating climate change considerations into their planning and decision-making processes. In particular, there is a growing interest in Canada to advance climate change adaptation action to enhance resilience in the ways we interact with aquatic environments, ecosystems, and species.

In 2017, an audit report titled "Adapting to the Impacts of Climate Change" (Office of the Auditor General of Canada 2017) examined the extent to which Canadian federal organizations had made progress in adapting to climate change. The audit recognized DFO as one of the five federal departments that completed comprehensive risk assessments and integrated adaptation into their programs and activities. The ACCASP, along with the risk assessments (see section 2.1) that the program produced, were key factors contributing to this recognition. While acknowledging these successes, the audit underscored remaining needs for action, emphasizing that the cost of inaction would far exceed the cost of proactive measures. It called on federal departments to actively manage climate-related risks to ensure they can effectively deliver on their mandates.

Between August 2019 and January 2020 an "Evaluation of the Aquatic Climate Change Adaptation Services Program (ACCASP)" (DFO 2020a) was conducted by DFO's Evaluation Division in accordance with the Policy on Results (Treasury Board of Canada Secretariat 2016), including all DFO regions, and covering a period of four years from 2016-2017 to 2019-2020. The evaluation determined that, as the only dedicated federal source of aquatic climate change science to inform decision making in support of climate change adaptation efforts, ACCASP was not well equipped in funding or capacity to respond to growing emerging needs and pressures. The top impediments listed were: continuously increasing ACCASP responsibilities within program-specific activities while program resources have remained unchanged; increasing involvement by ACCASP staff in activities driven by the broader climate change context (refer to the 2020 evaluation above for details; DFO 2020a), which exceeds the current program mandate and is clearly beyond the program's original design; and insufficient communication of ACCASP science outputs to influence decision making.

The evaluation called for the Department to develop a long-term strategy to address climate change challenges in a holistic and coordinated manner.

Also in 2020, Environment and Climate Change Canada (ECCC) led development of a report entitled "Advancing Science and Knowledge on Climate Change" (ECCC 2020), which led to the publication of "National Priorities for Climate Change Science and Knowledge" (ECCC 2024). Both reports highlight the assertion of the United Nations Framework Convention on Climate Change (UNFCCC) that *"Science provides the evidence and data on the impacts of climate change, but it also gives us the tools and knowledge as to how we need to address it. (...) We are now clearly in the era of implementation, and that means action. But none of this can happen without data, without evidence to inform decisions, or the science that supports programs and policies"*. The UNFCCC outlined foundational capacity needs for knowledge synthesis and mobilization at the science-policy interface, monitoring and observations, digital and data infrastructure (including high-performance computing and tools to manipulate and visualize data), open science, national coordination, and international engagement. Following from these foundational capacity needs, the reports then outlined needs for holistic science to better understand Earth's climate system, climate extremes, and carbon cycles and storage, as well as the impacts of climate change on infrastructure, natural resources, human health and well-being, species, and ecosystems. These needs are relevant across all government departments and are reflected in the needs outlined below in section 2 of this technical report.

2. National Climate Change Science Community Needs Evaluation 2025

To initiate a holistic and collaborative approach to advancing and prioritizing climate change-related work in DFO, DFO's Domestic Ocean Adaptation Policy (DOAP; Strategic Policy Sector) and Climate Change Science (CCS; Ecosystem and Ocean Science Sector) teams have established a process to assess departmental climate change-related science needs, i.e., gaps in knowledge, capacity, or materials, that should be filled to more effectively support decision making. The first step in this process was to identify and prioritize cross-cutting climate change-related science needs that could be addressed via strategic science planning and/or cross-sectoral collaboration. This report provides a foundation for subsequent cross-sectoral discussions by outlining science and other sectoral needs identified by climate change experts to address climate change risks in a holistic manner across all levels of DFO science and governance, ultimately supporting climate-resilient decision making in the department (Figure 1).

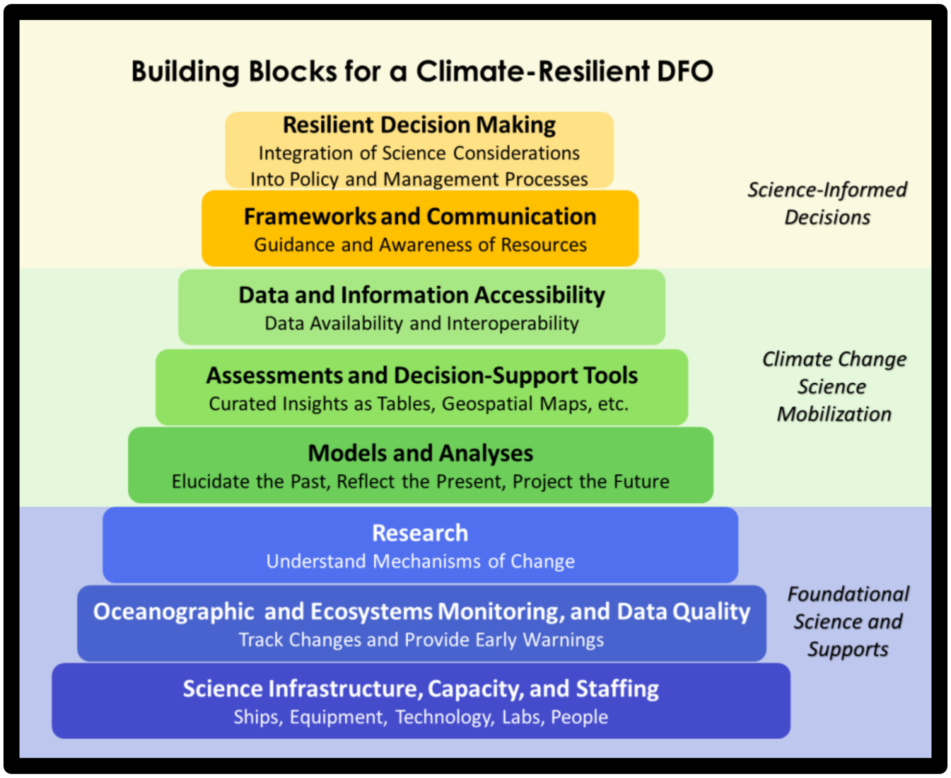

Figure 1. A schematic conceptualization of climate change science in a holistic sense, such that the upper tiers of the "pyramid" are dependent on human resource and infrastructure capacity, monitoring, research, and, subsequently, modelling. Decision-support tools, accessible and communicable science, and, ultimately, mobilization of science into decision making would not be possible without the base of the climate change science pyramid.

2.1 Building on the Past

The March 19, 2025 needs evaluation meeting was held to establish a foundation of climate change-related needs for future discussions using information from previous assessments. This was accomplished through refining and updating needs previously identified through:

1) The 2005 "Climate Change Risk Assessment for Fisheries and Oceans Canada" report (Interis Consulting Inc. 2005), which identified six broad climate change risks (Table 1) relevant to DFO's mandate, grouped into two overarching categories of departmental concern related to ecosystems and operations/infrastructure,
2) A series of CSAS processes in 2013 (DFO 2013a,b,c,d) titled "Risk-Based Assessment of Climate Change Impacts and Risks on the Biological Systems and Infrastructure within Fisheries and Oceans Canada's Mandate" for each of the Pacific, Arctic, Atlantic, and inland Freshwater Large Aquatic Basins(LABs); participants and contributors (hereafter collectively referred to as "participants") described core climate change risk drivers, potential consequences or threats, opportunities, and knowledge gaps for each of six identified Departmental climate change risks (see Appendix 1: Summary of Departmental Threats

Associated with Climate Change Risks Identified through 2013 Large Aquatic Basin Risk Assessments for list of departmental threats associated with risks identified in Table 1), and

3) A subsequent informal 2022 ACCASP Climate Change Science Needs Analysis process conducted through the National ACCASP Working Group, during which knowledge gaps and needs from the 2013 Risk Assessments were validated and expanded upon.

Table 1. A summary of the departmentally relevant core risks identified in the 2005 Climate Change Risk Assessment for Fisheries and Oceans Canada and further defined regionally through the 2013 Canadian Science Advisory Secretariat (CSAS) process titled "Risk-Based Assessment of Climate Change Impacts and Risks on the Biological Systems and Infrastructure within Fisheries and Oceans Canada's Mandate" for each of the Pacific, Arctic, Atlantic, and inland Freshwater Large Aquatic Basins (LABs).

Risk Category	Risk	Description
Ecosystem & biological risks	**Risk 1:** Ecosystem and Fisheries Degradation and Damage	Impacts on DFO's ability to steward the management and protection of fish habitats, lead Canada's Ocean Strategy, and promote the sustainability of oceans and their resources.
	Risk 2: Changes in Biological Resources	Shifts in the distribution and productivity of DFO's managed resources (fish stocks, shellfish, and marine mammals) *e.g.*, those managed under the *Fisheries Act*.
	Risk 3: Species Reorganization and Displacement	Altered distribution of species and restructuring of ecological communities in Canadian aquatic habitats, which could result in the introduction or spread of invasive aquatic species, as governed by the *Species at Risk Act*.
Operational & infrastructure risks	**Risk 4:** Increased Demand to Provide Emergency Response	Increased marine incidents linked to climate change, potentially straining the Canadian Coast Guard's (CCG was previously under the same ministry as DFO, but moved to Canada's Department of National Defense in 2025) capacity to respond.
	Risk 5: Infrastructure Damage	Impacts on DFO's extensive infrastructure, which supports operational and scientific activities in marine and freshwater environments, including buoys, slipways, labs, navigation aids, small craft harbours, and aquaculture facilities.
	Risk 6: Changes in Access and Navigability of Waterways	Impeded access caused by changes in sedimentation, water levels, severe weather, wave energy, icebergs, and sea ice.

Participants of the March 19, 2025 meeting and contributors to subsequent discussions included regional members of the National Climate Change Science Sub-Committee and Ocean Chemistry Working Group coordinated by the National Capital Region (NCR) CCS team (see Appendix 2: Participants and Contributors to this). Their involvement helped ensure that the resulting list of science needs accurately reflected the expertise of DFO's climate change science community across regions, specifically the community of scientists whose work focuses entirely, or almost entirely, on climate change in aquatic environments. Participants were also encouraged to consult with their regional colleagues. The goal was to develop a comprehensive, well-structured, and targeted list of science needs to advance actions addressing the six core risks to DFO's mandate (Table 1). This could also serve as a solid foundation for productive, strategic follow-up discussions with other Science programs and management sectors. For consistency, the identified needs were organized according to four predetermined science themes (Monitoring, Modelling, Research, and Knowledge Mobilization) and categorized by the type of climate change-related risk they address ("Ecosystem & biological Risks" and "Operational & infrastructure Risks" as described in Table 1; also see Appendix 1: Summary of Departmental Threats Associated with Climate Change Risks Identified through 2013 Large Aquatic Basin Risk Assessments for more detailed descriptions of the threats to DFO's mandate and activities presented by these risks, as defined during the 2013 CSAS processes).

2.2 Meeting and Discussion Outcomes: Climate Change Science Needs

At the March 19th meeting, as a first step, climate change-related science needs that were previously identified (n = 79) through the 2013 Large Aquatic Basin Risk Assessments (DFO 2013a,b,c,d) and the 2022 informal ACCASP needs assessment process were reviewed. Of these 79 needs, 15 were removed due largely to a lack of clear linkage to climate change, DFO's mandate, or DFO science activities (see Figure 2 below; see Appendix 3: Needs Removed for a list of needs removed). During subsequent discussions, the remaining 64 needs were further reviewed, and additional needs arising from advanced scientific understanding of climate change impacts, remaining uncertainties, and emerging issues like increasing pressure to advance mitigation activities were identified. Hereafter, existing needs that required only minor updates are classified as "*continuing*," while existing needs that were substantially expanded upon during the discussions, along with the newly identified needs, are classified as "*emerging*."

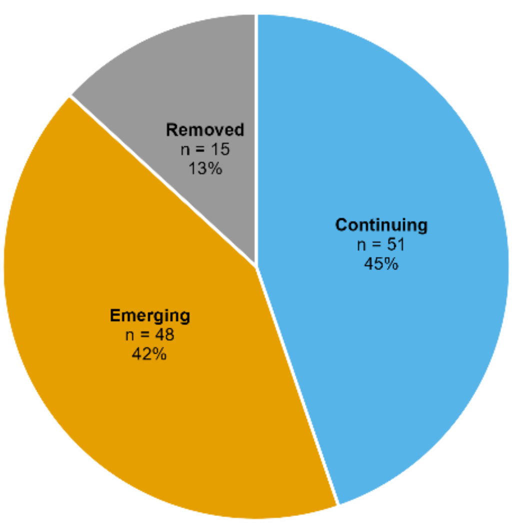

Figure 2. Pie chart depicting a total of 114 climate change-related science needs evaluated during the March 19, 2025 Climate Change Science Needs Evaluation meeting. Segments of the pie represent the percentage of those needs that were (1) new needs not previously identified or needs that have expanded in detail or scope ("*Emerging*"), (2) previously identified from the 2013 CSAS processes and a 2022 Climate Change Science Needs Assessment process that are considered still relevant ("*Continuing*"), and (3) previously identified from the 2013 CSAS processes and a 2022 Climate Change Science Needs Assessment process but removed due to a lack of clear linkage to climate change or DFO's mandate ("Removed"; see Appendix 3 for list of needs removed). This report discusses the 99 e*merging* and co*ntinuing* needs.

In total, 99 climate change-related needs relevant to DFO were selected and documented (see Figure 3 below; and Appendix 4: Needs and Their Associated Risk Categories for the full list of needs). These needs fall within three categories:

i. Fisheries and Oceans Canada's Ecosystems and Oceans Science Sector (DFO-EOS) needs – within the roles and responsibilities of DFO-EOS and could be addressed through strategic science planning and operational science activities within the sector;
ii. Cross-sectoral needs – Outside DFO-EOS's direct responsibilities but could be addressed by other DFO sectors in collaboration with DFO-EOS;
iii. Cross-departmental needs – Outside DFO's jurisdiction but relevant to advance DFO-EOS mandates; would require action by other federal departments, either independently or in collaboration with DFO.

Details on the *continuing* and *emerging* needs that fell outside the jurisdiction of DFO-EOS and/or DFO can be found in the grey sections of Tables 2-5 and in the discussion in section. It was also noted that several broad DFO departmental pressures cannot be addressed by the activities of DFO-EOS operational science staff nor through cross-sectoral collaboration, but impact the ability of DFO-EOS to conduct science and address science needs. These included limited data management, monitoring, and oceanographic modelling capacities, in addition to strained human resource capacity.

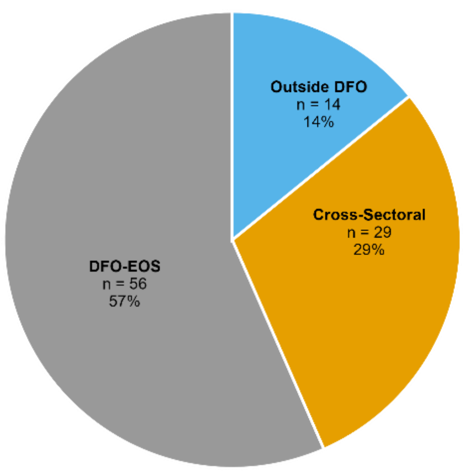

Figure 3. Pie chart depicting the 99 ongoing (*continuing* and *emerging*) climate change-related science needs identified. Segments of the pie represent the percentage that fell: (1) within the roles and responsibilities of Fisheries and Oceans Canada's Ecosystems and Oceans Science Sector (DFO-EOS, n= 56; 27 *continuing* and 29 *emerging*), (2) outside the roles and responsibilities of DFO-EOS but could be addressed by other DFO sectors (Cross-Sectoral, n=29; 15 *continuing* and 14 *emerging*), and (3) outside the jurisdiction of DFO (n=14; 9 *continuing* and 5 *emerging*).

Continuing and *emerging* needs were organized based on whether they addressed **ecosystem & biological risks** or **operational & infrastructure risks** (as in Table 1), and according to four science themes: (1) **monitoring**: Strengthening oceanographic and ecosystem monitoring and investments in technology; (2) **modelling**: Advancing model development and output accessibility; (3) **research**: Expanding ecological/biological research and tool development; and (4) **knowledge mobilization**: Empowering climate action and climate-smart decisions (e.g., for fisheries, aquaculture, coastal infrastructure, habitat restoration, conservation planning, etc.) through knowledge mobilization.

The majority of needs that could be addressed through DFO-EOS science activities fell under the theme of **monitoring** (n = 21; 37%), followed closely by **research** (n = 18; 32%), with fewer under the themes of **modelling** (n = 10; 18%) and **knowledge mobilization** (n = 7; 13%) (Figure 4). Of the 21 EOS needs identified that fell under the **monitoring** theme, 11 were *continuing* and 10 were *emerging*, reflecting participants' concerns regarding the feasibility of monitoring to address emerging issues within the current budget, and their suggestions that new technologies and data streams could be better leveraged to enhance productivity and ensure existing monitoring programs are not diminished. Under the **modelling** theme, 4 needs were *continuing* and 6 were *emerging*, suggesting that investment is needed to build on previous work and innovate in this field. Under the **research** theme, fewer needs were *continuing* (n = 7) relative to *emerging* (n = 11), indicating that, while some fundamental questions remain to be answered, the evolving nature of climate change demands ongoing investment into research to answer new questions, building on a growing knowledge base (Figure 4). Fewer *continuing* (n = 5) and *emerging* (n = 2) needs under the **knowledge mobilization** theme falling within the jurisdiction of DFO-EOS potentially implied slower growth in this area; however, the majority of **knowledge mobilization** needs overall (n = 15) fell under the jurisdiction of other DFO sectors outside of EOS, requiring cross-sectoral collaboration (see section 2.3).

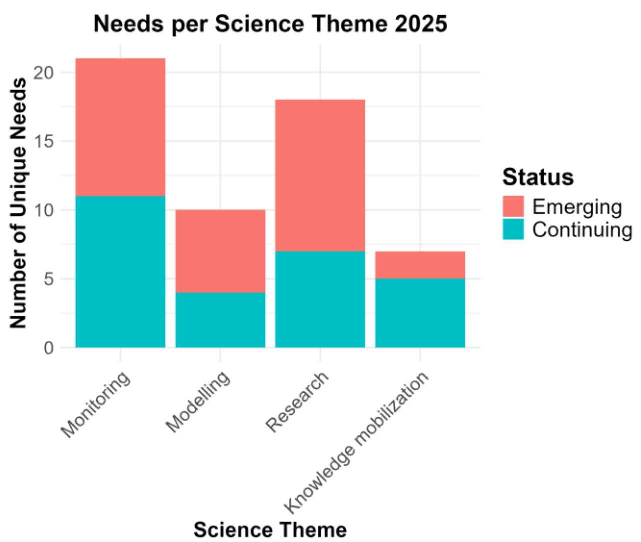

Figure 4. Bar chart depicting the number of *continuing* and *emerging* needs identified under each of four science themes through the 2025 Climate Change Science Needs Evaluation meeting and subsequent discussions that fall within the roles and responsibilities of DFO's Ecosystems and Oceans Science sector.

The following subsections summarize all *continuing* and *emerging* climate change-related science needs identified during the March 19, 2025 meeting and subsequent discussions and are organized by science themes as described above. Tables containing the full list of needs for each of the two risk categories are provided in each sub-section and the subsections are labelled and ordered according to the four overarching science themes. Needs that could be addressed through DFO-EOS science activities are listed first, while needs that fall within the jurisdiction of other DFO sectors or other federal departments are listed second.

2.2.1 Monitoring: Strengthening oceanographic and ecosystem monitoring and investments in technology

In summary, a clear need was identified for sustained and enhanced observation and documentation of climate change trajectories, extremes, impacts, and vulnerabilities. Observational data gaps were highlighted in freshwater and Arctic regions in particular, and for a broad range of environmental variables relevant to address both ecological and operational risks categories. The need for investments in monitoring technologies to improve spatiotemporal coverage and efficiency of monitoring programs was also identified.

Strengthening oceanographic and ecosystem monitoring and investments in technology would improve monitoring efficiency, reduce uncertainty of oceanographic and ecological models through enhanced validation, support a deeper understanding of ocean conditions, and improve early detection of acute changes.

Monitoring changes in Canada's oceans and aquatic environments is a priority for DFO. The department systematically monitors essential climate and ecosystem variables annually through regional oceanographic monitoring programs (*e.g.*, Atlantic Zone Monitoring Program, Pacific Line P Monitoring Program, and others) and ecosystem surveys (*e.g.*, Maritimes Region Ecosystem Survey and Pacific Region Integrated Pelagic Ecosystem Survey; Clark et al., 2021; King et al. 2025). DFO also supports Continuous Plankton Recorder monitoring programs in both Atlantic and Pacific oceans. ACCASP contributes annual funding to each region to monitor ocean chemistry and assess its impacts on marine organisms. Additionally, oceanographic and ecosystem properties are regularly monitored over a specific period or ad hoc in key areas through national science programs and funding initiatives like the National Monitoring Fund, Coastal Environmental Baseline Program, and Marine Conservation Targets Program. These efforts form a vital part of DFO's broader monitoring activities and contribute to its ability to detect and respond to climate-driven shifts in aquatic ecosystems; however, continued adaptation and enhancement of these programs will be necessary as climate change evolves.

To address **ecosystem & biological risks** associated with climate change (Table 2), *continuing* needs included the need to assess the effectiveness of climate-adaptive management actions such as managing shifting fisheries or establishing conservation areas, and to obtain baseline data for important species including Species at Risk (SAR), Aquatic Invasive Species (AIS), and habitat-forming species (*e.g.*, eelgrass meadows, kelp forests, and deep-sea coral and sponge beds). The *continuing* needs to track distribution shifts of species of ecological importance and maintain ecosystem monitoring to support ecosystem assessments and modelling were highlighted. Participants also noted *continuing* needs for sustaining and enhancing annual monitoring of ocean chemistry and to ensure sustainability and equal monitoring capacities across regions. *Emerging* needs included strengthening in-house analytical capacities and capabilities (*e.g.*, taxonomy, ocean/carbonate chemistry), expanding monitoring of essential climate variables (*e.g.*, temperature, salinity, dissolved oxygen, and pH), expanding monitoring of environmental conditions and biodiversity in freshwater ecosystems, and standardizing methods to monitor climate change impacts on marine conservation objectives.

For **operational & infrastructure risks**, *continuing* monitoring needs included sustaining sea-level change monitoring through the DFO Canadian Hydrographic Service (CHS) national tide gauge network, improving coastal mapping, dynamic charting, and real-time observations, and investing in a Canadian Arctic observation network. *Emerging* needs included improving monitoring of physical oceanography in high-risk shipping areas, implementing seasonal environmental monitoring to support emergency response, and developing and maintaining ocean observation stations to monitor key environmental and ecosystem parameters with near real-time data production.

For risks overlapping **both categories**, *continuing* needs included strengthening monitoring to fill baseline gaps for habitats and species of interest, sustaining long-term monitoring to determine local climate baselines and variability (*e.g.*, extremes, sea level, waves, storm frequency and strength), and stabilizing and improving existing core and long-term programs to include biological, chemical, nearshore, and coastal water monitoring. *Emerging* needs included investing in autonomous and real-time monitoring technologies for use during multi-species and oceanographic surveys, further developing community-led monitoring (including Indigenous contributions) to support adaptive planning for change—especially in the Arctic—enhancing seasonal oceanographic monitoring using autonomous technologies, and improving monitoring of the Arctic open-water season.

Needs requiring cross-sectoral and cross-departmental collaboration included strengthening interdepartmental and international cooperation to support monitoring related to marine Carbon Dioxide Removal (mCDR) activities, maintaining provincial partnerships on fish and aquatic habitat monitoring, and continuing support for SAR and AIS monitoring programs. Additional needs outside DFO-EOS jurisdiction included conducting baseline condition assessments for environmental emergency recovery planning and maintaining an inventory of real property holdings in freshwater environments to support climate change risk assessments. Interdepartmental engagement will be needed to increase land-water interaction monitoring (*e.g.*, nutrient fluxes, sediment transport, contaminants), monitor freshwater habitat, hydrography, and biodiversity (e.g., including seabirds and land-ocean mammals like Polar bears), and improve erosion and sediment monitoring in coastal zones.

Continued and improved long-term monitoring efforts are crucial for detecting changes in aquatic environments, enabling more informed emergency responses and planning for DFO's Real Property, Small Craft Harbours (SCH), and related maritime activities. These efforts also generate comprehensive data that reduce uncertainties in oceanographic and ecological models through validation, and offer accurate baseline knowledge. Continued data acquisition requires maintaining existing infrastructure while investing in new autonomous or otherwise more efficient monitoring technologies and techniques to optimize human resources and vessel time, and expanding spatiotemporal coverage. Addressing the monitoring needs outlined in this report would provide a solid foundation for all other climate change-related science and knowledge mobilization efforts in the department.

Table 2. A summary of the climate change-related science needs identified under the **monitoring** theme (Strengthening environmental monitoring and investments in technology) across all regions addressing the two risk categories*. Continuing* needs refer to needs identified in previous assessments that are still relevant today. *Emerging* needs refer to new needs reflecting the evolving nature of climate change science and broader needs associated with climate change mitigation and adaptation. Monitoring needs that fall outside the roles and responsibilities of DFO's Ecosystems and Oceans Science sector, which would require cross-sectoral or cross-departmental collaboration, are listed in grey at the bottom of the table.

Risk Category Addressed	Status	Need
Ecosystem & biological risks	Continuing	Assess the effectiveness of climate adaptive management actions (*e.g.*, management of shifting fisheries or conservation areas (e.g., Marine Protected Areas, Other Effective Area-based Conservation Measures, Marine Reserves, Fisheries Closures.).
		Obtain baseline data for important species, especially Species at Risk (SAR), habitat-forming species (*e.g.*, seagrass, kelps), deep-water ecologically-sensitive species (corals, sponges), and Aquatic Invasive Species (AIS; such as information on their range, habitat requirements and other ecological parameters).
		Track distribution shifts of ecologically important species (*e.g.*, commercial species, AIS, and SAR).
		Maintain ecosystem monitoring to support ecosystem assessments.
		Strengthen and stabilize monitoring on ocean chemistry to ensure long-term sustainability and equity among regions.
	Emerging	Strengthen in-house analysis capabilities (taxonomy, ocean/carbonate chemistry).
		Expand monitoring of essential climate variables across all regions, including temperature, salinity, dissolved oxygen, and pH (and impacts of changes).
		Standardize methods to monitor climate change impacts on marine conservation objectives.
Operational & infrastructure risks	Continuing	Maintain or expand monitoring of sea-level change with the DFO CHS national tide gauge network.
		Improve coastal mapping, dynamic charts, and real-time observations.
		Invest in Canadian Arctic network (nodes) of observation.
	Emerging	Improve monitoring of physical oceanography in high-risk shipping areas.
		Seasonal environmental monitoring to support emergency response.

		Develop and maintain a system of ocean observation stations to monitor key environmental and ecosystem parameters with (near) real-time data production.
Common across Ecosystem & biological risks and Operational & infrastructure risks	Continuing	Strengthen monitoring necessary to fill baseline gaps for habitat and species of interest, and identify climate change risks, impacts, and vulnerabilities.
		Sustained monitoring to determine local climate baseline and variability (*e.g.*, extremes, sea level, waves, storm frequency and strength) and to support modelling of environmental change and risk to infrastructure.
		Stabilize and improve existing core and long-term programs to include biological, chemical, nearshore, and coastal water monitoring.
	Emerging	Invest in autonomous/real-time technologies to monitor key environmental and ecosystem parameters during multi-species surveys and oceanographic surveys.
		Further develop community-led monitoring (including Indigenous contributions) to support assessment/adaptive planning for change, especially in the Arctic.
		Enhance seasonal oceanographic monitoring by leveraging autonomous technologies.
		Improve monitoring of the open-water season in the Arctic.

Jurisdiction	Need
Needs requiring cross-sectoral collaboration	• Strengthen Interdepartmental/International collaboration to support monitoring related to marine Carbon Dioxide Removal (mCDR) activities. • Strengthen ongoing partnerships with provincial agencies who lead fish and aquatic habitat monitoring programs within Operations and Policy sectors. • Continued support for SAR and AIS monitoring programs. • Baseline condition assessments for recovery planning in the context of environmental emergencies. • Inventory of Real Property holdings in freshwater environments to support climate change risks assessments.
Needs requiring interdepartmental engagement	• Increase land-water interaction monitoring (*e.g.*, nutrient fluxes, sediment transport). • Monitor freshwater habitat, hydrography, biodiversity. • Improve erosion and sediment monitoring in coastal zones.

2.2.2 Modelling: Advancing numerical model development and output accessibility

In summary, needs for ocean-climate model downscaling, scenario-based output product development, hydrodynamics modelling, and improved accessibility and visualization of model outputs are among the most pressing modelling-related needs discussed in this report (Table 3.). Overall, participants highlighted the need to further advance predictive oceanographic, biogeochemical, ecosystem and species distribution modelling to support proactive and adaptive decision making and management activities across multiple sectors addressing both ecological and operational/infrastructure-based risks.

Advancing these modelling efforts and accessibility of resulting outputs would lead to more accurate predictions and projections of ocean conditions, provide higher-resolution data for decision-support tools, and enhance the ability of DFO and coastal communities to anticipate changes in resources and coastal hazards for infrastructure and operations.

The development of numerical models supports our understanding how climate is changing, predicting future conditions, and assessing its implications for aquatic environments, ecosystems, and species. DFO modelling work includes predictive ocean-climate models (reviewed by Han et al. 2022), biogeochemical models (reviewed by Lavoie et al. 2025), ecosystem models (reviewed by Cogliati et al. 2025), and species distribution models (SDMs; *e.g.*, DFO 2020b; Czich et al. 2023; Nephin et al. 2023; Thompson et al. 2023; Cogliati et al. 2025), which analyse and predict conditions at different geographic scales (*e.g.*, local, regional, national, global) and temporal scales (*i.e.*, near-term forecasts, seasonal predictions, and decadal and climate projections). At appropriate scales, models can predict present-day and future climate change impacts relevant to support climate-adaptive and proactive resource management and governance. Since 2011, ACCASP has supported diverse ocean-climate modelling efforts through internal review processes, directed funds, DFO-NOAA (National Oceanic and Atmospheric Administration) collaborations, and DFO's Competitive Science Research Fund (CSRF). Previously identified modelling priorities have included refining ocean-climate/sea ice and biogeochemical models, extending model geographic scope and applications to targeted regions (as discussed in Lavoie et al. 2025), running simulations under various climate scenarios, and improving predictions and projections of water temperature, primary productivity, acidification, hypoxia, sea level, and species distributions. Other ocean modelling work (including hindcasting and forecasting ocean-climate conditions over shorter time frames) is managed through DFO's Ocean Sciences Branch in collaboration with ECCC (*e.g.*, through the Canadian Operational Network of Coupled Environmental Prediction Systems [CONCEPTS]). These modelling efforts contribute to DFO's ability to understand and anticipate climate-driven changes and inform proactive, science-based adaptation measures. Continued parameterisation refinements, downscaling, uncertainty reduction, expanded spatial coverage, new model development, and accessible outputs are required to keep pace with a changing climate and contribute to the advancement of global climate modelling efforts (*e.g.*, the Coupled Model Intercomparison Project (CIMP) overseen by the World Climate Research Program, outputs of which are provided in IPCC 2023).

To address **ecosystem & biological risks**, participants identified *continuing* needs to improve species distribution models and forecasting capabilities for key aquatic species, AIS, SAR, habitat-forming species such as kelps and seagrass, and harvested species (Table 3.). The goal is to project changes in their productivity, abundance, and spatial distribution in response to climate-driven pressures. Additionally, participants emphasized the importance of improving the spatial resolution (both horizontal and vertical) of biogeochemical and ecosystem models to ensure outputs are relevant and usable for decision-making at regional and local levels (particularly in nearshore areas). *Emerging* needs included the development of future scenario projection products derived from climate-scale physical, biogeochemical, and ecological models, and conducting climate vulnerability and risk analyses to understand how future environmental conditions, such as ocean warming, acidification (low pH), deoxygenation (low dissolved oxygen), and harmful algal blooms, will impact species, communities, and ecosystem carrying capacity.

Addressing **both ecosystem and operational & infrastructure risks**, participants highlighted *continuing* needs to maintain and improve capacities for climate-scale oceanographic projections and circulation models, including the need to update and downscale these models to finer spatial resolutions applicable to nearshore and regional planning. Additionally, continued development of extreme event prediction models and risk assessments, such as for floods, storm surges, and marine heatwaves, was identified as a priority. *Emerging* cross-cutting modelling needs focused on establishing formal feedback loops between observational data and model development, in order to support validation, improvement, and real-time applications of models. Participants also emphasized the importance of characterizing the predictive skill and uncertainty of oceanographic and drift models, especially as ocean circulation patterns shift due to climate change. Further, advancing both long-term climate projection models and shorter-term forecasting models was recommended to improve preparedness and response for coastal hazards, navigation, and emergency incidents. Lastly, enhancing accessibility of model outputs, particularly for scientists, managers, decision-makers, and the public, was identified as a key step for ensuring models inform timely and actionable climate responses.

Needs requiring interdepartmental engagement encompassed a broad suite of climate-driven modelling priorities, including coastal erosion and sediment transport in vulnerable shoreline areas, and continued investment in particle and drift modelling to support maritime safety, search and rescue, and environmental emergency response. Participants also identified gaps in climate-hydrography modelling in freshwater systems (*e.g.*, temperature and flow predictions), enhanced modelling of permafrost thaw and its ecosystem implications, and forecasting of vessel traffic and boater behavior in light of reduced sea ice and shifting circulation patterns, to support risk assessments for vulnerable and at-risk species, including AIS and SAR.

Collective advancements in modelling would enable more accurate predictions and projections of marine and freshwater conditions, including critical climate change impacts on aquatic resources, species, and ecosystems. Efforts towards advancing model development, evaluation, and verification to reduce uncertainty, downscaling, ensemble prediction, and output accessibility would result in improved predictive capabilities, reduced uncertainty, and user-friendly model outputs that transparently explain their limitations. These efforts would enhance DFO's ability to make proactive climate-smart decisions in fisheries, conservation, infrastructure, and operations, especially in high-risk areas like the Arctic and coastal communities.

Table 3. A summary of the climate change-related science needs identified under the **modelling** theme (Advancing ocean-climate model and output development) across all regions addressing the two risk categories. *Continuing* needs refer to needs identified in previous assessments that are still relevant today. *Emerging* needs refer to new needs reflecting the evolving nature of climate change science and broader needs associated with climate change mitigation and adaptation. Modelling needs that fall outside the roles and responsibilities of DFO's Ecosystems and Oceans Science sector, which would require cross-sectoral or cross-departmental collaboration are listed in grey at the bottom of the table.

Risk Category Addressed	Status	Need
Ecosystem & biological risks	Continuing	Species distribution models and forecasting of key aquatic species populations – such as Aquatic Invasive Species, ecologically important habitat-forming species like kelps and seagrass, species at risk, and harvested species – to project changes in their distribution, productivity, abundance, and/or biomass.
		Improve downscaling (*i.e.*, horizontal and vertical resolution) of biogeochemical and ecosystem models at relevant scales for decision making.
	Emerging	Develop future scenario projection products from climate-scale biogeochemical, physical, and ecological models at time scales relevant to management timelines.
		Conduct climate vulnerability/risk analyses of the impacts of future physical and biogeochemical conditions (*e.g.*, high temperature, low pH, low dissolved oxygen, harmful algal blooms) on carrying capacity and species/communities of interest.
Common across Ecosystem & biological risks and Operational & infrastructure risks	Continuing	Modelling, predictions, and risk assessments for extreme events.
		Keep climate-scale oceanographic model projections and ocean circulation models up-to-date and improve model projection downscaling at relevant scales for decision making (*e.g.*, near shore), including dynamical and statistical downscaling.
	Emerging	Enhance data management and intrasectoral communication to ensure observational data are readily available to support modelling efforts.
		Characterize the predictive skill and uncertainty of physical oceanography and drift models as circulation patterns evolve under climate change.
		Advance long-term climate projection models alongside forecasting (which may be more seasonal, annual) for ocean-climate, coastal hazards, navigation, and incident response, including floods, waves, and storm surges.

		Improve accessibility of model outputs to scientists, managers/decision makers, and the public.

Jurisdiction	Need
Needs requiring cross-sectoral collaboration	• Formalize cross-departmental partnerships for sharing modelling expertise, service provision, and data management responsibilities (*e.g.*, Memorandum of Understanding with ECCC). • Maintain and enhance partnerships with other agencies and academics conducting predictive hydrographic and ecological modelling in freshwater.
Needs requiring interdepartmental engagement	• Coastal erosion and sediment transport modelling in the coastal zone. • Continue support for particles and drift modelling is essential for ECCC, DFO, and CCG to improve predictive skill to support maritime safety, search and rescue, and environmental response as physical ocean conditions change. • Improve climate-hydrography modelling for freshwater (*e.g.*, predictions of warming and flow). • Improve modelling to understand permafrost thaw and implications for aquatic ecosystems. • Forecast traffic and boater behaviour (*e.g.*, in response to ice melt and changes in ocean circulation patterns) to support risk assessments for SAR and AIS.

2.2.3 Research: Expanding ecological research and tool development

In summary, continued research is essential to advance understanding of the impacts of climate change on species, ecosystems, fisheries, aquaculture, operations, and infrastructure (Table 4) Identified needs include integrated ecosystem assessments, improved predictions of complex climate effects, and expanded evaluation of the impacts of nature- and technology-based solutions on relevant species. Participants expressed a growing urgency to integrate science into decision making and develop tools that can support proactive and adaptative actions to improve the resilience of aquatic ecosystems and coastal infrastructure.

Expanding ecological research and tool development in these areas would yield a deeper mechanistic understanding of climate impacts, well-informed decision-support tools, improved detection of environmental change, while cultivating a better understanding of new climate mitigation strategies and technologies and their effects on aquatic ecosystems.

Research is critical to understanding the vulnerability of fisheries/aquaculture, aquatic species/ecosystems, and coastal infrastructure to climate change, as it provides foundational clarity on the complex interactions and linkages between multiple, often interconnected variables. Within DFO, research on climate-related topics has been supported through various avenues, for example ACCASP, ACCASP's DFO-NOAA collaborations, Strategic Program for Ecosystem-based Research and Advice (SPERA), and CSRF. Thus far, ACCASP has dedicated resources to investigate how climate change-related stressors (*e.g.*, ocean acidification, deoxygenation, temperature changes, altered circulation, sea-level rise, and freshwater input) interact and affect the vulnerability and resilience of key species, ecosystems, and infrastructure. This research also improves our ability to predict the future state of aquatic ecosystems and coastal infrastructure under future climate scenarios. These research efforts establish the foundations for proactive adaptation planning and climate resilience across DFO, yet it is important to recognize that continued research is required to address emerging and evolving climate challenges.

To address **ecosystem & biological risks**, participants identified several *continuing* research needs (Table 4). These included conducting integrated ecosystem assessments that combine research, monitoring, modelling, and analyses to evaluate climate impacts across a broad range of species. Participants emphasized expanding research into nature- and technology-based climate solutions, both managed and unmanaged, particularly focusing on carbon burial rates and carbon cycling. There is also a need to evaluate species and habitat vulnerability to increasing vessel and boat traffic in marine and freshwater systems, improve understanding of how species respond to climate-driven changes (such as acidification and warming) and anthropogenic habitat change (such as habitat loss due to mCDR activities), and invest in assessing freshwater ecological baselines. A particular focus was placed on understanding multi-stressor impacts across the full lifecycle of key species, especially those of economic and ecological importance. *Emerging* research needs included the development of freshwater-specific climate vulnerability assessments, exploring climate impacts on Earth system interactions (*e.g.*, land-ocean and terrestrial-aquatic), and investigating how climate change is affecting predator-prey relationships and life-cycle timing (phenology). Participants identified gaps in DFO's ability to predict AIS expansion and their consequences, better understand coastal buffering capacity (alkalinity, salinity), and investigate warming, freshening, and borealization in the Arctic with a focus on fisheries priority species. Other emerging needs included systematic risk and vulnerability assessments, developing freshwater adaptation strategies, and weaving Knowledge Indigenous knowledge systems with DFO research programs to enrich understanding and inform responses.

For **operational & infrastructure risks**, *continuing* research needs included improving understanding of global drivers and impacts of global and regional sea-level rise, and how changing ocean circulation and sea ice conditions are affecting marine operations and infrastructure planning.

For risks overlapping both **categories**, participants identified emerging needs to conduct coastal community vulnerability assessments and investigate how extreme climate events (in terms of frequency, duration, and intensity) affect marine species' resilience. These assessments will be vital for both ecosystem management and infrastructure protection in vulnerable coastal zones.

Needs requiring cross-sectoral collaboration included forming interdisciplinary teams that bring together Indigenous Knowledge holders, environmental, infrastructure, ecosystem, and socioeconomic expertise to strengthen understanding of climate effects. Participants emphasized improving the science-policy interface to better prioritize investments in areas with significant knowledge gaps. Specific research needs include assessing the impacts of AIS on infrastructure, evaluating how offshore wind farms affect Atlantic coastal resources (*e.g.*, potential electromagnetic field impacts on fisheries), and understanding how extreme weather, sea ice loss, ocean chemistry shifts, and storms affect infrastructure integrity. Further needs include assessing how changing ocean chemistry influences SCH and research vessels, particularly steel infrastructure, and advancing research on climate-resilient infrastructure, including cost-benefit analyses and experimental designs for vulnerable or frequently damaged assets.

Needs requiring interdepartmental engagement included studying the impacts of weather-driven changes in silt load, coastal permafrost thaw impacts on aquatic ecosystems, and evaluating vessel design and ship routing under changing climate and ocean conditions.

Research is part of DFO Science's foundation. Addressing the identified research needs would expand understanding of climate change impacts (*e.g.*, cumulative effects of multiple stressors, land–sea interactions, ocean acidification, socio-economics) and provide data (*e.g.*, species thermal thresholds) to support the development of vulnerability and risk assessments, which can influence climate-resilient decision making in resource, habitat, ecosystem, and species-at-risk management. It would also provide evaluations of potential benefits, risks, and impacts to marine ecosystems of new and emerging climate change mitigation strategies and technologies, such as mCDR (which can include ocean alkalinity enhancement, nutrient fertilization, artificial upwelling and downwelling, direct ocean capture, and macrophyte and macroalgae aquaculture).

Table 4. Summary of the climate change-related science needs identified under the **research** theme (Expanding ecological research and tool development) across all regions addressing the two risk categories. *Continuing* needs refer to needs identified in previous assessments that are still relevant today. *Emerging* needs refer to new needs reflecting the evolving nature of climate change science and broader needs associated with climate change mitigation and adaptation. Research needs that fall outside the roles and responsibilities of DFO's Ecosystems and Oceans Science sector, which would require cross-sectoral or cross-departmental collaboration are listed in grey at the bottom of the table.

Risk Category Addressed	Status	Need
Ecosystem & biological risks	Continuing	Conduct integrated ecosystem assessments (research, monitoring, modelling, and analyses) to address the impacts of climate change across a broad range of species.
		Expand research on nature-based climate solutions (managed and unmanaged) including carbon burial rates and carbon cycling.
		Evaluate species and habitat vulnerability to changes in vessel/boat traffic patterns in marine and freshwater habitats.
		Improve understanding of species responses to climate-driven change (acidification, temperature, freshening, extremes) and anthropogenic habitat change (marine Carbon Dioxide Removal), especially multi-stressor effects at all phases of species' lifecycles, with a focus on key resource populations.
		Invest in assessing biodiversity and baselines in freshwater environments.
	Emerging	Develop and conduct freshwater climate change vulnerability assessments.
		Explore climate change effects on interactions across Earth system spheres (*e.g.*, land-ocean, terrestrial-aquatic), including near-shore oceanography.
		Further explore climate change impacts on predator-prey interactions and life-cycle timing (physical and biogeochemical phenology).
		Improve understanding and prediction of invasive species range expansions and their impacts on vulnerable species and ecosystems.
		Improve understanding of coastal buffering capacity (alkalinity, salinity).
		Improve understanding of warming/freshening and borealization in the Arctic, with a focus on fisheries priority species or ecosystems to support community adaptation.
		Systematic assessment of risk and vulnerability of resources.
		Test the effectiveness of existing adaptation recommendations in freshwater.
		Weave Indigenous Knowledge and knowledge tools with DFO research.
Operational & infrastructure risks	Continuing	Improve understanding of contributing factors to global and regional mean sea-level rise (*e.g.*, role of changes in the Antarctic and Greenland ice sheets).
		Improve understanding of the impacts of changing ocean circulation and sea ice conditions on marine operations.

Common across Ecosystem & biological risks and Operational & infrastructure risks	Emerging	Conduct coastal community vulnerability assessments.
		Investigate the frequency, strength, and duration of extreme events and their impact on and recovery potential of various marine species.

Jurisdiction	Need
Needs requiring cross-sectoral collaboration	• Develop interdisciplinary teams, including Indigenous Knowledge holders, that integrate environmental, infrastructure, ecosystem, and socioeconomic expertise, at appropriate scales, to enhance the understanding of climate effects (*e.g.*, strengthen engagement with policy and economics to improve risk assessments). • Improve science-policy interface so that investments can be prioritized to address current knowledge gaps that will inform management decisions. • Assessments of AIS impacts on infrastructure. • Evaluate wind farm impacts to Atlantic coastal resources (*e.g.*, electromagnetic field impacts on fisheries resources). • Assess the effects of extreme weather events, ice cover changes, ocean chemistry shifts, and storms on infrastructure. • Evaluate the impact of ocean chemistry changes on vessels and Small Craft Harbours (SCH) infrastructure, particularly steel structures. • Advance climate-resilient infrastructure research, including testing and experimental design. • Cost-benefit economic analysis of SCH infrastructures that are repeatedly damaged – need for internal policy for cost/benefit of maintaining infrastructure.
Needs requiring interdepartmental engagement	• Research impacts of weather changes on silt load. • Conduct research on impacts of coastal permafrost thaw on aquatic ecosystems. • Evaluate vessel design under new/changing conditions. • Research for improved ship routing under a changing climate.

2.2.4 Knowledge Mobilization: Empowering climate action and decisions through knowledge mobilization

In summary, effectively supporting climate-resilient species, ecosystems, industries, operations, and communities through science-informed decision making requires translating knowledge and scientific outputs into accessible, understandable, and usable formats, or providing clear guidance for their direct application (Table 5). Overarching departmental needs include improving data accessibility, integrating science advice into decision making, developing predictive and adaptive tools, fostering multidisciplinary work to address the complexity of climate change impacts, implementing effective science communication strategies for managers and policymakers (including user-friendly tools and applications), and increasing stakeholder engagement.

Empowering climate action and decision making by translating complex scientific findings into easily digestible and accessible formats can help strengthen the science-policy interface, enhance the capacity for collaborative climate change solutions, and lead to more informed, climate-resilient communities.

Knowledge mobilization is essential to ensure that important scientific research and data are accessible beyond disciplinary silos, furthering public understanding and evidence-based decision making. This involves translating complex scientific topics into accessible formats through plain-language summaries, interactive data visualization tools and applications, or curated data summaries. For data users, this means improved awareness, availability, and accessibility of information. Through the ACCASP, project information is being made publicly available on the DFO website, with data managed according to Government of Canada Open Government directives via Open Data or other publicly accessible platforms. Ongoing collaboration with NOAA also supports cross-border knowledge sharing. Within DFO, climate-informed decision making is being advanced through the development and dissemination of tools like the Canadian Extreme Water Level Adaptation Tool (CAN-EWLAT), Coastal Infrastructure Vulnerability Index (CIVI, Greenan et al. 2018), Risk Equivalency Decision-support Framework (Roux et al. 2022), and the Lobster Vulnerability Assessment (Greenan et al. 2019b), as well as species status assessment processes (*e.g.*, State of Canadian Pacific Salmon: Macdonald & Grant 2023), Canadian Science Advisory Secretariate processes (including the Fisheries Science Advisory Report), and ongoing cross-sectoral discussions and initiatives (*e.g.*, the Resilient and Adaptive Fisheries Strategy). These efforts reflect DFO's commitment to scientific excellence and open science, as outlined in the department's *Open Science Action Plan* (DFO 2024). While these efforts represent important progress, continued effort is needed to fully meet the growing demands for accessible, integrated, up-to-date and actionable climate science for a climate-resilient DFO.

To address **ecosystem & biological risks** associated with climate change, participants identified a *continuing* need to develop multi-disciplinary, predictive, and adaptive decision-support tools Table

5) highlighting that these tools should integrate, synthesize, and visualize data, such as forecasting systems and vulnerability prediction tools, and be tailored for use in both internal and external decision-making. Emphasis was placed on enhancing communication between climate research scientists and stock assessment scientists, as well as improving accessibility and usability of science products for a variety of stakeholders. *Emerging* needs for this risk category included synthesizing existing methods, tools, research outcomes, and science advice to better estimate the impacts of climate change on freshwater fish and aquatic habitats. This synthesis is intended to support the development of applied responses to emerging risks and inform science-based freshwater management.

Under **operational & infrastructure risks**, participants identified *continuing* needs to develop and refine tools that support long-term planning for coastal infrastructure and marine operations. These tools should align with climate change projections to better inform risk assessments and infrastructure investment decisions.

For risks overlapping both ecological and operational categories, *continuing* needs included enhancing decision-support systems such as visualization platforms and automated data summarization tools to better inform science advice processes. Participants emphasized the importance of strengthening the science-policy interface to improve support for the development of adaptation and mitigation strategies. In addition, there is a need to improve openness, accessibility, and management of scientific data, model outputs, research products, and science advice to meet the evolving needs of internal clients and external partners. *Emerging* cross-cutting needs focused on increasing the department's capacity for data management and the dissemination of oceanographic, biogeochemical, and ecological model outputs. These enhancements would ensure that key information is readily available to inform responsive and proactive decision-making across sectors.

Knowledge mobilization needs requiring cross-sectoral collaboration were extensive (n = 14) and focused on enhancing climate resilience, governance, and communication. Key priorities include advancing tools and strategies for climate-resilient ocean and resource management, infrastructure planning, contaminated site management, marine emergency response, and shipping operations using predictive models and assessments. The needs to modernize legacy tools (*e.g.*, CIVI, CAN-EWLAT) and provide ongoing technical and training support for science tools used by management sectors was also noted. Participants called for improved communication of economic risks and climate impacts via online platforms, science advisory reports, and conservation reporting. They also noted the need for rapidly adaptable policy frameworks and strategies to integrate science into planning and management processes. Participants highlighted the need to improve engagement with Indigenous communities for co-developed monitoring and adaptation. Updating reference levels for tide tables and supporting the Canadian Hydrographic Service (CHS) in managing increased vessel traffic through updated navigation tools and traffic regulation mechanisms were also noted. Overall, cross-sectoral collaboration is required to facilitate integration of climate change science outputs into decision-making processes, strengthen the science-policy interface and science communication, enhance data-sharing across federal, provincial, territorial, and Indigenous governments and organizations, and support the integration of diverse data sources, including internationally.

Needs requiring interdepartmental engagement included enhancing the ability to provide real-time ice-ocean data to support community-level safety and operational decision-making in changing environments. Further collaboration was seen as necessary to increase cooperation at all levels, international, intergovernmental, and interdepartmental, to support climate-smart governance of aquatic ecosystems. Formalization of data-sharing agreements, such as a Memorandum of Understanding (MOU) with Environment and Climate Change Canada (ECCC) on ocean-climate modelling and data exchange, was also suggested to improve Canada's modelling capacity, abilities to predict future environmental and ecological change, and capacity to produce actionable insights.

Effective knowledge mobilization is fundamental to climate action. It forms the basis of the science-policy interface by translating complex scientific knowledge into clear, actionable guidance for aquatic resource management (*e.g.*, decision frameworks, geospatial mapping tools), enabling more effective, science-driven decisions. It also fosters a greater capacity for collaborative climate solutions in Canada and globally. This increased capacity builds on a multidisciplinary understanding of interconnected climate change impacts by leveraging new and existing partnerships (*e.g.*, ECCC, NRCan) and embracing Open Science policies. Ultimately, these efforts could foster more informed and resilient fisheries and communities across Canada through accessible information, transparent risk communication, user-oriented data systems, and intuitive tools that enhance climate-smart decision making as well as local adaptation and preparedness.

Table 5. Summary of the climate change-related science needs identified under the **knowledge mobilization** theme (Empowering climate action and decisions through knowledge mobilization) across all regions addressing the two risk categories. *Continuing* needs refer to needs identified in previous assessments that are still relevant today. *Emerging* needs refer to new needs reflecting the evolving nature of climate change science and broader needs associated with climate change mitigation and adaptation. Knowledge mobilization needs that fall outside the roles and responsibilities of DFO's Ecosystems and Oceans Science sector, which would require cross-sectoral or cross-departmental collaboration are listed in grey at the bottom of the table.

Risk Category Addressed	Status	Need
Ecosystem & biological risks	Continuing	Develop multi-disciplinary, predictive, adaptive, interactive tools that integrate, synthesize, and visualize/map data (including forecasting and vulnerability prediction systems, and syntheses) to enhance accessibility, support decision making (tailored), and improve internal (*e.g.*, links between climate research scientists and stock assessment scientists) and external science communication.
	Emerging	Produce synthesis of existing methods and tools, research outcomes, and science advice to estimate impacts of climate change on freshwater fishes and habitats.
Operational & infrastructure risks	Continuing	Develop and refine tools to support long-term planning for coastal infrastructure and marine operations.
Common across Ecosystem & biological risks and Operational & infrastructure risks	Continuing	Enhance decision support tools (*e.g.*, visualization and autonomous data summarization tools) for ongoing science advice.
		Enhance science-policy communication to improve science support for development of adaptation and/or mitigation tools/techniques/approaches.
		Improve the openness, accessibility, and overall management of data, model output products, research outputs, and scientific advice to better address client needs.
	Emerging	Enhance capacity for data management and dissemination of oceanographic, biogeochemical, and ecological model outputs.

Jurisdiction	Need
Needs requiring cross-sectoral collaboration	• Advance development of climate-resilient infrastructure, contaminated site management strategies, environmental emergency response, protection measures, and shipping plans, using climate prediction models, in marine and fresh waters. • Communicate economic risk over time scales through websites, Fisheries Science Advisory Reports, marine conservation reporting, etc. • Develop a strategy to integrate science into marine response planning under climate change. • Adjust departmental policies and management frameworks to be more adaptable, i.e., to be able to respond to or prepare for climate-related changes more effectively (e.g., in managing fisheries, conservation areas, in a changing environment). • Develop understanding of climate change impacts on management processes. • Communicate actionable science knowledge regarding climate change risks to management sectors. • Increase international, intergovernmental, and inter- and intra-departmental cooperation for climate-smart governance of aquatic ecosystems. • Improve collaborations with Indigenous communities and organizations to support community-based monitoring and research, as well as mobilization of model predictions to support community adaptation. • Increase science-policy and science-client communication and data sharing within and between Federal, Provincial, Territorial, and Indigenous governments. • Integrate data sources across data repositories at large (including International repositories). • Modernize existing tools where applicable (*e.g.*, CIVI, CAN-EWLAT).

	• Strengthen science-policy interface for climate change. • Provide technical science support for tool delivery and on-going training for management sectors. • Update reference levels for tide tables and charts, particularly for nearshore environment, and provide support and tools for Canadian Hydrographic Services (CHS) to manage growing vessel traffic, including traffic zone regulation and compulsory reporting.
Needs requiring interdepartmental engagement	• Enhance capacity to provide real-time accessibility of ice-ocean data for community safety and decision making. • Formalize a Memorandum of Understanding (MOU) for ocean-climate modelling and data sharing with ECCC.

2.3 Addressing Needs that Require Cross-Sectoral and Cross-Departmental Collaboration

A total of 29 identified needs fell outside DFO-EOS sector's direct roles and responsibilities (*i.e.*, cross-sectoral needs) but are critical to mobilizing science outputs, responding to climate change risks, and enhancing the climate change resilience of the department as a whole. The majority of needs that were outside DFO-EOS jurisdiction fell under the theme of **knowledge mobilization** (n = 14; 48%), followed by **research** (n = 8; 28%), **monitoring** (n = 5; 17%), and **modelling** (n = 2; 7%).

These needs highlight key opportunities for cross-sectoral collaboration and systems-level integration (see "Needs requiring cross-sectoral collaboration" in Tables 2-5). These areas, such as infrastructure planning, emergency response, governance, collaborations, communications, decision-support tools, climate-smart decision-making processes, and large-scale data management, require integrating science with operational and policy expertise across the department. Addressing these needs could involve collaboration with the DOAP team, which supports DFO's climate change science-policy interface by supporting the integration of climate change into departmental policy, planning, and operations.

Additionally, there were 14 needs identified that fall outside DFO's jurisdiction (*i.e.*, cross-departmental needs) but remain relevant to the department's science mandate. These specifically represent crucial opportunities for collaboration with other federal departments (*e.g.*, Crown Indigenous Relations and Northern Affairs (CIRNAC), Transport Canada, ECCC, NRCan), provincial and territorial governments, and external partners (*e.g.*, academia and other non-governmental and international organizations) on ocean-climate, ice, freshwater, permafrost, erosion, sedimentation, and shipping monitoring, modelling, research, and knowledge mobilization efforts. Addressing these needs through external activities and/or collaboration would support a whole-of-society approach to advancing climate change resilience in Canada (*e.g.*, as encouraged in the National Adaptation Strategy for Canada), and also ensure relevant data are available for use in DFO's own modelling, research, and knowledge mobilization activities. For example, permafrost and sedimentation data from ECCC could support DFO cumulative impact assessments, projections of future shipping patterns from Transport Canada could support DFO risk assessments for migratory species, and land ice melt and runoff data from NRCan and ECCC, respectively, support NRCan-led development of sea-level rise projections, which support DFO-led risk assessments for coastal infrastructure (*e.g.*, Can-EWLAT; CIVI; Greenan et al. 2018), and ocean biogeochemical modelling efforts.

3. Discussion

The 2025 CCS Community Needs Evaluation meeting and subsequent discussions revealed critical gaps and opportunities to advance climate change science and its integration into policy and management actions within DFO. This report outlines the science and science-adjacent needs identified by DFO's climate change science community (sections 2.2-2.3) to address the six ongoing climate change risks relevant to DFO's mandate (Table 1; summarized in Appendix 4: Needs and Their Associated Risk Categories). This work represents a preliminary effort to identify departmental climate change-related needs that can and should lead to further engagement across science programs and sectors. Any initiative to address the needs raised in this report would benefit from collaborative and strategic planning with key internal and external partners (e.g., fisheries managers, conservation practitioners, coastal communities), as climate change risks (Table 1) are likely to affect the capacity of all management sectors to fulfill their mandates. Addressing the identified needs would help to reduce the risks identified and of relevance to various sectors.

The ability to sustain and build upon ongoing work while simultaneously addressing evolving climate change impacts and related issues was a key concern applicable across all research themes (*i.e.*, monitoring, modelling, research and knowledge mobilization). Stable internal capacity (infrastructure, personnel, expertise, equipment, etc.) within the public service is essential, as climate change science is a highly technical and continually evolving field. This stability is especially critical for data-poor areas (particularly in freshwater and Arctic regions), and for ensuring the continuity of long-term datasets and legacy programs (such as specialized in-house sample analysis capacities) for which the public service is the sole provider and primary director of applications to natural resource management and large-scale conservation and restoration efforts.

Participants consistently emphasized the urgent requirement to fill baseline data gaps and ensure sustained and expanded investment within DFO to support the stability of long-term monitoring efforts and sample analysis technologies. These investments are needed to improve spatial coverage, maintain temporal consistency, increase operational efficiency, and most importantly, to retain the skilled personnel required to process samples and interpret data. Strengthened and stabilized long-term environmental monitoring, especially for hydrology, biodiversity, ocean chemistry, species ranges, and habitat conditions, continues to be crucial to identify, understand, and respond to the impacts of climate change across Canada's aquatic ecosystems.

Additionally, participants stressed the necessity of advancing predictive modelling capabilities. High-priority areas included downscaling ocean-climate models and advancing biogeochemical, species distribution, and ecosystem models (and their validation), and increasing the development and accessibility of scenario-based model projections (output products) for changing environmental and ecological conditions and coastal hazards (*e.g.*, sea-level rise). These models are essential for proactive decision making to protect both ecological integrity and critical infrastructure, particularly in data-poor high-risk areas such as the Arctic, freshwater, and coastal zones (*i.e.*, addressing both ecological and operational/infrastructure-related departmental climate change risks).

Regarding research, the identified needs included integrated ecosystem assessments in marine and freshwater environments as well as interdisciplinary investigations into cumulative impacts of multiple stressors on key species, ecosystems, industries, and communities. Participants also emphasized the importance of assessing infrastructure vulnerabilities to climate extremes, as well as further research on AIS, sea-level rise, sea ice changes, and extreme event return times critical for operational planning. Some emerging research needs include Arctic warming/freshening, land–sea interactions, evaluation of nature-based climate adaptation strategies, and evaluations of the potential benefits and impacts of mCDR technologies.

Essential to these science needs and related monitoring, modelling, and research efforts, knowledge mobilization ensures their relevance and usability for decision makers and Canadians, to support the mitigation of ecological and operational/infrastructure-related risks. Collected data should be accessible to other researchers and relevant individuals. Ensuring data accessibility and timeliness of data sharing with stakeholders, communities, and modellers is imperative for the advancement of climate change science and the agile responses to observed changes or events. Interpreted data and outcomes should also be publicly available and presented in a clear, easily digestible format to ensure the intended information is tangible and usable for the general public and decision makers. Participants reiterated that science products must be mobilized through better knowledge translation, communication tools, and integration of scientific advice into policy and operational decision making. Ultimately, effective knowledge mobilization – supported by data accessibility, decision-support tools and applications, and enhanced collaboration across DFO sectors and governmental, Indigenous communities, and international partners – is vital to ensure that science informs timely, climate-resilient actions to address climate change risks.

Strategic science planning across multiple programs, considering clients' requirements, would be essential to address these needs efficiently, coherently, and effectively. Identification of existing climate change science products and tools in conjunction with identified needs would also support efficiency in filling critical gaps. A structured and integrated planning approach would encourage the allocation and prioritization of investments in long-term monitoring and modelling capacities, model advancement and product accessibility, research to fill remaining knowledge gaps, data storage and management, and development of decision-support systems. By aligning efforts across departmental programs to address common identified climate change-related science needs, duplication of effort could be minimized, critical gaps could be filled, and synergies between ecological, operational, and infrastructure-focused initiatives (*e.g.*, see “Common across Ecosystem & biological risks and Operational & infrastructure risks” in Tables 2-5) could be leveraged to strengthen DFO’s capacity to incorporate climate change considerations into decision making. This would ensure that scientific endeavors align with federal mandates and support a robust and resilient Canada amidst ongoing environmental change.

4. Conclusion

Canada’s climate is changing, and the federal government has a mandate to prepare Canadians for the impact of these changes. DFO has played a key role in helping Canada to assess and respond to the impacts of climate change in Canada’s oceans and aquatic environments through various initiatives, such as the 2005 Climate Change Risk Assessment for Fisheries and Oceans Canada report (Interis Consulting Inc. 2005), the creation of the ACCASP in 2011, and the completion of the 2013 Large Aquatic Basin Risk Assessments for each basin (DFO 2013a,b,c,d). The importance of climate adaptation remains high on the national agenda, as demonstrated by the 2017 *Adapting to the Impacts of Climate Change* report and reaffirmed in the 2025 Prime Minister’s Mandate Letter highlighting the continued commitment to address climate change and ensure that the country is well positioned to adapt. The needs outlined in this report provide a roadmap to guide science support for continued delivery of DFO’s mandate amidst the changing climate.

Through the process of reviewing previously identified climate change risks to DFO’s mandate and related science needs, several high-level conclusions emerged. The first conclusion is that all six risks previously identified in the earlier risk assessments (Table 1) remain relevant as climate change continues to pose these risks to DFO’s mandates related to aquatic species, ecosystems, industry, operations, and infrastructure, resulting in challenges for decision makers including fisheries managers and conservation practitioners, among others. Similarly, most of the previously identified needs for science that would support decision makers in addressing those risks remain relevant or have increased in urgency and/or scope.

In addition to these ongoing needs, several new needs have emerged, particularly in response to accelerating climate pressures, for example, increasing urgency of international calls for action has led to requests for science to test the effectiveness and risks of mitigation approaches, and more evident shifts in stock distributions and local abundances has led to increasing requests for science advice to support fisheries management responses. A high number of new needs related to research and knowledge mobilization indicate an increase in scope and demand for innovation, integrated approaches, improved science-to-policy translation, and the human and institutional capacity to meet these needs.

Needs related to the maintenance and/or expansion of existing monitoring and modelling systems and programs (*e.g.*, capacity and expertise for the continued processing of existing, increased, or new types of laboratory samples, and for the ongoing refinement of evolving climate models) highlight the foundational nature of these systems to supporting core science capabilities and to address climate risks. Regional modelling efforts, for example, have achieved significant successes, but these gains must be maintained and built upon to remain responsive and relevant under changing climate conditions, and to provide the most up-to-date products needed for researchers to develop predictions of present and future ecological states (*e.g.*, to support proactive decisions for fisheries and conservation).

A consistent message raised during the meeting and reiterated throughout the development of this report is the importance of maintaining and strengthening long-term science programs, while integrating new technologies and innovations to enhance data quality and program efficiency. Long-term datasets resulting from sustained, continuous efforts are essential for detecting change over time and for informing effective adaptation and mitigation strategies. Stable, government-led science provides the necessary continuity, independence, and relevance for departmental decision making that cannot be met through short-term or privately-funded research alone. Large-scale, long-term annual monitoring programs, in particular, require public investment, as only the federal government has the mandate and capacity to support such efforts over the long-term. As a regulatory agency that administers legislation such as the *Fisheries Act* and the *Oceans Act*, DFO holds a responsibility to conduct both foundational and applied science work that benefits all Canadians.

Overall, this report outlines which comprehensive scientific efforts in monitoring, modelling, research, and knowledge mobilization are needed to increase DFO's resilience in an increasingly complex climate future. It highlights key areas for improvement, such as enhancing understanding of climate change impacts on aquatic species, ecosystems, industries, and coastal communities, strengthening predictive capabilities, and developing robust decision-support tools. It also provides a starting point towards strategic science planning to support climate change resilience in the ways aquatic ecosystems (*e.g.,* through conservation and protection), fisheries and aquaculture resources and critical infrastructure are managed in DFO. These efforts would collectively strengthen the department's ability to detect and respond to change, predict future vulnerabilities, manage risks, and implement science-based adaptation solutions.

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Appendix 1: Summary of Departmental Threats Associated with Climate Change Risks Identified through 2013 Large Aquatic Basin Risk Assessments

Table A2.1. Outcomes of the 2013 Climate Science Advisory Secretariat (CSAS) processes, “Large Aquatic Basin-specific Risk-Based Assessments of Climate Change Impacts and Risks on the Biological Systems and Infrastructure within Fisheries and Oceans Canada's Mandate”: A summary of the threats (potential consequences) to DFO departmental mandates presented by the **ecosystem and biological risks** identified across the four Large Aquatic Basins.

Shared threats	Large Aquatic Basin-specific threats
Ecosystem and Fisheries Degradation and Damage: • Negative impacts on commercial and subsistence fishing, hydroelectric, oil, gas, and marine industries. • Economic losses, increased operational costs, and regulatory pressures, • Altered fish stock abundance impacting fishing industries, local communities, and traditional knowledge. • Increased costs, decreased revenues, and investment for fisheries and aquaculture operations. • Increased demand for economic analysis of cultured and wild fisheries interactions. • Increased legal pressure on fisheries management and food security concerns. • Greater demand for policy changes (balancing economic opportunities and species protection), integrated management, and interdepartmental cooperation. • Need for improved stock assessments, infrastructure, and international fisheries cooperation. • Demand for ecosystem-based management and Marine Protected Areas (MPAs). **Changes in Biological Resources:** • Loss of habitat and changes species distribution affecting aquatic ecosystems, species diversity, and productivity. • Changes in ocean and freshwater conditions altering ecosystem structure, species mortality, growth, reproduction, and distribution. • Timing mismatches between species and their prey affecting critical life stages. • Organisms with calcium carbonate structures will face survival challenges. **Species Reorganization and Displacement:** • Challenges in defining and protecting critical habitats, with increased legal and environmental conflicts. • Growing threat of invasive species altering ecosystems, and need for AIS regulations • Increased ice-free periods and stratification will raise the risk of blue-green algal blooms and deep-water anoxia. • Habitat loss and shifts in species distribution will contract cold water fish habitats and expand warm-water fish habitats northward.	**Pacific:** • Ecosystem reorganization requiring new management systems, recovery strategies, and shifts in regional priorities. • Limited resources for the Species at Risk Program and unknown indirect climate change effects on departmental business. • Potential decreased efficiency of Small Craft Harbour facilities due to shifts in fisheries. • Ecosystem Risk Assessments, fisheries closures, and related policy decisions affecting fisheries, potentially increasing by-catch interactions and changing quotas. **Arctic:** • Economic losses for subsistence harvesters. **Atlantic:** • Increased parasites, diseases, fouling, and Harmful Algal Blooms at aquaculture sites. • Emerging fisheries complicating the establishment of Marine Protected Areas. **Freshwater:** • Commercial fishing, seafood processing, and recreational activities facing economic losses due to decreased revenues, increased costs, and investment uncertainty. • Increased demand for aquatic invasive species control and expanded sea lamprey control programs.

Table A2.2. Outcomes of the 2013 Climate Science Advisory Secretariat (CSAS) processes, "Large Aquatic Basin-specific Risk-Based Assessments of Climate Change Impacts and Risks on the Biological Systems and Infrastructure within Fisheries and Oceans Canada's Mandate": A summary of the threats (potential consequences) to DFO departmental mandates presented by the **operational and infrastructure risks** identified across the four Large Aquatic Basins.

Shared threats	Large Aquatic Basin-specific threats
Increased Demand for Emergency Response: • Rising demand for search and rescue (SAR), environmental response (ER), and emergency preparedness. • Greater workload and costs for the Department of Fisheries and Oceans (DFO) and the Canadian Coast Guard (CCG). • Increased frequency of extreme weather events and climate-driven hazards impacting response capacity. • Higher risk of environmental damage from marine incidents. • Growing public and international focus on environmental risks and marine safety. **Infrastructure Damage:** • Rising sea levels, storm surges, and erosion threatening coastal infrastructure. • Increased maintenance and adaptation costs for harbors, docks, and navigation systems. • Pressure on DFO to upgrade and maintain infrastructure despite funding constraints. • Higher insurance costs and legal liabilities from failing to address infrastructure risks. • Potential conflicts over infrastructure responsibilities within DFO sectors. **Changes in Access and Navigability of Waterways:** • Altered ice conditions, water levels, and sedimentation affecting navigability. • Increased dredging requirements and costs. • Challenges in maintaining accurate marine navigation charts and aids. • Greater pressure on CCG for ice-breaking and waterway maintenance. • Competing interests complicating Marine Protected Area (MPA) establishment.	**Arctic** • More extreme weather (ice hazards, fog, unpredictable storms) impacting navigation and response. • Need for better Arctic monitoring, updated charts, and predictive models. • Increased demand for international collaboration on Arctic marine traffic management. • Public pressure to renew and maintain Arctic infrastructure. **Atlantic** • Disappearing sea ice and increased shipping activity leading to higher SAR and ER needs. • Coastal erosion and flooding endangering harbor structures and safety. • Increased demand for aquaculture adaptations due to shifting fisheries. • Potential legal consequences from infrastructure failures. **Pacific** • Storm surges, spring floods, and shoreline erosion altering harbor access. • Increased biofouling, impacting aquaculture and navigation infrastructure. • Higher risks of vessel collisions and environmental incidents due to storm-driven debris. • Growing conflicts over dredging and habitat conservation efforts. **Freshwater** • Lowered water levels affecting harbor and pier access. • Shorter ice periods reducing ice-fishing opportunities. • More frequent storm-related disruptions to recreation, tourism, and fisheries. • Increased responsibility for inland waterway maintenance and sediment management.

Appendix 2: Participants and Contributors to this Report

A sincere thank you to everyone who contributed to the 2025 Climate Change Science Needs Evaluation process and the writing of the report. The NCR CCS team greatly appreciates your active participation as well as the thoughtful edits and comments provided throughout. Your time and effort in helping to inform climate change science activities and their mobilization in DFO is appreciated.

Table A1. List of participants to the March 19th, 2025 Climate Change Science Needs Evaluation meeting, and contributors who provided valuable input for this report. Participants and contributors include, but are not limited to, valuable members of DFO's national Climate Change Science Sub-Committee and Ocean Chemistry Working Group, and supportive regional colleagues.

Name	Region
NCR Climate Change Science Coordination team: Lamarche, Marie-Claude (Chair) Dauphin, Guillaume Ong, Jie Yuen Stortini, Christine	NCR
Grant, Sue	PAC
Norgard, Tammy	PAC
Pearce, Christopher	PAC
Peña, Angelica	PAC
Robb, Carrie	PAC
Steiner, Nadja	PAC
Wan, Di	PAC
Capelle, David	ARC
Niemi, Andrea	ARC
Stow, Jason	ARC
Chu, Cindy	O&P
Gardner Costa, Jesse	O&P
Drolet, David	QC
Lavoie, Diane	QC
Lizotte, Martine	QC
Mckindsey, Chris	QC
Small, Daniel	QC
Starr, Michel	QC
Chassé, Joël	Gulf
Greenan, Blair	MAR
Gurney-Smith, Helen	MAR
Shackell, Nancy	MAR
Andres, Heather	NL
Bélanger, David	NL
Maillet, Gary	NL
Penney, Jared	NL
Soontiens, Nancy	NL
Sutton-Pande, Vanessa	NL

Appendix 3: Needs Removed

Table A3. A list of climate change-related need previously identified in either 2013 DFO Large Aquatic Basin Risk Assessments or 2022 Aquatic Climate Change Adaptation Services Program Needs Assessment, but removed from this 2025 Climate Change Science Needs Evaluation because the needs were either too vague, duplications, or not related to climate change in aquatic environments ("Not CCS")

Risk Category	Science theme	Need	Reason for removal
Operational and infrastructure risks	Research	Address knowledge gaps to support coastal infrastructure management decisions.	Too vague
Ecosystem and biological risks	Monitoring	Monitor all environmental (physical/biological/chemical) variables, including OA and its impacts	Too vague
Operational and infrastructure risks	Monitoring	More monitoring of ice cover	Not DFO mandate
Operational and infrastructure risks	Modelling	Global Ice-Ocean Prediction Systems to support maritime safety and search and rescue.	Not DFO mandate
All risks	Modelling	Models to predict the impacts of human activities, development, and marine traffic	Too vague, not DFO mandate, and not CCS
Ecosystem and biological risks	Research	Improve understanding of interspecies fisheries and harvest interactions (*e.g.*, redfish/shrimp)	Not CCS
Ecosystem and biological risks	Research	Species response assessments for recovery planning in the context of environmental emergencies	Duplicated in Monitoring
Ecosystem and biological risks	Research	Baselines for emergency response (*i.e.*, Oil spill)	Not CCS
Ecosystem and biological risks	Research	Risk assessment of high traffic areas and identify highly sensitive habitats	Not CCS
Ecosystem and biological risks	Research	Improve understanding of the impacts and the recovery of oil spills on the habitat and trophic ecology in FW environments and ecosystems.	Not CCS
Ecosystem and biological risks	Research	More information on the impacts of dredging in freshwater.	Not CCS
Operational and infrastructure risks	Research	Improved scientific research to support emergency response risk assessments	Too vague
Operational and infrastructure risks	Research	Managing Climate and Industry-Related Risks	Too vague
Ecosystem and biological risks	Research	Conduct research on coastal permafrost thaw	Duplicated

Appendix 4: Needs and Their Associated Risk Categories

Following the review and finalization of the needs evaluation report by co-authors and March 19th meeting participants, three National Capital Region Climate Change Science (CCS) team members reviewed the full list of needs identified, and determined by consensus, which of the specific 2005 (Interis Consulting Inc. 2005) and 2013 CSAS-identified departmental climate change risks (DFO 2013a,b,c,d) could be addressed by fulfillment of each need. Given the broadness of the risk categories descriptions (Table A4.1), the specific needs often addressed several of these risks (Table A4.2). The main risk(s) addressed by a given need was identified by a '**X'**, while minor risk addressed were identified by 'o'. This table, while somewhat subjective, should support the identification of science needs that should be fulfilled in order to address the most pressing climate change risks facing particular "client" sectors and/or DFO's mandate overall.

Table A4.1. A summary of the departmentally-relevant core risks identified in the 2005 Climate Change Risk Assessment for Fisheries and Oceans Canada and further defined regionally through the 2013 Canadian Science Advisory Secretariat (CSAS) process titled "Risk-Based Assessment of Climate Change Impacts and Risks on the Biological Systems and Infrastructure within Fisheries and Oceans Canada's Mandate" for each of Pacific, Arctic, Atlantic, and inland Freshwater Large Aquatic Basins (LABs).

Risk Category	Risk	Description
Ecosystem & biological risks	**Risk 1:** Ecosystem and Fisheries Degradation and Damage	Impacts on DFO's ability to steward in managing and protecting fish habitats, lead in Canada's Ocean Strategy, and promote the sustainability of oceans and their resources.
	Risk 2: Changes in Biological Resources	Shifts in the distribution and productivity of DFO's managed resources (fish stocks, shellfish, and marine mammals) *e.g.*, under the *Fisheries Act*.
	Risk 3: Species Reorganization and Displacement	Altered distribution of species and restructuring of ecological communities in Canadian aquatic habitats, which could result in the introduction or spread of invasive species, as governed by the *Species at Risk Act*.
Operational & infrastructure risks	**Risk 4:** Increased Demand to Provide Emergency Response	Increased incidence of marine incidents due to climate change factors, which could strain the Canadian Coast Guard's (CCG) capacity to respond.
	Risk 5: Infrastructure Damage	Impacts on DFO's extensive infrastructure, which supports operational and scientific activities in marine and freshwater environments, including buoys, slipways, labs, navigation aids, small craft harbours, and aquaculture facilities.
	Risk 6: Changes in Access and Navigability of Waterways	Impeded access caused by changes in sedimentation, water levels, severe weather, wave energy, icebergs, and sea ice.

Table A4.2. A list of all needs identified in this report and the climate change-related risks (Table A5.1; DFO 2005, DFO2013a,b,c,d) that they address. Given the broadness of the risk categories descriptions (Table A4.1), the specific needs often addressed several risks. The main risk(s) addressed by a given need was(were) identified by a '**X**', while risks that would only be partially or somewhat addressed by fulfilling the need were identified by 'o'. This table, while somewhat subjective, can support managers in identifying the expert-identified science and cross-sectoral needs that correspond to the risks impacting their mandated activities, which can subsequently support cross-sectoral discussions to strategize and prioritize the fulfilment of those needs.

Theme	Jurisdiction	Need	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5	Risk 6
Monitoring	DFO-EOS	Further develop community-led monitoring (including Indigenous contributions) to support assessment/adaptive planning for change, especially in Arctic.	o	**X**	o			o
		Improve monitoring of the open-water season in the Arctic.	o	o	o	o		**X**
		Stabilize and improve existing core and long-term programs to include biological, chemical, near-shore, and coastal water monitoring.	**X**	**X**	**X**	o	o	o
		Invest in autonomous/real-time technologies to monitor key environmental and ecosystem parameters during multi-species surveys and oceanographic surveys.	**X**	**X**	**X**		o	o
		Assess the effectiveness of climate adaptive management actions (*e.g.*, management of shifting fisheries or establishment of conservation areas).	o	**X**	o		**X**	
		Obtain baseline data for important species, especially Species at Risk (SAR), habitat-forming species (*e.g.*, seagrass, kelps), deep-water ecologically-sensitive species (corals, sponges), and Aquatic Invasive Species (AIS; such as range and habitat requirements etc.).	**X**	**X**	**X**			
		Track distribution shifts of species of ecological importance (*e.g.*, commercial species, AIS, and SAR).	**X**	**X**	**X**			
		Expand monitoring of essential climate variables across all regions, including temperature, salinity, dissolved oxygen, and pH (and impacts of changes).	**X**	**X**	**X**		o	
		Strengthen monitoring necessary to fill baseline gaps for habitat and species of interest, and identify climate change risks, impacts, and vulnerabilities.	**X**	**X**	**X**			
		Maintain ecosystem monitoring to support ecosystem assessments.	**X**	**X**	**X**			
		Standardize methods to monitor climate change impacts on marine conservation objectives.	**X**	o	o			
		Sustained monitoring to determine local climate baseline and variability (*e.g.*, extremes, sea level, waves, storm frequency and strength) and to support modelling of environmental change and risk to infrastructure.				o	**X**	o
		Enhance seasonal oceanographic monitoring by leveraging autonomous technologies.	**X**	**X**	**X**	**X**	**X**	**X**
		Invest in Canadian Arctic network (nodes) of observation.	**X**	**X**	**X**			**X**
		Develop and maintain a system of ocean observation stations to monitor key environmental and ecosystem parameters with (near) real-time data production.	**X**	**X**	**X**			**X**
		Strengthen and stabilize monitoring on ocean chemistry to ensure long-term sustainability and equity among regions.	**X**	**X**	**X**		o	

		Strengthen in-house analysis capabilities (taxonomy, ocean/carbonate chemistry).	X	X	X			
		Improve monitoring of physical oceanography in high-risk shipping areas.				X		X
		Seasonal environmental monitoring to support emergency response.	o			X		o
		Maintain monitoring of sea level change with the DFO CHS national tide gauge network.					X	X
		Improve coastal mapping, dynamic charts, and real-time observations.	x			X	X	X
	DFO cross-sectoral	Baseline condition assessments for recovery planning in the context of environmental emergencies.	X	o	o	o		
		Continued support for SAR and AIS monitoring programs.	X	X	X			
		Maintain ongoing partnerships with provincial agencies who lead fish and aquatic habitat monitoring programs within Operations and Policy sectors.	X	X	X			
		Strengthen Interdepartmental/International collaboration to support monitoring related to marine Carbon Dioxide Removal (mCDR) activities.	X					
		Inventory of Real Property holdings in freshwater environments to support climate change risks assessments.					X	
	Cross-departmental	Monitor freshwater habitat, hydrography, biodiversity.	X	X	X			o
		Improve erosion and sediment monitoring in coastal zones.					X	X
		Increase land-water interaction monitoring (*e.g.*, nutrient fluxes, sediment transport, etc.).	o	X	o		X	o
Modelling	DFO-EOS	Keep climate-scale oceanographic model projections and ocean circulation models up-to-date, and improve model projection downscaling at relevant scales for decision making (*e.g.*, near shore), including dynamical and statistical downscaling.	X	X	X	X	X	X
		Create feedback loops to connect observational data and modelling efforts through model development and evaluation.	X	X	X	X	X	X
		Advance long-term climate projection models alongside forecasting (which may be more seasonal, annual) for ocean-climate, coastal hazards, navigation, and incident response, including floods, waves, and storm surges.	X	X	X	X	X	X
		Improve accessibility of model outputs to scientists, managers/decision makers, and public.	X	X	X	X	X	X
		Characterize the predictive skill and uncertainty of physical oceanography and drift models as circulation patterns evolve under climate change.		X		X		
		Species distribution models and forecasting of key aquatic species populations – such as Aquatic Invasive Species, ecologically important habitat-forming species like kelps and seagrass, species at risk, and harvested species – to project changes in their distribution, productivity, abundance, and/or biomass.	X	X	X			

		Improve downscaling (*i.e.*, horizontal and vertical resolution) of biogeochemical and ecosystem models at relevant scales for decision making.	X	X	X		o	
		Develop future scenario projection products from climate-scale biogeochemical, physical, and ecological models.	X	X	X	o	o	o
		Conduct climate vulnerability/risk analyses of the impacts of future physical and biogeochemical conditions (*e.g.*, high temperature, low pH, low dissolved oxygen, harmful algal blooms) on carrying capacity and species/communities of interest.	X	X	X			
		Modelling, predictions, and risk assessments for extreme events.	X			X	X	X
	DFO cross-sectoral	Formalize cross-departmental partnerships for sharing modelling expertise, service provision, and data management responsibilities (*e.g.*, Memorandum of Understanding with ECCC).	X	X	X	X	X	X
		Maintain and enhance partnerships with other agencies and academics conducting predictive hydrographic and ecological modelling in freshwater.	X	X	X	X	X	X
	Cross-departmental	Traffic and boater behaviour forecasting/projections (*e.g.*, due to ice melt and changes in ocean circulation patterns) to support risk assessments for species at risk and invasive species.			X	o		o
		Improve modelling to understand permafrost thaw and implications for aquatic ecosystems.	X	X	X			o
		Improve climate-hydrography modelling for freshwater (*e.g.*, predictions of warming and flow).	X	X	X	X	X	X
		Coastal erosion and sediment transport modelling in the coastal zone.					X	X
		Continue support for particle and drift modelling is essential for ECCC, DFO, and CCG to improve predictive skill to support maritime safety, search and rescue, and environmental response as physical ocean conditions change.				X		o
Research	DFO-EOS	Conduct integrated ecosystem assessments (research, monitoring, modelling, and analyses) to address the impacts of climate change across a broad range of species.	o	X	o			
		Evaluate species and habitat vulnerability to changes in vessel/boat traffic patterns in marine and freshwater habitats.	X	o	X			
		Improve understanding of species responses to climate-driven change (acidification, temperature, freshening, extremes) and anthropogenic habitat change (marine Carbon Dioxide Removal), especially multi-stressor effects at all phases of species' lifecycles, with a focus on key resource populations.	X	X	X			
		Invest in assessing biodiversity and baselines in freshwater environments.	X	X	X			
		Develop and conduct freshwater climate change vulnerability assessments.	X	X	X		o	o
		Explore climate change effects on interactions across Earth system spheres (*e.g.*, land-ocean, terrestrial-aquatic, etc.), including near shore oceanography.	X	X	X		X	X
		Further explore climate change impacts on predator-prey interactions and life cycle timing (physical and biogeochemical phenology).	X	X	X			

		Improve understanding and prediction of invasive species range expansions and their impacts on vulnerable species and ecosystems.	X	X	X			
		Improve understanding of warming/freshening and borealization in the Arctic, with a focus on fisheries priority species or ecosystems to support community adaptation.	X	X	o			
		Systematic assessment of risk and vulnerability of resources.	X	X	o		o	
		Weave Indigenous knowledge and knowledge tools with DFO research.	X	X	X			
		Investigate the frequency, strength, and duration of extreme events and their impact on and recovery potential of various marine species.	X	X	X	o	X	o
		Conduct coastal community vulnerability assessments.	X	X	X	X	X	X
		Expand research on nature-based climate solutions (managed and unmanaged) including carbon burial rates and carbon cycling.	X					
		Improve understanding of coastal buffering capacity (alkalinity, salinity, hypoxia).	X					
		Test the effectiveness of existing adaptation recommendations in freshwater.	X				o	
		Improve understanding of the impacts of changing ocean circulation and sea ice conditions on marine operations.				X		X
		Improve understanding of contributing factors to global and regional mean sea level rise (*e.g.*, role of changes in the Antarctic and Greenland ice sheets).					X	X
	DFO cross-sectoral	Develop interdisciplinary teams, including Indigenous Knowledge holders, that integrate environmental, infrastructure, ecosystem, and socioeconomic expertise, at appropriate scales, to enhance the understanding of climate effects (*e.g.*, strengthen engagement with policy and economics to improve risk assessments).	X	X	X	X	X	X
		Improve science-policy interface so that investments can be prioritized to address current knowledge gaps that will inform management decisions.	X	X	X	X	X	X
		Evaluate wind farm impacts to Atlantic coastal resources (*e.g.*, electromagnetic field impacts on fisheries resources).	X	X	X			
		Assessments of AIS impacts on infrastructure.			o		X	
		Assess the effects of extreme weather events, ice cover changes, ocean chemistry shifts, and storms on infrastructure.					X	
		Evaluate the impact of ocean chemistry changes on CCG vessels and Small Craft Harbours (SCH) infrastructure, particularly steel structures.					X	
		Advance climate-resilient infrastructure research, including testing and experimental design.					X	
		Cost-benefit economic analysis of SCH infrastructure that are repeatedly damaged – need for internal policy for cost/benefit of maintaining infrastructure.					X	
	Cross-departmental	Conduct research on impacts of coastal permafrost thaw on aquatic ecosystems.	X	X	X			o
		Research for improved ship routing under a changing climate.				X		X

		Research impacts of weather changes on silt load.					X	x
		Evaluate vessel design under new/changing conditions.				X	x	x
Knowledge mobilization	DFO-EOS	Enhance decision support tools (*e.g.*, visualization and autonomous data summarization tools) for ongoing science advice.	X	X	X	X	X	X
		Enhance science-policy communication to improve science support for development of adaptation and/or mitigation tools/techniques/approaches.	X	X	X	X	X	X
		Improve the openness, accessibility, and overall management of data, model output products, research outputs, and scientific advice to better address client needs.	X	X	X	X	X	X
		Enhance capacity for data management and dissemination of oceanographic, biogeochemical, and ecological model outputs.	X	X	X	X	X	X
		Develop multi-disciplinary, predictive, adaptive, interactive tools that integrate, synthesize, and visualize/map data (including forecasting and vulnerability prediction systems, and syntheses) to enhance accessibility, support decision making (tailored), and improve internal (*e.g.*, links between climate research scientists and stock assessment scientists) and external science communication.	X	X	X	X	X	X
		Produce synthesis of existing methods and tools, research outcomes, and science advice to estimate impacts of climate change on freshwater fishes and habitats.	X	X	X			
		Develop and refine tools to support long-term planning for coastal infrastructure and marine operations.				X	X	X
	DFO cross-sectoral	Communicate actionable science knowledge regarding climate change risks to management sectors.	X	X	X	X	X	X
		Integrate data sources across data repositories at large (including International repositories).	X	X	X	X	X	X
		Strengthen science-policy interface for climate change.	X	X	X	X	X	X
		Increase international, intergovernmental, and inter- and intra-departmental cooperation for climate-smart governance of aquatic ecosystems.	X	X	X			
		Improve collaborations with Indigenous communities and organizations to support community-based monitoring and research, as well as mobilization of model predictions to support community adaptation.	X	X	X			
		Increase science-policy and science-client communication and data sharing within and between Federal, Provincial, Territorial, and Indigenous governments.	X	X	X	X	X	X
		Provide technical science support for tool delivery and on-going training for management sectors.	X	X	X	X	X	X
		Develop rapidly adaptable policies and frameworks.	X	X	X	X	X	X
		Communicate economic risk over time scales through websites, Fisheries Science Advisory Reports, marine conservation reporting, etc.		X			x	
		Modernize existing tools where applicable (*e.g.*, CIVI, CAN-EWLAT).	X	X	X	X	X	X
		Develop understanding of climate change impacts on management processes.	X	X	X	X	X	X

		Advance development of climate-resilient infrastructure, contaminated site management strategies, environmental emergency response, protection measures, and shipping plans, using climate prediction models, in marine and fresh waters.				X	X	X
		Update reference levels for tide tables and charts, particularly for nearshore environment, and provide support and tools for Canadian Hydrographic Services (CHS) to manage growing vessel traffic, including traffic zone regulation and compulsory reporting.				X	X	X
		Develop a strategy to integrate science into marine response planning under climate change.	x			X		
	Cross-departmental	Formalize a Memorandum of Understanding (MOU) for ocean-climate modelling and data sharing with ECCC.	X	X	X	X	X	X
		Enhance capacity to provide real-time accessibility of ice-ocean data for community safety and decision making.				X		X

Appendix 5: Acronyms Index

ACCASP – Aquatic Climate Change Adaptation Services Program

AIS – Aquatic Invasive Species

CAN-EWLAT – Canadian Extreme Water-Level Adaptation Tool

CCG – Canadian Coast Guard

CCS – Climate Change Science

CHS – Canadian Hydrographic Service

CIMP – Cumulative Impact Monitoring Program

CIVI – Coastal Infrastructure Vulnerability Index

CONCEPTS Canadian Operational Network of Coupled Environmental Prediction Systems

CSAS – Canadian Science Advisory Secretariat

CSRF – Competitive Science Research Fund

DFO – Department of Fisheries and Oceans (Fisheries and Oceans Canada)

DOAP – Domestic Ocean Adaptation Policy

EAFM – Ecosystem Approach to Fisheries Management

ECCC – Environment and Climate Change Canada

EOS – Ecosystems and Oceans Science Sector

LAB – Large Aquatic Basin

mCDR – marine Carbon Dioxide Removal

MOU – Memorandum of Understanding

MPO – Pêches et Océans Canada

NCR – National Capital Region

NOAA – National Oceanic and Atmospheric Administration

OSB – Ocean Science Branch

SAR – Species at Risk

SCH – Small Craft Harbours Sector

SPERA - Strategic Program for Ecosystem-based Research and Advice

UNFCCC – United Nations Framework Convention on Climate Change