

Development and application of a resilience framework to assess climate consideration in Canadian fisheries management

Kayla M. Hamelin, Karen L. Hunter, Nancy L. Shackell, Daniel G. Boyce, Blair J.W. Greenan, Nicolás Talloni-Alvarez, Natalie C. Ban, Jenn M. Burt

Science Branch, Maritimes Region
Fisheries and Oceans Canada
Bedford Institute of Oceanography
1 Challenger Drive
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Kayla M. Hamelin^{1,2}, Karen L. Hunter³, Nancy L. Shackell⁴, Daniel G. Boyce⁵, Blair
J.W. Greenan⁴, Nicolás Talloni-Alvarez^{1,2}, Natalie C. Ban¹, Jenn M. Burt²

⁴ Bedford Institute of Oceanography
Fisheries and Oceans Canada
Dartmouth, NS, B2Y 4A2

¹ Department of Environmental Studies
University of Victoria
Victoria, BC, V8P 5C2

² Nature United
Toronto, ON, M5A 3X9

³ Pacific Biological Station
Fisheries and Oceans Canada
Nanaimo, BC, V9T 6N7

⁵ Wild Ocean Research
Cow Bay, NS, B3G 1K9

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ABSTRACT

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Managing living natural resources in a changing climate is a complex challenge requiring consideration of all available capacities and resources. We developed an institution-based resilience framework and survey tool designed to assess how Fisheries and Oceans Canada (DFO) commercial fish stock management is situated to respond to climate change. A collaboration of cross-departmental and external researchers piloted the Fisheries Management Assessment of Climate Consideration (FiMACC) framework and survey for 30 commercial fish stocks within the DFO Maritimes Region. We gathered responses from departmental scientists and managers to explore how climate considerations are incorporated into fisheries management across resilience attributes, including data and scientific analyses (i.e. Information, Analysis and Integration), participation, transparency (i.e. documentation of data accessibility, analysis and decision-making), responsiveness, capacity for action, and learning . The highest score across resilience attributes was for “Participation”, followed by “Information” demonstrating commitment to scientific endeavours and engagement from the broader fisheries community. Many of the stocks studied in this pilot study scored lower on “Analysis and Integration”; a main component of the Information attribute. Most stocks scored low to moderate on “Transparency , reflecting limited data accessibility, supporting analyses, and/or documented management processes. The scores for “Responsiveness” and “Capacity for action” suggest that these attributes provide an opportunity for improving resilience. The FiMACC framework and survey yield an informational synthesis product and offer a repeatable approach for examining resources and actions addressing climate risks to fisheries management. The assessment output helps identify challenges and opportunities for improving fisheries management adaptation preparedness, at the individual stock level and, more broadly, from a resilience planning perspective. The Maritimes FiMACC pilot allowed for the operationalization of this assessment, providing valuable insights into how to refine the survey and demonstrating its potential utility for tracking adaptation over time, in other DFO regions, or in other jurisdictions. Overall, the FiMACC framework and survey approach demonstrates the value of institutional self-assessment in supporting resilient and adaptive fisheries management.

RÉSUMÉ

Hamelin, K.M., Hunter, K.L., Shackell, N.L., Boyce, D.G., Greenan, B.J.W., Talloni-Alvarez, N., Ban, N.C., Burt, J.M. 2026. Development and application of a resilience framework to assess climate consideration in Canadian fisheries management. Can. Tech. Rep. Fish. Aquat. Sci. 3815: v + 74 p. <https://doi.org/10.60825/2ydd-8a84>

La gestion des ressources naturelles vivantes dans un climat changeant est un défi complexe qui exige la prise en compte de toutes les capacités et ressources disponibles. Nous avons élaboré un cadre de résilience axé sur les institutions et un outil d'enquête conçu pour évaluer comment Pêches et Océans Canada gestion des stocks de poissons commerciaux (MPO) est en mesure de répondre aux changements climatiques. Une collaboration de chercheurs interministériels et externes a mis à l'essai le cadre et le relevé de l'évaluation de la gestion des pêches en fonction des considérations climatiques pour 30 stocks de poissons commerciaux dans la région des Maritimes du MPO. Nous avons recueilli les réponses des scientifiques et des gestionnaires du Ministère pour explorer comment les considérations climatiques sont intégrées dans la gestion des pêches pour l'ensemble des attributs de la résilience, y compris les données et les analyses scientifiques (c.-à-d. l'information, l'analyse et l'intégration), la participation, la transparence (c.-à-d. la documentation de l'accessibilité des données, l'analyse et la prise de décisions), la réactivité, la capacité d'action et l'apprentissage. La note la plus élevée pour tous les attributs de résilience a été attribuée à la « Participation », suivie de la note « Information » démontrant l'engagement envers les efforts scientifiques et l'engagement de la communauté des pêcheurs au sens large. De nombreux stocks étudiés dans le cadre de cette étude pilote ont obtenu de moins bons résultats en matière d'analyse et d'intégration ; un composant principal de l'attribut Information. La plupart des stocks ont obtenu une note faible à modérée pour la « transparence », reflétant l'accessibilité limitée des données, les analyses à l'appui et/ou les processus de gestion documentés. Les notes attribuées à la « Réactivité » et à la « Capacité d'action » suggèrent que ces attributs offrent une occasion d'améliorer la résilience. Le cadre et l'enquête du FiMACC produisent un produit de synthèse informationnelle et offrent une approche reproductible pour examiner les ressources et les mesures visant à faire face aux risques climatiques pour la gestion des pêches. Les résultats de l'évaluation aident à cerner les défis et les possibilités d'amélioration de la préparation à l'adaptation à la gestion des pêches, au niveau des stocks individuels et, plus largement, du point de vue de la planification de la résilience. Le projet pilote FiMACC des Maritimes a permis l'opérationnalisation de cette évaluation, fournissant des informations précieuses sur la façon d'affiner l'enquête et démontrant son utilité potentielle pour le suivi de l'adaptation au fil du temps, dans d'autres régions du MPO ou dans d'autres administrations. Dans l'ensemble, le cadre et l'approche d'enquête du FiMACC démontrent la valeur de l'autoévaluation institutionnelle pour soutenir une gestion des pêches résiliente et adaptative.

1. INTRODUCTION

Contemporary marine fisheries management systems have evolved over the last century to increasingly consider the effects of key anthropogenic environmental stressors on the viability of marine ecosystems and the resources they provide. This process is ongoing as management agencies adapt science, policy, and regulations to account for the complex interactions, multidimensional systems, and interrelated ecosystem, climate, and socioeconomic risks and impacts that drive fishery outcomes (Jentoft and Chuenpagdee 2009; Hare 2020; Roberts et al. 2024). Recognizing that stressors on marine systems can cause disturbance or lead to significant changes, there is growing interest in determining how fisheries social-ecological systems can exhibit resilience to drivers of change (Mason et al. 2021; Maltby et al. 2023; Schiller et al. 2024; Eurich et al. 2024).

The concept of resilience was developed to understand the capacity of complex systems (e.g., ecosystems) to absorb and recover from change (Holling 1973). Resilience theory has also been extended to social systems, recognizing that human communities, like natural systems, face external stresses and disturbances (e.g., Nelson et al. 2007; Cote and Nightingale 2012; Berkes and Ross 2013; Cinner and Barnes 2019). Social resilience can be defined as “the ability of [human] communities to cope with external stresses and disturbances as a result of social, political, and environmental change” (Adger 2000). Over time, this multifaceted concept of resilience has become a helpful lens through which to examine the degree to which interlinked social-ecological systems, such as fisheries, can prepare for, resist, cope with, recover from, and adapt to stressors (Pinsky and Fogarty 2012; Holsman et al. 2019; Maltby et al. 2023; Vogel et al. 2023; Eurich et al. 2024).

Models that use resilience as the core framing for assessing climate change risks and adaptive capacity have gained support and been applied in several fisheries contexts worldwide (Cinner et al. 2018; Cinner and Barnes 2019; Mason et al. 2021). For example, the resilience-based assessment model by Mason et al. (2021) has emerged as a well-supported and integrated framework that offers a heuristic process through which to explore the attributes that influence the resilience of a fishery to climate change with respect to its ecological (e.g., species abundance, age structure, genetic diversity, mobility, dispersal, plasticity, etc.), social (e.g., economic opportunity, social capital, place attachment, infrastructure, knowledge diversity, etc.), or institutional/governance dimensions (e.g. responsiveness, accountability, transparency, participation, leadership, etc.). This model has been applied to inform analyses of global fisheries case studies (Eurich et al. 2024) and assess real world strategies to enhancing U.S. regional fisheries management systems to climate change (Golden et al. 2024 a, b). This resilience framing is helpful in that it can be applied to specific contexts to identify strengths and weaknesses across various system attributes that influence desired outcomes, including healthy marine ecosystems, sustainable fishery resources, and human benefits for the future (per e.g., Global Biodiversity Framework, UN Sustainable Development Goals). Assessing these attributes supports the investigation of how the resilience of a fishery – for example, the

institutional subsystem of a fisheries system – may be strengthened or compromised by a particular stressor.

Anthropogenic climate change has emerged as a key stressor on fishery systems, including those in Canadian waters, requiring adaptations to promote fishery resilience (Pinsky et al. 2018; Free et al. 2019; Bryndum-Buchholz et al. 2021; Woods et al. 2021). Climate change is associated with long-term warming, acidification, sea ice loss, and deoxygenation of the global ocean (Harley et al. 2006; Feely et al. 2009; Breitburg et al. 2018; IPCC 2023), as well as greater intensity and duration of climate extreme events, including marine heatwaves (Boldt et al. 2020; Cheung and Frölicher 2020; Bellquist et al. 2021). These changes are associated with various potential ecological impacts, including shifting geographic distributions of species, systemic reductions in organism body sizes, altered trophic dynamics, modified phenology cycles, and changes in metabolic rates (Scheffers et al. 2016). As a result, there are many potential consequences for fisheries - including changes in stock recruitment, mortality, and overall productivity of target species – which all have important social, cultural, economic, and governance implications (Brander 2010; Lam et al. 2016a; Spijkers and Boonstra 2017; Free et al. 2019; Marushka et al. 2019; Lotze et al. 2019; Boldt et al. 2020; Whitney et al. 2020; Palacios-Abrantes et al. 2020; Gill et al. 2023; Lawlor et al. 2024).

Fisheries have always been characterised by uncertainty and variability, resulting from the complex and dynamic nature of fishery social-ecological systems. However, ‘modern’ fisheries management has long assumed that the environment, and key productivity terms associated with it, were stationary or linear over the long term (i.e., their statistical properties remained constant) (Hilborn and Walters 1992). In reality, fisheries have fluctuated greatly over time, and ocean climate drivers may induce additional incremental changes, leading to shifts in longer-term means and variance, as well as sudden, unpredictable extreme events (Frölicher and Laufkötter 2018; Oliver et al. 2018; IPCC 2019). For example, anomalous warm water masses observed in the Atlantic (2012) and Pacific (2013, 2019) have led to significant ecological and fisheries disruptions (e.g., reductions in target Maximum Sustainable Yield; Free et al. 2019; Tai et al. 2024). Moreover, climate drivers interact with ecosystem or socioeconomic stressors that together may yield unexpected changes (Crain et al. 2008; Lam et al. 2016b; Holsman et al. 2017; Lawlor et al. 2024). Furthermore, the directionality of climate-driven changes will often involve ‘winners’ and ‘losers’ as different species, ecosystems, and human communities are affected in different ways (Madin et al. 2012; Bates et al. 2014; Gaines et al. 2019; Lawlor et al. 2024), potentially exacerbating existing and persistent fisheries challenges (Runnebaum et al. 2023). As a result, the variability and uncertainty imposed by the changing climate on system resilience represents a fundamental challenge facing fisheries managers and fisheries management institutions.

Fisheries institutions play a significant role in the functioning of fisheries as social-ecological systems, establishing management structures, processes, and rules that influence both fished species and their ecosystems, as well as the humans and communities relying on fishing (Figure 1). However, knowledge on the extent to which management institutions are ready for climate adaptation remains limited (Biesbroek et al. 2013; Gupta et al. 2010; Termeer

2012; Berang-Ford et al. 2011). A large portion of the climate-fisheries literature focuses on the resilience and adaptation of the fish species and aquatic ecosystems, and associated management adaptation options (e.g., McClanahan et al. 2012; Hunter and Wade 2015; Stortini et al. 2015; Hare et al. 2016; Crozier et al. 2019; Boyce et al. 2021). Assessments of adaptation and resilience of the human fishing communities have also been undertaken for numerous jurisdictions (e.g., Allison et al. 2009; van Putten et al. 2014; Colburn et al. 2016; Greenan et al. 2019). However, understanding and assessing resilience characteristics of fisheries management institutions remains a missing element in fisheries assessment (Mason et al. 2021). Here, we focus on fisheries “institutions”, defined as the agencies, departments, and organizations responsible for fisheries management, recognizing that there are diverse ways to conceptualize institutions in the social science literature (Gupta et al. 2010).

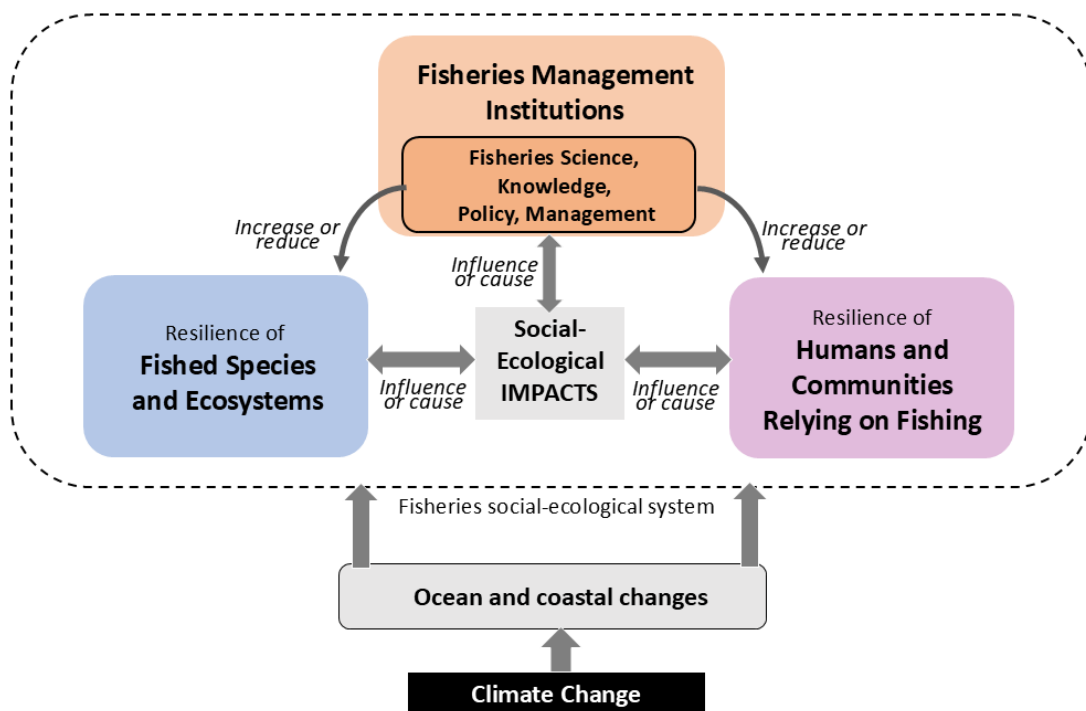


Figure 1: Within fisheries social-ecological systems facing a range of stressors (e.g., climate change, explored here), fisheries management institutions have a critical influence on the resilience of both fished species and their ecosystems, as well as the humans and communities relying on fishing.

Globally and across sectors, large regulatory institutions tend to be incremental and conservative in adapting to forces of change (Gupta et al. 2010; Fulton et al. 2020), and particularly to climate change (Miller et al. 2010; IPCC 2019). Often government-based, these institutions typically operate this way due to their responsibility to the public, substantial historical investments, the need for rightsholder / stakeholder buy-in, and their function to support stability over time (March and Olsen 2004; Gupta et al. 2010). However, institutional stability may come at the expense of the flexibility and nimbleness required to respond to a rapidly changing system under extreme and/or cumulative stressors (Craig et al. 2017;

Galappaththi et al. 2022). The uncertainty and instability associated with long-term and episodic climate stressors already make fishery assessment, consultation, decision-making, and policy integration challenging for fisheries institutions (Free et al. 2020; Lomonico et al. 2020). Preliminary efforts investigating climate consideration have sought to identify, understand, and address challenges and opportunities in these management systems (Comte and Pendleton 2018; Whitney and Ban 2019), sometimes referred to as building “climate-ready” fisheries (Pinsky and Mantua 2014; Wilson et al. 2018; Bell et al. 2020; Lomonico et al. 2020; Bryndum-Buchholz et al. 2021; see examples, Appendix 1). While the growing examples of actions to support climate consideration in fisheries management are encouraging, fisheries management institutions often do not focus on resilience in a pragmatic sense to understand where current institutional challenges and opportunities are emerging across their complex fisheries portfolios. Institutional adaptation would be well-informed by understanding how the existing organizational structures interact with climate considerations, toward the goal of managing for resilience.

By framing and assessing aspects of fisheries institutions that are implicated in climate change adaptation, it becomes possible to determine institution-level resilience to a considerable change-agent (Mason et al. 2021). This study presents a resilience-based evaluation of climate consideration within fisheries stock management by Fisheries and Oceans Canada (DFO) through the development and application of an assessment framework and survey – the *Fisheries Management Assessment of Climate Consideration* (FiMACC). We explore the degree to which the current fisheries management structures and procedures show attributes associated with resilience as a reflection of the institutional consideration and integration of climate change. This research is timely given that departures from normal physical ocean conditions are already affecting marine habitats and fisheries in all three ocean regions of Canada and are projected to continue over the foreseeable future (Greenan et al. 2019; Cheung and Frölicher 2020; DFO 2020; Bryndum-Buchholz et al. 2020; Boyce et al. 2021, 2024). This research is also timely, given that DFO has begun efforts to document ecological climate vulnerabilities (e.g., Shackell 2013; Hunter and Wade 2015; Greenan et al. 2018; Grant et al. 2019), understand how climate change is included in stock assessment (Pepin et al. 2020, 2022; Kulka et al. 2022), and explore conceptual frameworks for incorporating climate change into fisheries science advice (Duplisea et al. 2020, 2021; Pepin et al. 2020, 2022).

The FiMACC framework takes a resilience-based approach (adapted from Mason et al. 2021) to collecting and interpreting information regarding the degree to which DFO is incorporating climate considerations into their 1) fisheries monitoring and data collection, 2) scientific analysis and advice, and 3) management processes and decision-making, for individual fish stocks in a region. Through this evaluation, the FiMACC results illuminate stock-level management system insights regarding climate considerations that indicate strengths and challenges for institutional resilience, which can inform potential adaptation planning. We also characterize the broader institutional attributes that affect resilience in managing fisheries under increasing uncertainty from key (e.g., climate) stressors. In doing so, we offer a novel and pragmatic approach to compiling and synthesizing insights from different sectors within DFO to gain practical and operational insights that can inform resilience preparedness in a changing world.

2. METHODS

2.1 Resilience-Based Assessment Framework

The *Fisheries Management Assessment of Climate Consideration* (FiMACC) framework explores the capacity of a fisheries institution to consider and respond to climate change based on how the current management of fish stocks in Canada demonstrates resilience-related attributes. We developed this institutional assessment framework, survey, and synthesis approach to characterize how the current management of fish stocks takes into consideration climate change impacts and uncertainty. This, by necessity, included investigation of oceanographic, climate, and ecosystem (collectively, OCE) data and analyses (per Pepin et al. 2022) in addition to characterization of the broader knowledge-to-action process within the management system. While ecological data do not directly detect or measure climate change in the ocean in the way that “oceanographic” and “climate” data (“O” and “C”) do, they have been deemed essential to a comprehensive understanding of climate impacts on marine ecosystems, recognizing that cycles and forces beyond climate also influence ecological parameters (Pepin et al. 2022). Guided by federal fisheries managers, scientists, and policy experts, we piloted our approach using 30 fish stocks in DFO’s Maritimes Region. This work was led by a transdisciplinary team of cross-departmental DFO and external researchers working in a collaborative partnership.

As a first step, we derived key assessment criteria of relevance to climate resilience at DFO. The FiMACC framework was then designed to organize and link the stock-level assessment criteria to institutional attributes associated with resilience (Table 1). This framework structure was primarily informed by the framework developed by Mason et al. (2021), who compiled 38 literature- and expert-generated resilience attributes across ecological, socioeconomic, and governance dimensions of fisheries, categorized across five resilience domains (originally derived by Cinner et al. [2018]; Cinner and Barnes [2019]). We used the same five resilience domains to outline the key characteristics of resilience and form the overarching structure of our framework: Assets, Organization, Flexibility, Agency, and Learning (Table 1). We also identified eight institutional resilience attributes linked to these domains to guide our investigation (Table 1). Four of our resilience attributes were drawn directly from Mason et al. (2021): Participation, Transparency, Responsiveness, and Adaptation. We also expanded upon components and definitions within the Mason et al. (2021) framework to accommodate practical considerations of relevance to our institutional context. This resulted in the addition of three attributes (Information, Analysis & Integration, Communication) and the reframing of one attribute (Capacity for Action) that were not captured by Mason’s attributes but have importance in fisheries assessment and management at DFO. Together, these five resilience domains and eight institutional attributes provide a framework to identify and evaluate the features that influence how the management of fish stocks supports resilient fisheries under climate change (Table 1).

Table 1: Framework for Fisheries Management Assessment of Climate Consideration (FiMACC) survey, listing institutional resilience domains, attributes, and assessment criteria (see Appendix 3 table, which includes survey questions and assessment synthesis details). OCE = Ocean, Climate, and Ecological (data). ** Indicate assessment criteria that were able to be used in the assessment synthesis.

Resilience Domain	Institutional Resilience Attribute	Assessment Criteria
ASSETS	INFORMATION <i>Definition: Assets in the form of data or information which provide the foundation for a comprehensive understanding of the fishery system</i> <i>Rationale: Information assets are the foundation for understanding fishery systems and awareness of how they are changing with climate-related variability and impacts¹</i>	Overall degree of monitoring data available
		**Data types available (Stock), i.e., Biological parameters (Fishery-Dependent and Independent data)
		**Data types available (Ocean-Climate)
		**Data types available (Ecological)
		Existence of monitoring outside of DFO
	ANALYSIS AND INTEGRATION <i>Definition: Assets in the form of capacity, tools, and approaches to analyse and contextualize information assets</i> <i>Rationale: Using data and information to produce shared knowledge and science outputs allows for a synthesized understanding of the fishery system and climate interactions upon which to inform decisions and appropriate actions²</i>	**Incorporation of OCE data in stock assessment (and how)
		Other (not stock assessment) supporting analyses that consider OCE data
		OCE data types in stock assessment or supporting analyses
		**Use of complementary decision-support tools
		Existence of climate-related science / knowledge outside of DFO
ORGANIZATION	PARTICIPATION <i>Definition: The degree to which an institution empowers participants to share control in processes of decision-making, ranging from consultation to co-management</i> <i>Rationale: Participation aims to facilitate climate consideration and effective response by including diverse actors in knowledge-sharing, supporting legitimacy and compliance, and building trust among fisheries rightsholders and stakeholders³</i>	**Advisory committee participants, i.e., who provides input?
		Existence of stock co-management
		Managed by international treaty and/or organization
	TRANSPARENCY <i>Definition: Openness and accessibility of timely information and decision-making procedures</i> <i>Rationale: Transparency enables the free flow of fishery-related information to support learning and decision-making, which can support implementation</i>	Accessibility of monitoring data internal and external to DFO**
		Accessibility of supporting OCE analyses internal and external to DFO**
		Existence and type of rationale provided for decisions

¹ Pinsky and Mantua 2014; Bell et al. 2020; Pepin et al. 2020; Dorn and Zador 2020

² Bell et al. 2020; Mason et al. 2021

³ Leite and Pita 2016; Fraser and Kirbyshire 2017; Cvitanovic et al. 2018; Mason et al. 2021

	and perceived trustworthiness and legitimacy of decisions or actions that support responses to climate change ⁴	**Accessibility of decision rationale
FLEXIBILITY	RESPONSIVENESS <i>Definition: The sensitivity, readiness, speed, and accuracy with which a system can detect, process, and react to a stressor or changing trend</i> Rationale: Responsive fishery systems can resist and / or recover from disturbances through early detection and having structures/processes that enable the timely deployment of strategies, tactics, and actions ⁵	**Frequency of stock assessment completion + update
		**Frequency of fishery advisory committee meetings
AGENCY	CAPACITY FOR ACTION <i>Definition: Support and development of actors who mobilize and direct responses to disruptions and who take responsibility to act as necessary</i> Rationale: Leadership and staff are enabled to make use of available fisheries knowledge and resources to catalyze action for maintaining functionality in light of stressors ⁶	**Consideration of supporting OCE analyses in DFO Science advice
		**Consideration of external climate-related science and knowledge in DFO Science advice
		Existence of data collection barriers
		Existence of barriers to including OCE data in stock assessment
		Existence of barriers to taking climate-related management actions
LEARNING	COMMUNICATION <i>Definition: The transmission of knowledge and ideas to educate, establish a shared understanding, and/or mobilize the audience</i> Rationale: Communication (e.g., between scientists, managers, policymakers, fishery participants, and the public) is essential to building connections, collaboration, and consensus required to be responsive to climate change; Through regular and comprehensive communication channels, it is possible to establish shared visions, values, and pathways to operationalizing them ⁷	Manager awareness of climate issues
		**Methods used for communicating climate risks
		Nature of climate risks communicated
		Timeframe of climate risks communicated
	ADAPTATION <i>Definition: The ability to conduct an iterative process of continual innovation, testing, learning, and adjustment that facilitates action toward an objective</i>	**Climate-related management action response taken in last 5 years **Climate-related management action anticipated in next 5 years

⁴ Clark et al. 2015; Mason et al. 2021; Davis and Hanich 2022

⁵ Sheng 2009; Quentin Grafton 2010; Mason et al. 2021

⁶ Ostrom 2009; Gutiérrez et al. 2011; Crona et al. 2017; Mason et al. 2021

⁷ Maltby et al. 2023

	Rationale: Taking actions in fisheries management and reviewing them supports institutional capacity to experiment, learn, and adapt in the face of uncertainty and complexity ⁸	Existence of process to review stock management at end of season
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2.2 Operationalizing the Assessment Framework

Our FiMACC assessment framework is grounded in theoretical concepts, but is also designed for application in the operational context at DFO. Our assessment survey is conceptually modelled after the approach used in the DFO Sustainability Survey for Fisheries (SSF; <https://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/survey-sondage/index-en.html>). The SSF covers 199 fish stocks managed by DFO, and has been conducted to track fish stock health and the implementation of Sustainable Fisheries Framework policies (<https://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/overview-cadre-eng.htm>). The SSF began in 2015 and shows a precedent for, and the usefulness of, a qualitative approach to assessing fisheries status. We aimed to design a survey that could similarly provide an informational synthesis product showing the “climate consideration” status of individual fish stocks managed by DFO across key institutional resilience attributes. As such, the FiMACC framework and survey seek to expand upon the department’s existing interest in gathering information that informs the overall sustainability of fish stocks in Canada.

To generate the FiMACC assessment criteria and survey questions, we developed a simplified operational model for fisheries science and resource management within DFO (Figure 2; adapted from Boyce et al. 2023). This model describes and compartmentalizes four primary areas where climate considerations could be integrated: 1) *Information gathering*, 2) *Analysis and generating science advice*, 3) *Management processes and decision-making*, and 4) *Operationalizing decisions* (Figure 2). Distinguishing these DFO fisheries management components supported our survey development in several ways. First, these components vary across individual fish stocks, which is our desired unit of analysis for the assessment. As such, we did not focus on assessing political mandates, policies, or legal instruments which frame institutional objectives and priorities at a higher, overarching level (Figure 2). However, we recognize these elements are critical in influencing institutional climate adaptation on a larger scale.

⁸ Quentin Grafton 2010; Plagnyi et al. 2011; Davidson et al. 2013; Ojea et al. 2017; Bell et al. 2020; Mason et al. 2021

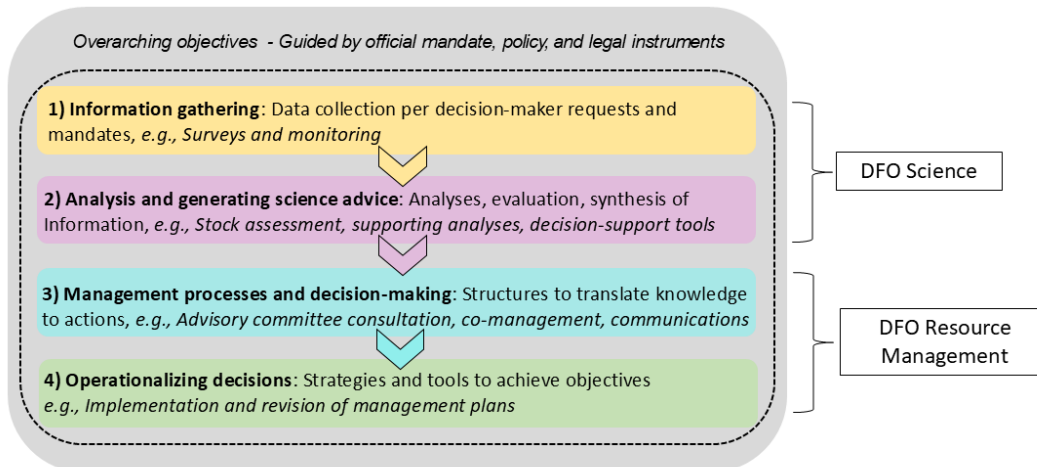


Figure 2: Simplified operational model for fisheries science and management within Fisheries and Oceans Canada (adapted from Boyce et al. 2023). Components 1 and 2 are the purview of DFO Science staff, and components 3 and 4 are the purview of DFO resource managers.

The four operational institution components enabled a convenient survey deployment because responses relating to information gathering, analysis, and science advice (components 1 and 2) are the purview of DFO Science personnel, while information about management processes and decision-making (components 3 and 4) are the purview of DFO Resource Management personnel (Figure 2). We developed a separate survey module for the Science versus Resource Management respondent groups, which provided the information for our fish stocks of interest. Finally, the operational model informed how our survey questions were developed. Under each operational component, we developed a series of questions that form a decision-tree structure (i.e. related questions follow a logical flow, see Appendix 2) and investigate numerous aspects of how climate could be considered in a DFO operational context. Most questions seek to gain insight into the presence or absence of various climate considerations throughout the science and management process, while others request the respondent's perceptions, for example of barriers and enabling conditions, or whether a stock is data-rich, moderate, or poor. Additional questions also helped characterize the management context for each fish stock, providing information about the stock status and trends, types of fisheries operating (e.g., commercial, recreational, Indigenous), gear types used, and whether the stock is captured as bycatch.

The final FiMACC framework results from integrating the theoretical climate resilience framing with the operational DFO management context that informed the survey design (Figure 3). The survey questions each link to a set of assessment criteria under an institutional resilience attribute (with rationale for climate linkage rooted in peer-reviewed literature; see Table 1 and Appendix 3), further nested under the resilience domains. All survey questions were developed with consultation, review, and input from DFO scientists and resource managers (from the National Capital, Pacific, Maritimes, and Newfoundland and Labrador Regions), national Policy and Economics Sector staff, and members of the Ecosystem Approach to Fisheries Working Group. A draft of the survey module targeting resource

managers was fully piloted by Maritimes Region DFO resource management staff before it was refined to the final suite of survey questions. The FiMACC survey consisted of 68 multiple-choice and free-text questions (to capture additional unique responses shared, where relevant), with 44 targeting the Science respondents and 24 for the Resource Management respondents. The survey was designed for an online platform using the Adobe Dreamweaver web development tool, hosted on a secure server and accessed on a website (www.climateadaptsurvey.ca).

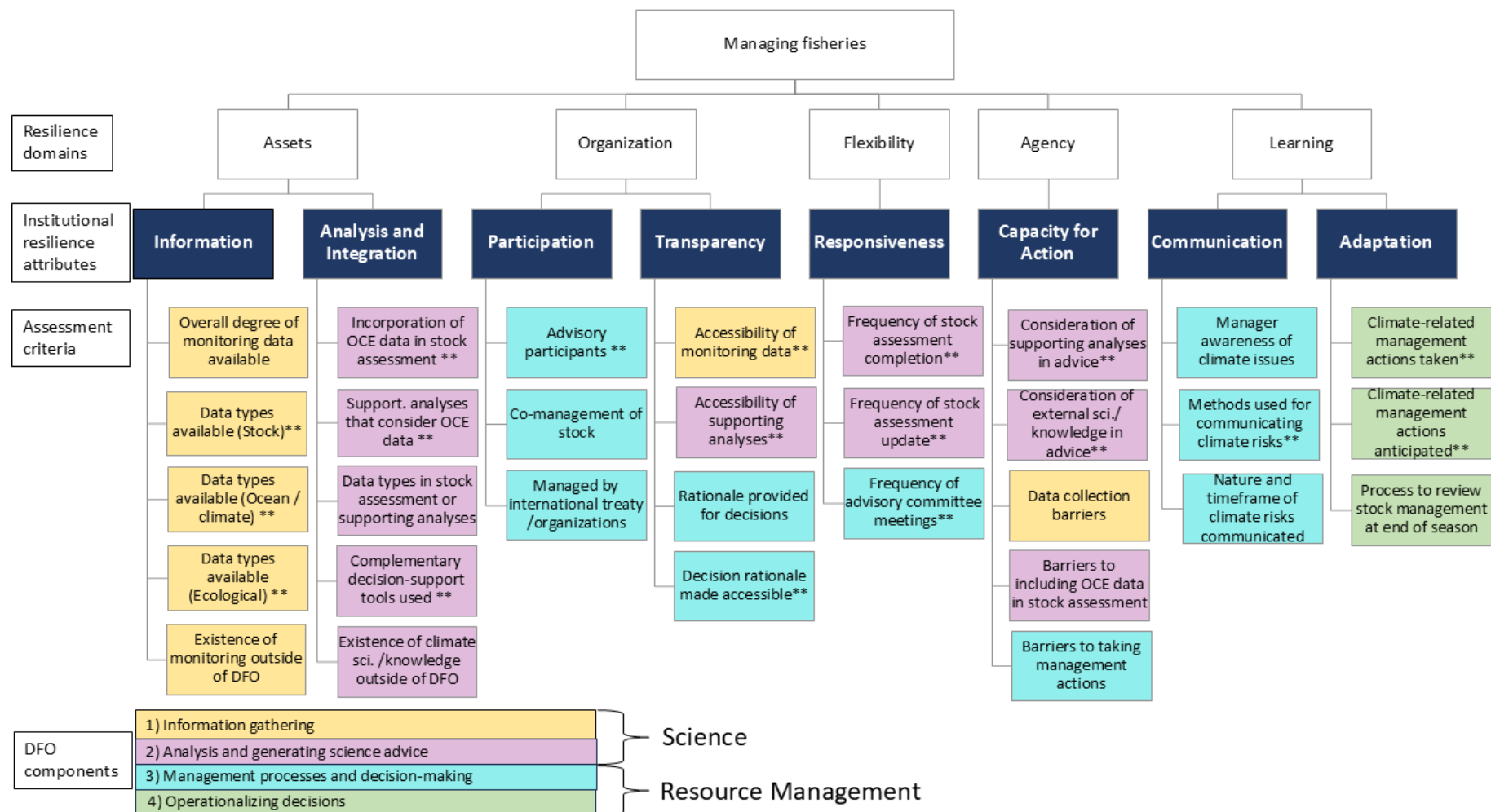


Figure 3: Framework for the Fisheries Management Assessment of Climate Consideration (FiMACC). “Assessment criteria” (coloured boxes) and survey questions (not pictured here) are organized by institutional resilience attributes (dark blue boxes) that are nested within five resilience domains (white boxes). Starred (**) assessment criteria were able to be used in the FiMACC survey scoring synthesis, although survey responses from all criteria are described in Results. The

*colours of the assessment criteria boxes correspond with a specific component of the DFO fisheries science and resource management process (see figure inset).
OCE indicates Ocean, Climate, and Ecological (data).*

2.3 Maritimes Region Pilot

The FiMACC survey was piloted for 30 commercial fish stocks (Appendix 4) within DFO's Maritimes Region (Figure 4). This area encompasses part of the ancestral and unceded territory of the Mi'kmaq, Peskotomuhkati, and Wolastoqiyik Peoples. The Maritimes regional context was selected because of the climate effects facing Atlantic Canadian fisheries (Shackell et al. 2010; Oceans North 2021, 2024; Bernier et al. 2023; Boyce et al. 2024) and the foundation of climate analysis already established by staff in this region (Greenan et al. 2019; Boyce et al. 2021, 2023; Pepin et al. 2022). We used the same 30 fish stocks assessed under DFO's Sustainability Survey for Fisheries in the Maritimes for continuity. This list excludes species that are managed outside of the Maritimes Region (e.g., bluefin tuna, Atlantic mackerel), some species at risk (e.g., Atlantic sturgeon, Atlantic whitefish), and some species that are in emerging fisheries (e.g., hagfish, Jonah crab).

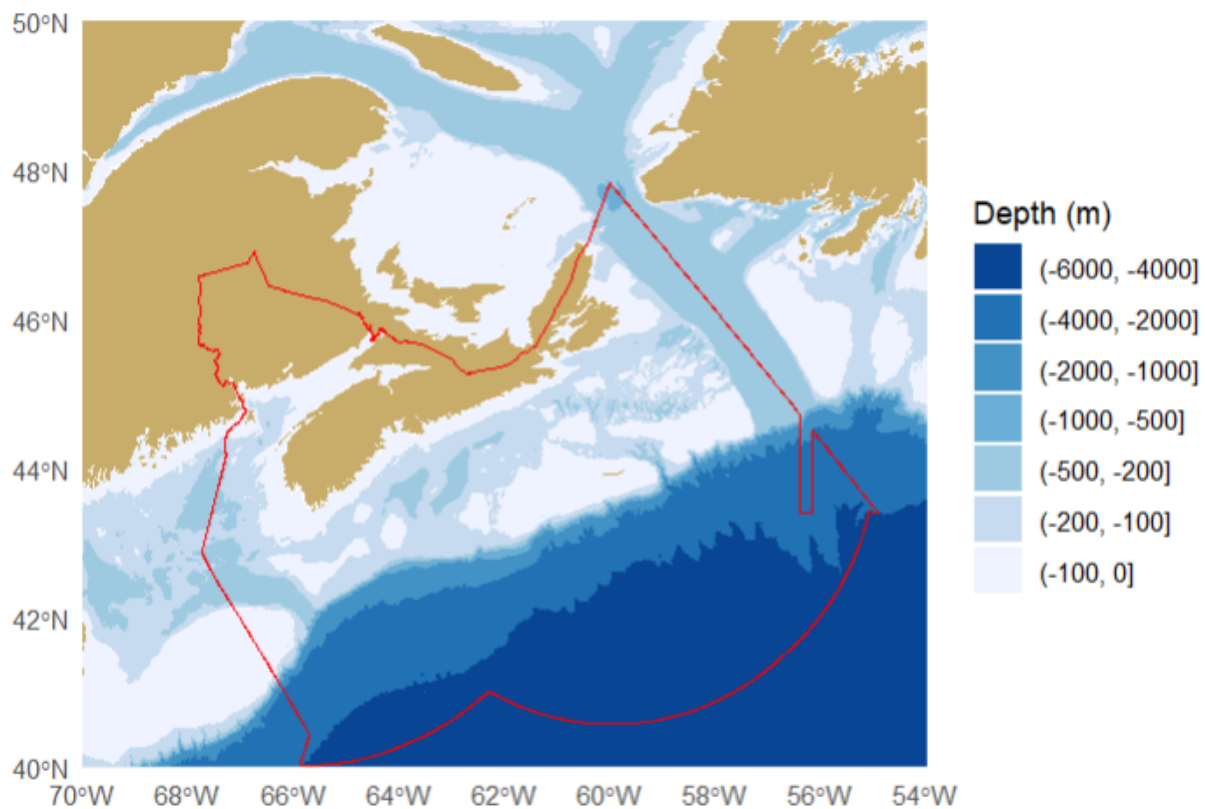


Figure 4: Map of the Maritimes Region managed by Fisheries and Oceans Canada.

The online survey was distributed via email to leads identified within the DFO Science and Resource Management branches responsible for managing the 30 stocks. Responses were collected between December 2022 and May 2023. Most commonly, one scientist responsible for a stock would complete the Science survey and one manager responsible for the stock would

complete the Resource Management survey. However, in several cases, some scientists or managers handled multiple stocks (of the same or different species) and thus completed the survey multiple times for their respective stocks. We note that responses reflect the experience, perspective, and question interpretation of the given survey respondent. Research ethics approval was obtained from the lead author's academic institution, the University of Victoria (ethics #22-0563), and consent was obtained from each respondent at the beginning of each survey submission.

2.4 Analysis and Assessment Synthesis

The survey responses populated an online database that was exported to a spreadsheet for analysis using R (R Core Team 2024). For each of the 30 Maritimes fish stocks, data were compiled, visualized, and summarized for each of the assessment criteria under the eight institutional resilience attributes within the FiMACC framework. There were five stocks for which we did not receive DFO Science survey submissions, and so data visualizations discussed below will show an "X" indicating "no data" for these stocks. The designation "NA", per convention in data science, indicates missing data, i.e., that there was no response for that question from that stock. In our visual synthesis (described below), reasons for missing data are further specified, e.g., a respondent skipping a question or leaving part of an answer blank ("NR" = no response), not receiving a question based on one of their 'upstream' responses ("NP" = not possible), or, in one case, respondents missing a question because of the 'branching' nature of the survey structure ("E" = survey error). Free text responses were summarized to capture additional unique responses shared, where relevant.

To provide a high-level synthesis of the FiMACC assessment, we visualized the results for all stocks across a condensed suite of assessment criteria (i.e., a subset of survey questions) that spanned the eight institutional resilience attributes of the FiMACC framework. This subset was selected because not all assessment criteria lent themselves well to the analysis of categorical data required for our synthesis approach, but we made efforts to include as many as possible. We developed a 3-level semi-quantitative scoring scheme, where 1 represents a low degree of climate consideration, and 3 represents a high degree (Appendix 3). The subset of selected assessment criteria/survey questions to include in this synthesis exercise depended partially on the feasibility of assigning a 3-level 'score' to survey response data, in addition to how well a given criterion provided a reasonable representation of the institutional attribute. In some cases, the three scoring levels corresponded directly to the three levels in a multiple-choice question. In other cases, we assigned responses to three appropriate bins to both capture nuance in the survey responses and enable consistency and ease of interpretation (details in Appendix 3). To determine relative overall scores by resilience attribute and by stock group, a pie chart was developed for each attribute. These charts visualize the proportion of total scores to maximum possible scores (i.e., excluding counts of "NA" responses), considering that a minimum score would be "1" across all categories. A similar set of pie charts was constructed to synthesize across stocks for the five taxonomic / functional groups. The results of these syntheses are visualized in a single figure.

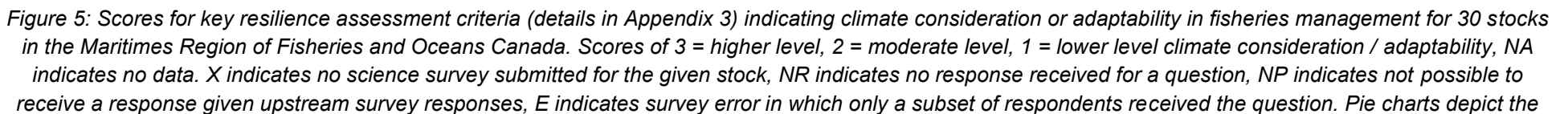
3. RESULTS

The *Fisheries Management Assessment of Climate Consideration* (FiMACC) assessment for 30 fish stocks in the DFO Maritimes Region was compiled from survey responses by 14 stock assessment scientists and 12 resource managers, reflecting that there were both scientists and resource managers responsible for multiple stocks. We did not receive responses to the Science survey for five stocks (Atlantic cod 4X5Y; Atlantic cod 5Zjm; Pollock 4X5; Redfish - Unit 3; Striped bass). Thus, results for these stocks came from the Resource Management survey alone. Results are sorted here by taxonomic / functional stock groupings: crustaceans (n=8), diadromous species (n=4), groundfish (n=9), pelagics (n=3), and molluscs (n=6). The 30 stocks considered represent a mix of Sustainable Fisheries Framework (SSF) 'status' categories across 'Healthy', 'Cautious', and 'Critical' levels, according to where the assessed stock biomass is in relation to the upper and lower limit reference points, or 'Uncertain' if data were insufficient to decide (Appendix 5a). Commercial fisheries mainly target these stocks, although food-social-ceremonial (FSC) fishing and (to a lesser extent) recreational fishing also occur for some of them (Appendix 5b). One exception is striped bass, which is exclusively a recreational and FSC fishery. Open-ended comments shared for this question noted communal-commercial and bycatch fisheries as additional types not captured by the multiple-choice options offered. Most Maritimes stocks have multiple gear types/fleets targeting them (Appendix 5c), and most stocks, except for lobster and the molluscs, are also caught as bycatch in other commercial fisheries (Appendix 5d).

3.1 FiMACC Assessment Synthesis

Highly variable climate consideration synthesis scores existed across resilience attributes and stocks, although some general patterns were discernible (Figure 5). The data revealed that the highest scores were found for the "Participation" attribute, although we acknowledge these scores were derived from a single assessment criterion investigating how many types of participants contributed to fisheries management. The "Information" attribute was the next highest scoring category, with the pelagic stocks exhibiting the strongest Information scores. This suggested that for Maritimes stocks, there was a relatively high number of datasets available, particularly fishery-dependent and independent data (first column, "Stock") and ocean-climate data (second column). However, for many stocks these higher Information scores did not correspond to higher scores under the "Analysis and Integration" attribute in this pilot study, mirroring other findings of this nature for the similar stocks (Pepin et al. 2022). A lower score for 'Analysis and Integration' indicated that available monitoring data were not necessarily integrated into stock assessments and supporting climate analyses. Stocks with higher scores included lobster, snow crab, sea scallop, and swordfish stocks, which revealed ocean, climate, and ecological (collectively referred to here as OCE per Pepin et al. 2022) data being used in analyses for climate-informed management. In this pilot study, most stocks had lower to moderate scores within the "Transparency" attribute as defined for this study), illustrating a limited documentation of the accessibility of existing data, supporting analyses, and management decision rationales. A notable exception was the higher data availability and accessibility for all sea scallop stocks. Relatively high scores are shown for the

“Responsiveness” attribute (), with many stocks exhibiting frequent stock assessments (e.g., lobster, snow crab, scallops) and relatively frequent advisory committee meetings (e.g., groundfish). Fewer data were available to score the “Capacity for Action” attribute (), mostly because for many stocks, responses were not possible (NP) due to the lack of existing supporting analyses or external science, and thus an inability to consider them in the science advice. The “Communication” () and “Adaptation” () attributes involved a mix of higher, moderate, and lower scores. Overall, the highly variable synthesis scores illustrate the importance of carefully exploring the individual assessment criteria within each attribute for a given stock (i.e., Section 3.2 – Survey Responses by Institutional Resilience Attribute). This more detailed investigation can capture the nuances of how current science and management processes and structures have different degrees of climate consideration or climate adaptability.



total synthesis score as a proportion of the maximum total synthesis score from key assessment criteria, summarized by institutional resilience attributes and by stock taxonomic / functional groups. OCE indicates Ocean, Climate, and Ecological (data).

3.2 Survey Responses by Institutional Resilience Attribute

3.2.1 Information

The “Information” attribute assesses both the perceived and realized (i.e., existing) level of raw OCE data and information available for each stock. Here we focused on scientific data, which we recognize excludes local or traditional knowledge systems, but reflects most current assets and operations within DFO at this time. Kulka et al. (2022) provides the definition of data categories (i.e., rich, moderate, poor) used in the FiMACC survey. More than half of the Science respondents identified their stocks as data “rich” for stock-related data (n=14, 56%) and ocean/climate data (n=13, 52%), while only 24% (n=6) selected “rich” for ecological data (Figure 6). Data “rich” was defined as having fishery-independent (i.e., from dedicated surveys) and fishery-dependent (i.e., catch) indices of abundance, data on age and/or size structure, independent data to estimate rates of change in growth or mortality rates and other biological data and/or knowledge. These data are used in conjunction with quantitative population models to estimate past and current population states, and project the consequences of management measures under current and/or changing environmental conditions (Kulka et al. 2022). Sea scallops (n=4 stocks) were ranked rich across all three categories. Similar to data-rich stocks, data “moderate” indicates some fishery-independent data along with fishery-dependent data, but limited detailed biological knowledge for which models provide population-aggregated estimates of the rates of change. Respondents reported many stocks received a moderate rating for stock (40%), ocean/climate (36%) and ecological (48%) data sources. “Data poor” describes stocks for which assessments rely on fishery-dependent indices of abundance, with limited or no data on age or size structure, i.e. information is not available for building more sophisticated assessment models. Only three stocks were considered “data poor” across both ocean/climate and ecological categories

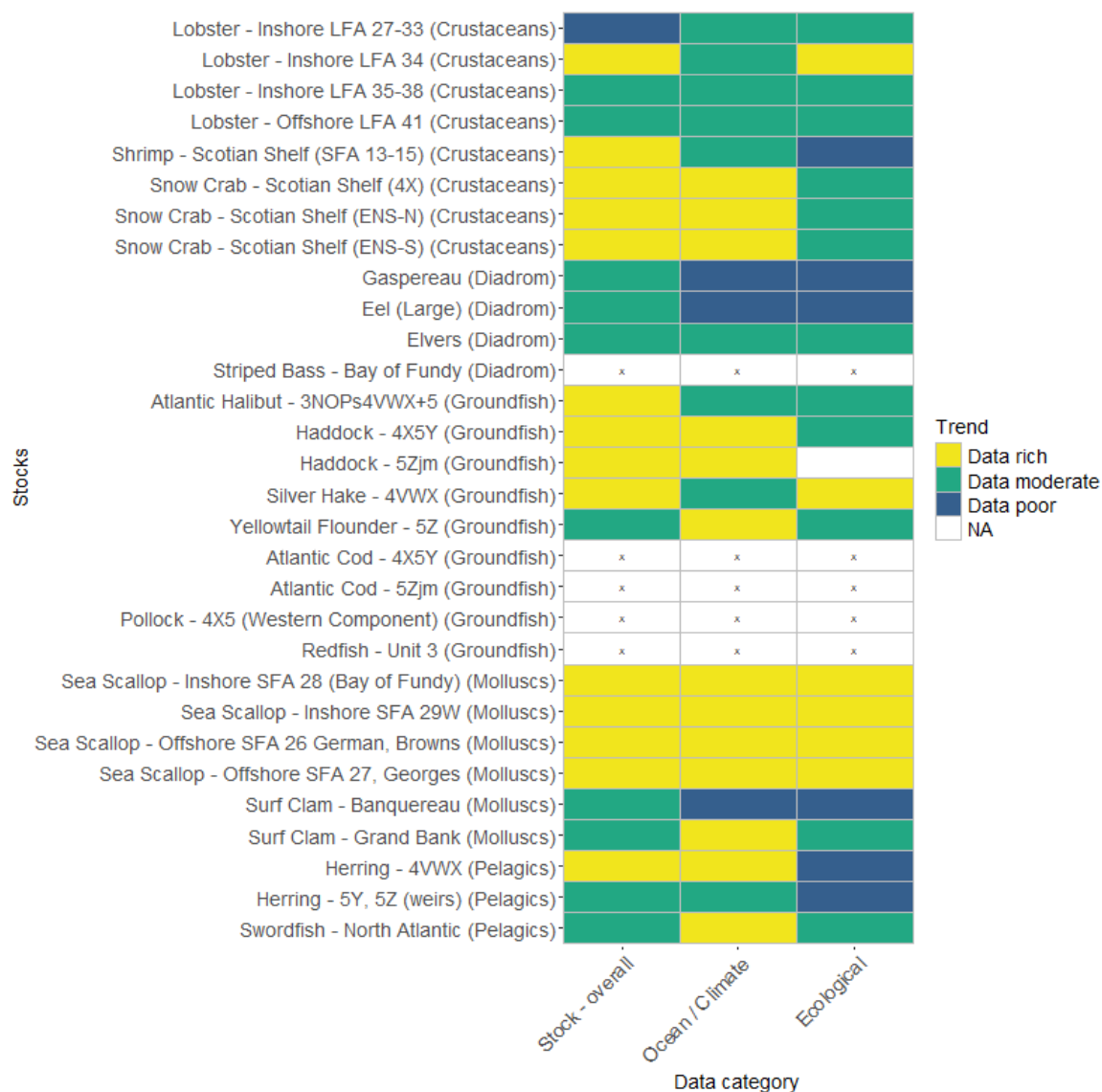


Figure 6: Perceived data availability by DFO Science staff for 1) overall (stock) data, 2) ocean and climate data, and 3) ecological data for 30 priority commercial stocks managed by Fisheries and Oceans Canada Maritimes Region.

Based on the presence/absence ranking of various kinds of data perceived to be available across stocks, fishery data types were collected via both fishery-dependent and fishery-independent means (Figure 7a,b). One key climate metric, temperature, was collected across most stocks (92%, n=23/25) (Figure 7c). Spatial structure was the most frequently collected ecological parameter (92%, n=23/25) (Figure 7d). These reported existing data generally reflected the perceived data availability from Figure 6, i.e., stocks perceived as data-rich tended to have more types of monitoring data available, although exact data composition varied widely among stocks (Figure 7).

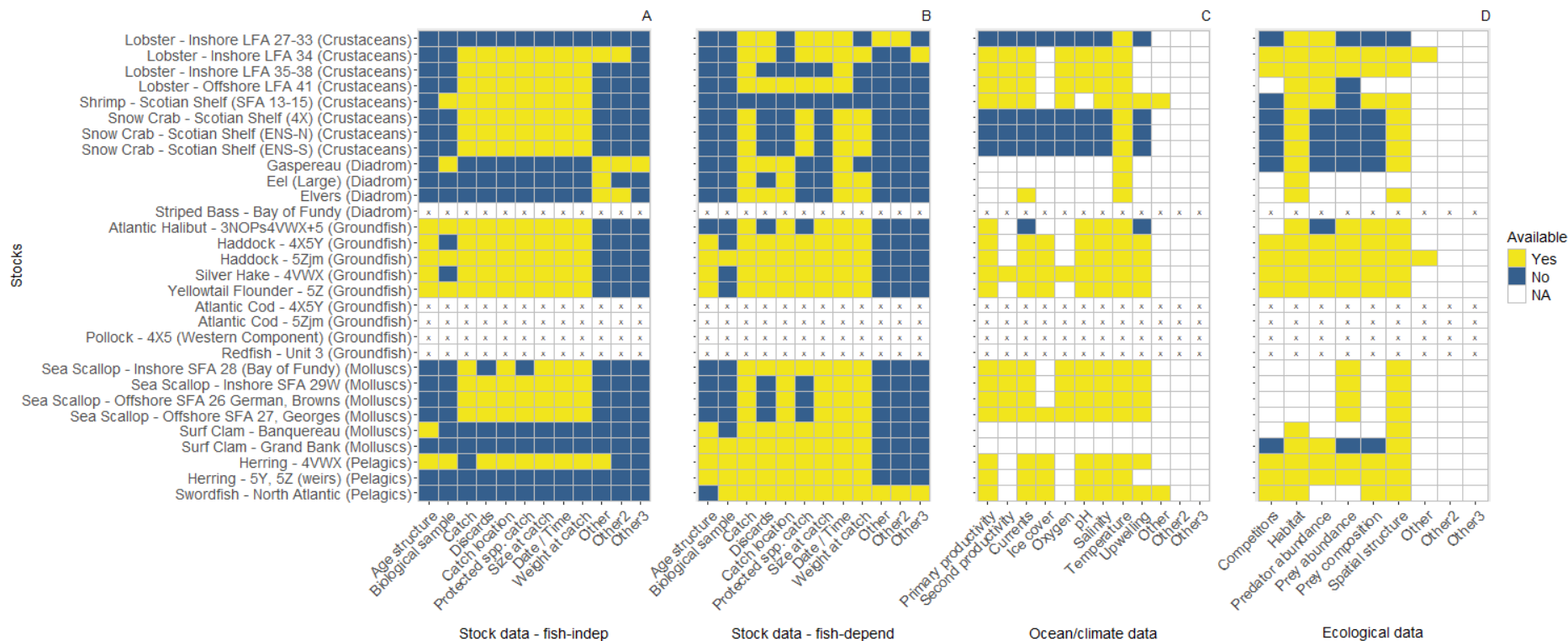


Figure 7: Data types relevant to climate readiness available according to DFO scientists, under the categories of (A-B) stock-related data types, C) oceanographic or climate data types, or (D) ecological data types for 30 priority commercial stocks managed by DFO Maritimes Region. “Other” boxes allowed for the indication of up to three additional data types not otherwise listed. NA indicates no data. An x indicates no survey response was provided.

In addition to information collected by or available within DFO, we asked Science respondents free-text questions about their awareness of monitoring data from outside of DFO that could be used scientifically for their stock (Appendix 6). For 48% (12/25) of stocks, external monitoring data of relevance were identified, mainly from other government agencies (e.g., NOAA, ECCC) or industry / academic surveys, although one respondent identified data use across DFO stocks in this category. We also asked what data were most needed for the stock and we received responses for 23/25 stocks, which primarily included various data in the OC (ocean/climate) category. We note, as one example, that sea scallops (George's Bank) were described as "data-rich" with many fishery, ocean/climate, and ecological data available, but the respondents also cited habitat mapping availability via Dalhousie University as a unique data stream that benefits their fishery. In contrast, eels were considered "data poor" (see Kulka et al. 2022), having few data types available and no estimates of eel productivity.

3.2.2 Analyses and Integration

We asked the degree to which oceanographic, climate, or ecological (OCE) data were considered in a) stock assessments or b) via supporting scientific analyses and models produced by DFO but not part of the stock's final assessment (Figure 8). We also explored which data types specifically were incorporated by various means - directly in stock assessment models, indirectly in stock assessment processes, or via supporting analysis external to stock assessment (Appendix 7). Thirteen of the 25 stocks (52%) with survey responses have already included OCE in stock assessment models in this pilot study. Ten stocks included OCE directly (i.e., environmental parameters are parameterized or implied within a quantitative model structure), and three stocks include OCE indirectly (i.e., includes environmental variables via linked analysis outside of the model, which are used to interpret and condition the model; Figure 8). Overall, OCE variables were most commonly parameterized in the crustacean stock assessment models.

Of the stocks considering OCE in their stock assessments, respondents reported which ocean/climate or ecological data types were typically used (Appendix 7). Temperature was the most common of the ocean/climate variables for both direct (n=4) and indirect (n=6) incorporation into stock assessment (Appendix 7). For the ten stocks that incorporate OCE *directly* in stock assessment, the ecological data used were prey composition, predators, and spatial structure of the stocks. Slightly different ecological data types were reportedly used for *indirect* incorporation into stock assessments: predators, prey, geographic shifts, spatial structure, and thresholds (Appendix 7). In addition, scientists for shrimp and sea scallop stocks noted using time-varying biological variables in stock assessments (primarily via natural mortality [M]). We note that we cannot comment on the nature of relationships that may or may not exist among climate change, biological or ecological changes, and fisheries productivity, as the focus on our survey was simply documenting availability and use of data.

Twelve of the 25 stocks with completed surveys had other supporting scientific analyses or models produced by DFO involving environmental data, but these products were not used for stock assessment model parameterization. Species distribution analyses were the most common (conducted for n=10 stocks) (Figure 8b). Lobster stocks appeared to have various supporting environmental analyses conducted to assess climate impacts on the stocks (i.e. climate projections, climate trends, vulnerability analyses, climate velocity, and species distribution). Shrimp and sea scallops have conducted species distribution analyses, and herring had climate projections and climate trend analyses.

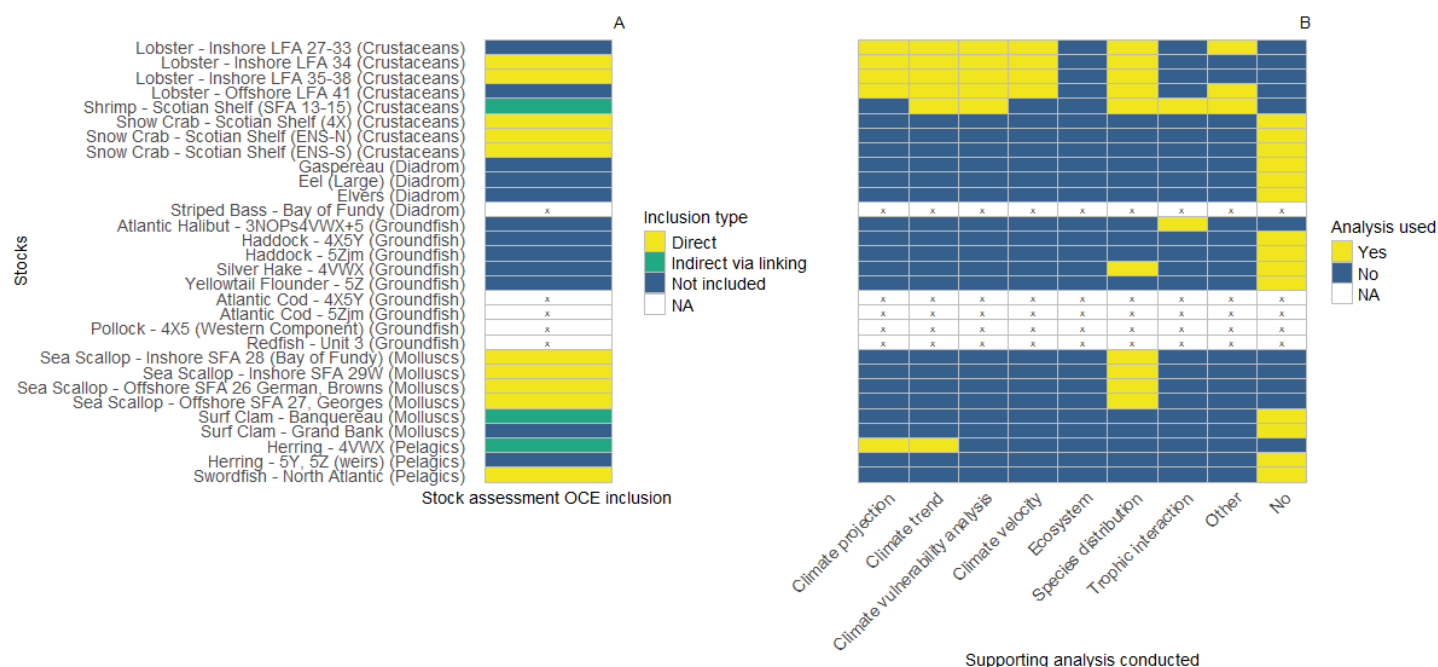


Figure 8: Consideration of Ocean, Climate, and Ecological (OCE) data in (A) stock assessment and (B) supporting analyses for 30 priority commercial stocks managed by Fisheries and Oceans Canada Maritimes Region.

We also asked Science respondents to identify if any complementary decision-support approaches/frameworks existed to advise specific management action(s) for the stock under environmental and climate change (options: “Management Strategy Evaluation [MSE]”, “Risk Equivalent Framework”, “Other” approaches, such as buffers or ecosystem indicator assessments). According to the surveyed DFO Science staff, one species (snow crab, n=3 stocks) had applied a risk equivalence framework, but further investigation of this response suggested that these methods were not those defined by the survey, per Roux et al. (2022). Additional notes were shared regarding the silver hake stock assessment using an “assessment framework” and the shrimp science team working with their resource managers to develop a “contextual approach”. Ultimately, in this pilot study, none of these strategies involved the quantitative tools typically considered “complementary decision-support approaches” for our purposes.

Finally, Science survey respondents listed any other science or knowledge conducted outside of DFO they were aware of (e.g., published research, industry reports, or Indigenous knowledge shared) that suggested climate change poses a risk to this stock. Results show 44% (n=11/25) of respondents identified climate-related science/knowledge conducted outside of DFO, with scientific articles from the primary literature being most frequently listed (Appendix 8).

3.2.3 Participation

A comprehensive assessment of empowerment, collaboration, and consultation within the DFO advising system was outside the scope of this study. However, we assessed “Participation” by asking which stakeholders, rightsholders, and other fishery participants provide input into the management of stocks via formal advisory committees or other channels. The management of all 30 Maritimes stocks involved the participation of a commercial fisheries representative or active commercial harvester (often both) to provide input on stock management, and all had an Indigenous representative. Most stocks had NGO input on management (70%, n=21/30), although results indicated there were fewer stocks with recreational fishers (47%, n=14/30) or external scientists (37%, n=11/30) engaged. The Resource Management survey respondents noted in the “other” free-text comments that additional participants on advisory committees included provincial representatives, US representatives, and members of the processing sector (Figure 9).



Figure 9: Presence/absence of stakeholders, rightsholders, and other fishery participants providing input into the management of stock for 30 priority commercial stocks managed by Fisheries and Oceans Canada Maritimes Region.

Also, under the attribute of “Participation,” we inquired about how co-management or international treaty agreements were implemented for individual fish stocks and, if so, whether a stock had any changes to their agreements based on climate uncertainty. Three groundfish stocks (Atlantic cod 5Zjm, Haddock 5Zjm, Yellowtail flounder 5Z) were identified by DFO managers as being co-managed; these are managed bilaterally with the United States within a Transboundary Management Guidance Committee (non-binding). Swordfish was also identified as a stock managed by an international treaty (i.e., International Committee on the Commission for Conservation of Atlantic Tuna, ICCAT) and was indicated as having had the agreement changed in response to climate concerns (see the 2022 Resolution by ICCAT on Climate Change: <https://www.iccat.int/documents/recs/compendiopdf-e/2022-13-e.pdf>). The current question framing did not explore the extent to which Indigenous sovereignty is exercised via agreements with DFO in the Maritimes Region, but we acknowledge that this remains an important area for future research within the scope of “co-management.”

3.2.4 Transparency

We investigated the “Transparency” attribute (i.e. documentation of data accessibility, analysis and decision-making) by asking Science respondents to rank the accessibility of stock-related (i.e., fishery-dependent and independent) and OCE data available for each stock according to the following scale: 1) data are externally/publicly accessible, 2) data are accessible to certain groups outside of DFO through sharing agreements or at advisory committees, 3) data exist internally at DFO and are shared across divisions/groups, 4) data exist internally at DFO, but are not [able to be] shared across divisions/groups. We assumed that higher data accessibility would benefit science, management and stocks overall, but this may be overstating the realities of sharing certain data – e.g. data used for very specific analytical purposes or data in mid-stream of collection or analysis.

Survey responses revealed that the various datasets existing for each stock have a wide range of different degrees of perceived accessibility (Figure 10). There was less public data accessibility indicated; 52% of stocks (n=13 / 25) had at least one data type that was publicly available data. Results showed sea scallop stocks made most of their data publicly available, whereas eight additional stocks reported at least one OCE data set publicly available. As reported by respondents in this pilot study, ocean/climate and ecological data types were not always shared easily, due most likely to digital storage and ease of access issues. Fishery data were more frequently shared or made accessible to certain external groups via sharing agreements and advisory committees (Figure 10). Improvements in data accessibility present an opportunity to increase climate resilience of stocks.

Using a similar scale, we asked Science respondents to rank the accessibility of any climate-relevant scientific analyses that DFO has conducted that were not considered part of a stock assessment process and outputs. Responses revealed that a majority (63%, n=7/11

stocks with responses) of climate-relevant scientific analyses conducted separately from the stock assessment process were publicly available, which may be because they were published in an academic journal or as a DFO Science document through the DFO Science Publication Series or the Canadian Science Advisory Secretariat. Finally, we asked two questions about the transparency associated with decision-making for the stock: whether a rationale was typically provided for fishery management decisions and, if yes, to what degree these rationales were made available (see scale above). Respondents participating in this pilot study reported that all stocks except for one (eel) stated that some rationale was shared. In an open-text question, we asked about the format in which the rationale was shared. Various sharing methods were described, including emails to advisory committees, briefing materials, stakeholder meetings, variation orders, international publications (e.g., ICCAT), meeting minutes, the Resource Management decision website, and harvest control rules. Inquiring further about the accessibility of the rationale provided, nearly all Resource Management respondents said it was accessible in some form, although the rationale was usually made accessible to specific and relevant external stakeholders, but not to the public.

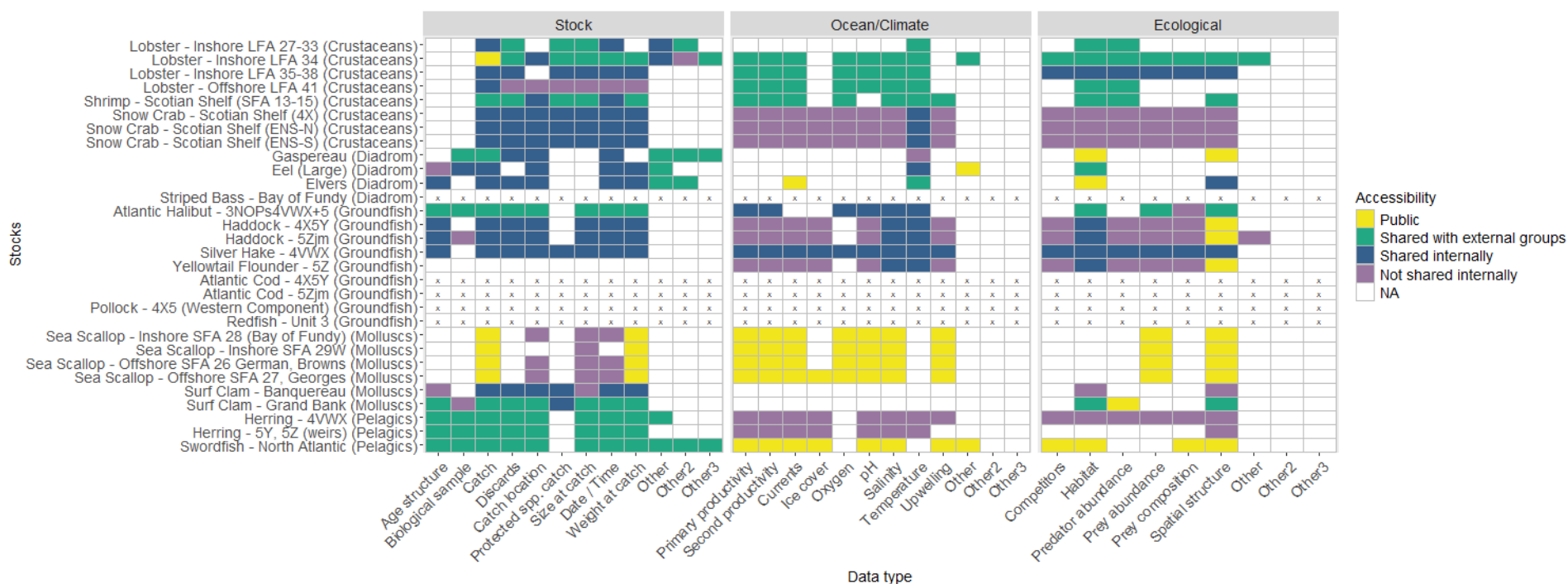


Figure 10: Accessibility of fishery, ocean/climate, and ecological data for 30 commercial stocks managed by Fisheries and Oceans Canada Maritimes Region. Levels of accessibility included “Public” (i.e., externally / publicly accessible; e.g., posted online), “Shared with external groups” (i.e., data are accessible to certain groups outside of DFO through sharing agreements or at advisory committees), “Shared internally” (i.e., data are internally accessible and shared across divisions / departments, e.g., DFO analytic team), “Not shared internally” (i.e., data exists internally within DFO but is not [able to be] shared across divisions / departments). “Other” boxes allowed for the indication of up to three additional data types not otherwise listed.

3.2.5 Responsiveness

The assessment of Responsiveness focused on 1) the frequency at which stock assessments are completed and updated, and 2) the frequency at which DFO engages rightsholder/stakeholder advisory bodies. In response to the question of how often a full stock assessment was completed or updated, responses (when available, n=13) showed that stock assessments were completed 1-6 times in 10 years (average 2.9), while stock assessment updates tended to occur more frequently (2-10 times in 10 years, average 5.9) (Table 2).

Table 2: Frequency of stock assessment completion or updates over 10 years for 13 commercial stocks managed by Fisheries and Oceans Canada Maritimes Region.

Stock	# assess. completed / 10 years	# assess. updated / 10 years
Lobster - Inshore LFA 34	2	8
Lobster - Inshore LFA 35-28	1	9
Shrimp – Scotian Shelf (SFA 13-15)	5	5
Snow Crab – Scotian Shelf (4X)	6	2
Snow Crab – Scotian Shelf (ENS - N)	6	2
Snow Crab – Scotian Shelf (ENS - S)	6	2
Sea Scallop – Inshore SFA 28 (BoF)	1	8
Sea Scallop – Inshore SFA 29W	1	7
Sea Scallop – Offshore SFA 26 (German, Browns)	1	8
Sea Scallop – Offshore SFA 27 (Georges)	1	8
Surf Clam - Banquereau	2	5
Herring – 4VWX	3	10
Swordfish – North Atlantic	3	3

The frequency of advisory committee meetings provided one metric to understand how often fishery rightsholders/stakeholders are in formal communication and thus to gauge how responsive fishery participants could be to climate-related changes. Most non-groundfish stocks met 1-2 times yearly, whereas groundfish, striped bass, and gaspereau met 5-7 times yearly (Table 3).

Table 3: Frequency of advisory committee meetings per year for 30 priority commercial stocks managed by Fisheries and Oceans Canada Maritimes Region

Stock	# advisory meetings per year
Lobster – Inshore LFA 27-33	2
Lobster - Inshore LFA 34	2
Lobster - Inshore LFA 35-28	2
Lobster – Offshore LFA 41	2
Shrimp – Scotian Shelf (SFA 13-15)	1
Snow Crab – Scotian Shelf (4X)	1
Snow Crab – Scotian Shelf (ENS - N)	2
Snow Crab – Scotian Shelf (ENS - S)	2

Gaspereau	5
Eel (Large)	2
Elvers	2
Striped Bass – Bay of Fundy	7
Atlantic Halibut – 3NOPs4VWX+5	6
Haddock – 4X5Y	6
Haddock – 5Zjm	6
Silver Hake – 4VWX	6
Yellowtail Flounder – 5Z	6
Atlantic Cod – 4X5Y	6
Atlantic Cod – 5Zjm	6
Pollock – 4X5 (Western Component)	6
Redfish (Unit 3)	6
Sea Scallop – Inshore SFA 28 (BoF)	1
Sea Scallop – Inshore SFA 29W	2
Sea Scallop – Offshore SFA 26 (German, Browns)	1
Sea Scallop – Offshore SFA 27 (Georges)	1
Surf Clam - Banquereau	1
Surf Clam – Grand Bank	1
Herring – 4VWX	2
Herring – 5Y, 5Z (weirs)	3
Swordfish – North Atlantic	1

3.2.6 Capacity for Action

We assessed “Capacity for Action” using two general approaches, as described in the results below.

We assessed whether climate-related knowledge gets translated into formal decision advice. To do this, we identified whether the formal Science Advice Report (SAR) produced as part of a Canadian Secretariat Science Advice (CSAS) stock assessment review considered scientific analyses or models (beyond specific stock estimation methods) produced by DFO that included environmental variables (i.e., SAR provides comprehensive scientific context on environmental effects on the stock or ecosystem AND explicit harvest advice for management). We also asked whether the SAR considered other science and/or knowledge outside of DFO that addresses climate change risk for a stock. Of the stocks that were reported to have scientific analyses or models produced by DFO (in addition to a stock assessment models and processes) in this pilot study, three cases (lobster, LFA 34 and LFA 35-38; shrimp, SFA 13-15) reported that this information was “fully considered” in the SAR which provides possible examples to other stocks looking to implement similar actions. Three other stocks that have environmental analyses were reported to have these analyses “moderately/minimally”

considered in the SAR.. Five stocks had additional environmental information or analyses, but this was not considered in the SARs).

Stock-related scientific activity lead by non-governmental contributors (n = 11 stocks) was reported to be most frequently discussed in CSAS meetings but not usually considered in the SAR as advice is normally based on the assessment model. Respondents did report an example where contributor analyses had been included for one stock (Shrimp – Scotian Shelf, SFA 13-15). These examples may provide some indication of how more of this type of collaboration might be included in assessment processes to improve resilience.

Instead, this information was most commonly (for n=8 stocks) discussed within CSAS meetings by participants. For one additional stock (elvers), external knowledge was “considered in a different setting/format.” The Science respondent for gaspereau indicated that they did not know if external knowledge was considered.

3.2.7 Communication

We focused our assessment of the Communication attribute on how climate-related risks, benefits, and/or uncertainties have been communicated to Resource Management. Most resource managers (for 77% of stocks, n=23/30) described some form of communication regarding climate risk and/or uncertainty concerning a given stock. The source of this climate-relevant information in most cases was DFO Science (n=20) or fishing industry representatives (n=13), with fewer from Indigenous representatives, ENGOs, or DFO Policy and Economics (Figure 12a). We note that this may reflect which groups have more communication channels with resource managers, and not necessarily which groups have the most climate concerns. The information was most often presented in a verbal form (i.e., conversation or science presentation without documentation) or qualitative (description in the text, e.g., advisory committee meeting minutes, correspondence, other documentation) (Figure 12b). The types of climate risks, benefits, or uncertainties communicated for a given stock selected most frequently included impacts on productivity (n=18), spatial distribution of target species (n=11), and predator/prey/competition dynamics (n=15) (Figure 12c). For most stocks with climate-relevant communications, the issue was considered relevant over all the time scale options provided: immediate, near-term (i.e., 1-5 years), and long-term (i.e., 5+ years) time scales.

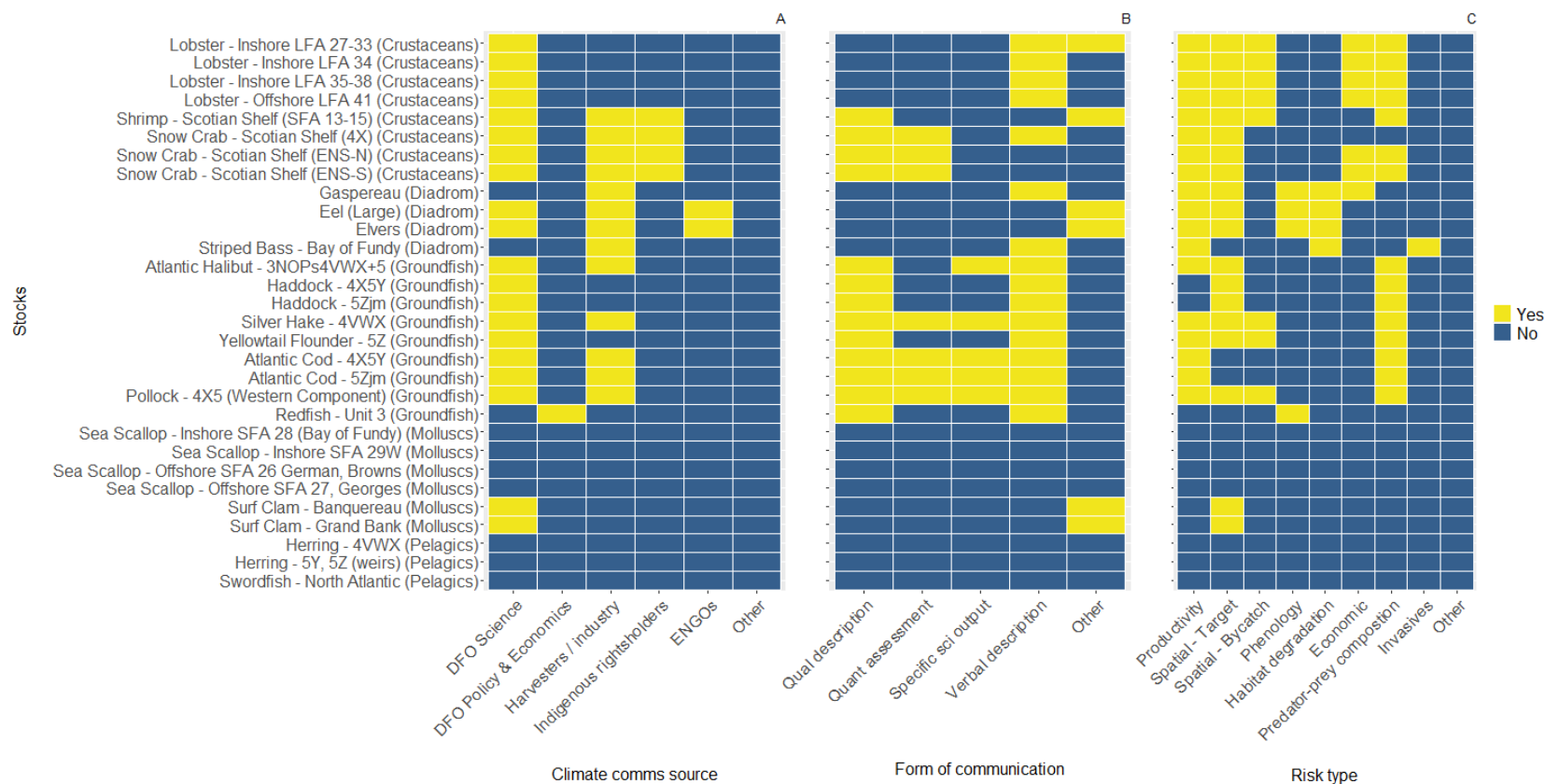


Figure 12: Awareness of communications in the past five years about climate-related risks, benefits, and/or uncertainties associated with 30 commercial stocks managed by DFO Maritimes Region: A) the reported sources of communication, (B) the forms of this communicated information, and C) the nature of the risk or uncertainty shared. “Qual description” = received a qualitative description in text (e.g., advisory committee meeting minutes, correspondence, other documentation), “Quant assessment” = quantified assessment provided by DFO Science or other reputable science organization (e.g., climate-informed TAC based on quantitative stock assessment, fishery management options under various climate scenarios, risk equivalent fishery management options); “Specific output” = specific scientific output (e.g., vulnerability assessment; “Verbal description” = verbal description, but nothing documented (e.g., conversation, science presentation, etc).

3.2.8 Adaptation

To assess the Adaptation attribute, we focused on exploring whether new or different management actions have been implemented to learn about or understand climate risks, benefits or uncertainties for a stock. We inquired with resource managers about actions taken in the last five years and actions that may be taken in the next five years in response to climate issues for a given stock.

The survey data in this pilot study revealed that few stocks (17%, n=5/30) have implemented management actions in response to climate risks or uncertainties in the past five years (Figure 13a). In contrast, most managers of stocks (70%, 21/30) anticipated taking climate-related management actions in the next five years. Managers of groundfish stocks anticipated the widest variety of possible actions in the future. Generally, changes to fishing removals (i.e. harvest levels; n=18 stocks), fishery timing (n=13 stocks), or increased DFO science requests (n=14 stocks) were predicted to be most likely to take place in the next five years (Figure 13b).

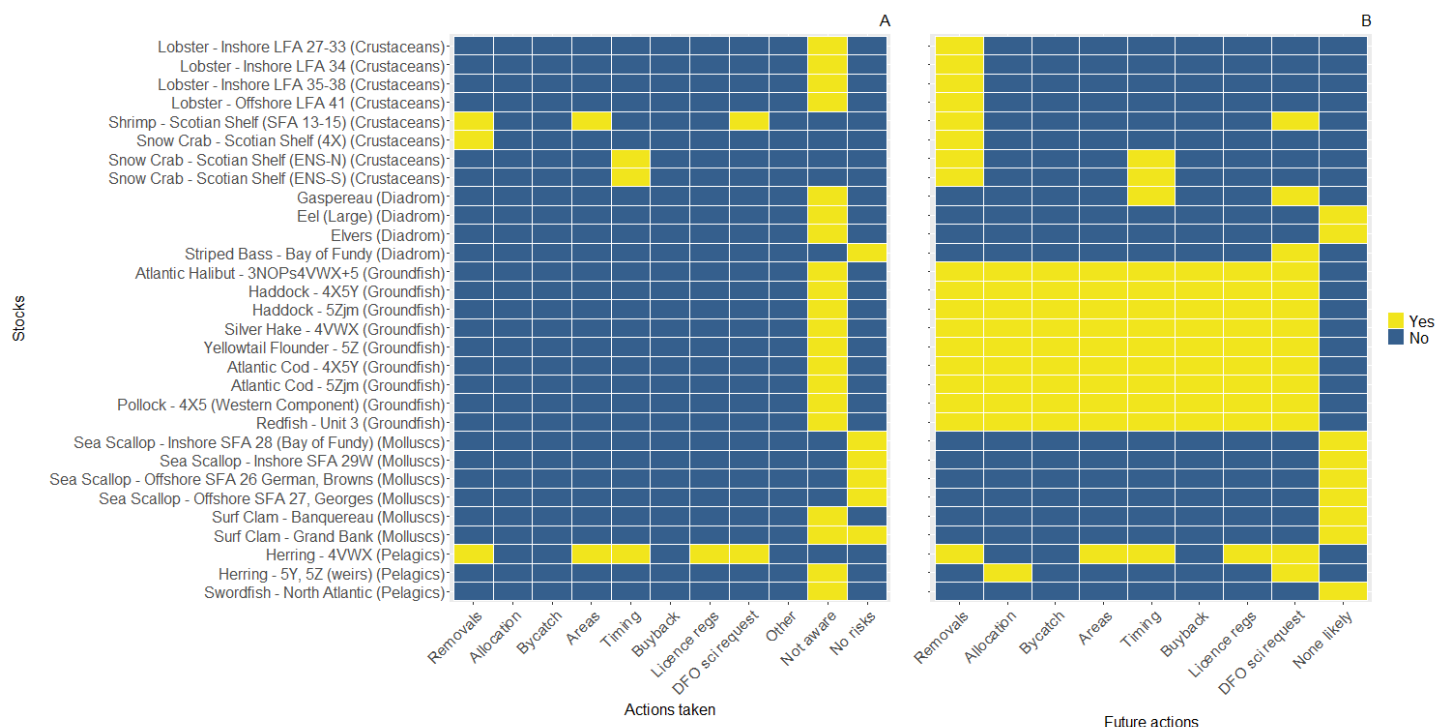


Figure 13: Climate actions taken in the past five years (A) or likely to be taken by resource managers over five years (B) for 30 priority commercial stocks managed by Fisheries and Oceans Canada Maritimes Region. “Removals” = adjustment to fishery removals (e.g., effort, TAC, quotas, etc); “Allocation” = adjustment to fishery allocations (e.g., distribution across groups, fleets, gear types); “Bycatch” = adjustments to amounts of retainable bycatch; “Areas” = changes to fishing areas; “Timing” = adjustments to the timing of fishery (e.g., opening, closing, etc) or to shifts in abundance, distribution or timing of target species or interactions with other fisheries experiencing climate-related shifts; “Buyback” = licence

buyback program; “Licence regs” = changes to licence provisions or regulations; “DFO sci request” = formal requests to DFO Science.

Another key component of adaptation is the ability to reflect and iterate on past actions taken. This creates an opportunity to respond to emerging issues and adjust actions to improve efficiency. As such, the survey asked whether management for a given stock included any explicit process or meeting to review or assess harvest decisions or fishery outcomes after the fishing season had concluded. When asked about post-fishing-season review opportunities for a given stock, it was almost always (97%, 29/30) determined that some post-season review method took place, although formats varied. An open-text question asked managers to describe the nature of this review, and they listed examples such as stock status updates, the CSAS process, post/pre-season advisory committee meetings, internal review (e.g., Conservation and Protection, Science, Resource Management, Policy and Economics), and international meetings (e.g., ICCAT) as possible venues for post-season review.

4. DISCUSSION

The Fisheries Management Assessment of Climate Consideration (FiMACC) responds to the need to map existing climate considerations in Canada’s fisheries management system to understand potential adaptation approaches and priority responses (Pepin et al. 2022; Fisheries and Oceans Canada 2024). The FiMACC assessment is timely given our results showed that resource managers for 70% of assessed Maritimes Region commercial stocks anticipate taking climate-related management actions within the next five years, and that 77% of surveyed resource managers received communications regarding climate risks, benefits, or uncertainties through a variety of sources. The FiMACC evaluation provides an informational synthesis product and offers a transparent, repeatable approach to explore how current institutional practices and procedures score for specific resilience assessment attributes and by stock under one framework. The synthesis and detailed survey data provide relevant information, resources, and actions on climate risks to fisheries management that are not compiled through any other product or service. Our investigative approach encompasses the “4 Cs of adaptation tracking,” per Ford and Berrang-Ford 2016: consistency (i.e., defines key terms and relationships for analysis), comparability (i.e., captures key metrics that could be explored over time or across jurisdictions), comprehensiveness (i.e., gathers data over a wide scope of relevant attributes), and coherency (i.e., alignment between inquiry and resilience objectives). This approach and the FiMACC outputs can help enable planning and problem solving beyond individual siloed sector objectives toward a more integrated and resilient management system (Borja et al. 2016; Stephenson et al. 2019). Ultimately, FiMACC may serve as a key tool to visualize and synthesize the degree of climate consideration in current DFO processes to help communicate positive actions and outcomes, and facilitate further development in support of resilience within Canada’s fisheries management system.

4.1 Resilience framing offers unique insights for institutional analysis

Using resilience to frame our evaluation of commercial fish stock management reveals a fulsome view of the many factors that influence the adaptability of DFO's fisheries management system in the context of climate uncertainty. Resilience theory focuses on understanding processes of change in complex, dynamic systems and thus is an appropriate lens through which to explore the potential for institutional response to a stressor such as climate change (Adger et al. 2011). Rather than strictly adhering to a predefined resilience framework from the literature, we sought resource management and scientific input from DFO staff across multiple regions to shape and refine our institutional assessment and survey. Formulating a DFO-centred product was both pragmatic and necessary, as it ensured that our assessment remained relevant and applicable within Canada's fisheries management structure. While other recent studies have offered methodologies to focus on specific elements of climate consideration within DFO – for example, Pepin et al. (2022) examined the use of OCE data in DFO stock assessments - we sought to explore the broader landscape of institutional assets and processes to understand more fulsomely the integration of climate change across the system. In addition to existing fisheries and OCE data and analyses, we examined a wider range of considerations that are relevant to managing for resilience, including the diversity of advisory perspectives represented, advisory committee engagement frequency, management communication channels, capacity constraints and enablers, and management actions. This approach aligns with literature on climate consideration in fisheries, which emphasizes issues ranging from data systems modernization to participation and social inclusion as key management elements that enable institutional responsiveness and facilitate actions to address climate uncertainty (Wilson et al. 2018; Lomonico et al. 2020). FiMACC thus brings together different types of information not normally considered together across a broad suite of attributes.

By examining the aggregate scores for the institutional resilience attributes, our work highlights strengths and weaknesses across diverse areas of the fisheries management system in the context of climate stressors and uncertainty. For example, "Participation" was the highest scoring resilience attribute with 85% of possible points scored. However, this attribute scoring was based on a single criterion (derived from survey question, "What stakeholders, rightsholders, and/or fishery participants take part in providing input into the management of this stock?") and thus is limited in the degree it can characterize "Participation" within the department (i.e., the extent / nature of participation, collaboration, or co-management) to make claims about the current contributions of "Participation" to climate preparedness in the department. "Information" (i.e., assets in the form of data sets and other information sources) was the next highest scoring resilience attribute at 77%. In this pilot study, other resilience attributes including "Analysis and Integration" (capturing scope and quantity of various analyses conducted), "Transparency" (capturing data and information sharing avenues), and "Capacity for Action" (capturing how scientific understanding is included in formal advice for decision making) were among the lowest scoring, reaching 30%, 43%, and 45% for each attribute, respectively and, therefore, represent opportunities for increasing climate resilience. These aggregated results also reveal important linkages across attributes, and such linkages are considered critical to explore in resilience assessments (Ojea et al. 2017; Cinner et al. 2018). For example,

while our results show there are some climate-related data assets available from monitoring (“Information”), there are relatively few analyses across all scientific contributions to capture climate considerations and illuminate an understanding of stock dynamics in a changing ocean (“Analysis and Synthesis”). There is also constrained internal and external accessibility of existing data and analyses, which contribute to the overall lower score for “Transparency.” For the climate-informed analyses that do exist (by DFO or external), Science survey respondents reported variable uptake and incorporation of this information into the formal science advice used to inform decision making (“Capacity for Action”). Overall, these aggregated results illustrate how applying a resilience lens can yield operational insights, identifying priority areas to attain more adaptive and nimble management.

The FiMACC framework also enables individual fish stocks, species, and stock groupings to be evaluated and compared across their scores for institutional resilience attributes. While overall there is high variability in resilience attribute scoring across stocks, higher scores across multiple attributes existed for lobster, shrimp, sea scallop, and swordfish stocks. All four of these species have high “Information”, whereas lobster stocks also show higher “Analysis and Integration” (due to having more supporting OCE analyses), scallop and swordfish stocks show higher levels of “Transparency” (a lot of data made publicly accessible), and the shrimp stock shows higher “Capacity for Action” (existing environmental analyses are considered in the formal science advice and influence harvest advice). Our results also indicated that the relative scoring across stock groupings, which are relatively similar except for diadromous stocks (gaspereau, eel, elvers), which all score relatively low across the attributes and assessment criteria. From an institutional resilience perspective, the FiMACC outputs provide an overarching assessment of climate consideration in stock assessment advice and the ability for fisheries management to consider this advice in decision making.

The FiMACC synthesis scoring results provide a quick snapshot for DFO scientists and managers of individual stocks to identify strengths and weaknesses in climate considerations across the regional fisheries management portfolio. Stocks with high-scoring resilience attributes may offer insights or models that could support improved science and management for other stocks. For example, DFO Science personnel might be able to use FiMACC to learn about data sets and analytical techniques existing for particular stocks that might be informative for their own work. Similarly, resource managers might be able to learn about climate communications received by different stock teams and compare anticipated actions or planned responses from their colleagues. It is important to consider, however, that the scoring discrepancies between species or stocks may be related to differences emerging from inherent characteristics such as their size and scale, economic importance, climate vulnerability, or other key differences. While making relative comparisons across stock synthesis scores is tempting, the high-level patterns we outline here should rather serve as a motivation for further exploring the stock-level information our assessment provides for each assessment criteria within the resilience attributes.

4.2 Institutional resilience attributes reveal institutional strengths and opportunities

Information is the foundation for understanding fishery system dynamics and recognizing climate-related variability and impacts (Pinsky and Mantua 2014; Bell et al. 2020; Dorn and Zador 2020; Pepin et al. 2022). Overall, we found that Maritimes stocks have high scores for “Information” assets, indicating relatively data-rich stocks and a high proportion of possible data types available across both fishery-independent and fishery-dependent sources, as well as climate and ecological data types (i.e. Figure 7 shows the presence/absence of 33 potential data types for each stock across 30 Maritimes Region stocks). Our results show that crustaceans (especially lobster and shrimp), groundfish, and pelagics (herring and swordfish) are groups with overall higher levels of fishery and OCE data relative to many other stocks. These results supported previous findings by Pepin et al. (2022) that crustaceans and pelagic stocks more frequently made use of environmental (i.e., OCE) data in stock assessment, but contrasted with their finding that environmental data are less frequently used for groundfish. It is possible that more detailed monitoring of these ‘high information’ stocks relates to their high economic value (Lobster = 41%, Northern shrimp 14%, as percentage of total landed seafood value for all Atlantic Canada [2010-2019]; Boyce et al. 2024) and/or the substantial socioeconomic reliance on these species in the region’s communities (Greenan et al. 2019). While our evaluation framework suggests that having more data can be valuable to improving climate adaptability, the FiMACC outputs also demonstrate that having a limited amount of targeted, accessible data is another pathway to facilitate climate analyses that enhance our understanding of climate influence for the stock (Pinsky and Mantua 2014; Bell et al. 2020). For example, snow crab stocks score low to moderate for OCE data, but score high for having OCE data directly incorporated and parameterized in their stock assessment model.

Our results revealed opportunities to enhance the existing status of the “Analysis and Integration” institutional attribute. Currently, fewer than half (12/25) of Maritimes Region stocks report having scientific analyses or models - outside of standard stock assessments - that make use of fishery or OCE data, and there are no current applications of decision-support tools. Decision-support tools are highlighted in the literature as being important strategies for incorporating environmental uncertainty into decisions about fisheries (Holsman et al. 2017). While Management Strategy Evaluation (MSE) is lauded for having the ability to model a range of management procedures and report the results in a way that exposes trade-offs in outcomes against a set of objectives (Kronlund et al. 2013), MSE can be data- and capacity-intensive (but see DePiper et al. 2017, Pittman et al. 2020) and thus is not possible in many stock management contexts. Alternatively, the Risk Equivalence Framework (REF) is a decision-support tool designed by DFO scientists capable of producing ‘climate-conditioned advice’ for a stock, including data-limited scenarios (Duplisea et al. 2020, 2021; Roux et al. 2022). The REF quantifies how environmental conditions alters the risk associated with alternate management options guiding harvest (Duplisea et al. 2021; Roux et al. 2022). This REF was used in a test case on Gulf of St. Lawrence Greenland halibut to validate the approach (Bahri et al. 2021). Risk equivalence as a broad concept has been identified as a useful tool for climate risk integration in other countries (CSIRO 2018; Dorn and Zador 2020). DFO’s REF is an example of

a recently-developed stock-level decision-support tool that offers a tangible option for making more responsive or proactive management decisions in the context of climate uncertainty.

Accessibility of data, analytical products, and reasons behind decision-making are fundamental to transparency in the management process, which in turn is fundamental to science and management legitimacy (Cash et al. 2003; Guggisberg et al. 2022). We found evidence of relatively low accessibility of data and analytical outputs for Maritime fish stocks, including DFO Science respondents identifying a “lack of accessibility of relevant data” as a particular barrier to obtaining oceanographic and climate data. Expanding data accessibility (within the scope of privacy laws) is a core component of ‘data modernization’ efforts and represents a key focus of programs enhancing data availability through the Government of Canada’s Open Data initiative. For example, more recently, ecosystem summary reports are being generated as supplemental science advising products to support stock assessments/review processes and improve oceanographic and ecological data availability and visibility. Scripts created through the R MAREA package and supplemental Atlantic Zone Monitoring Program data packages also improve transparency and accessibility in Maritimes Region. Other countries also validate these types of efforts through their own data transparency programs (e.g., Changing Ecosystems and Fisheries Initiative; NOAA 2024). Research suggests that when data and analyses are more available, they can be increasingly used and leveraged by fisheries scientists, industry, and academic researchers to support new collaborations and partnerships, and management solutions which can collectively support greater climate change understanding and response (Lomonico et al. 2020).

Transparency in decision making facilitates resilient fisheries management as it supports the credibility and legitimacy of institutional processes (Cash et al. 2003; Cash and Belloy 2020; Mason et al. 2021). While nearly all Maritimes stocks stated some form of rationale existed for decisions made about allocations or harvest specifications, only three stocks (sea scallop, swordfish, and elvers) are reported to make that decision rationale publicly accessible. Our FiMACC data suggest that there are many ways to share a decision rationale through various pathways, with a focus on getting the information to the people who want and need it. However, a lack of consistency in process across stocks to share decisions may hinder the ability or the perceived importance of making such information public. Overall, making existing fisheries data, analyses, and decisions more accessible and transparent could be ‘low-hanging fruit’ for strengthening institutional trust and leveraging collective buy-in to more adaptive management. Moreover, this trust and legitimacy may become increasingly important in a context of greater uncertainty where more rapid and novel actions may be required to navigate unpredictable climate events or conditions (Cash and Belloy 2020).

The resilience attribute “Capacity for Action” relates to how institutional staff, managers, or departments can transfer their knowledge or informational assets into decisions and actions in response to change, uncertainty, or disruptions (Mason et al. 2021). In this context, our FiMACC survey explored different pathways for integrating climate-related scientific knowledge into DFO Science advice, as presented in the SAR - a key input to fisheries decision-making that is designed to rely on the stock assessment model for harvest advice. Our results from this pilot

study showed that across stocks, aside from the stock assessments that incorporate OCE data, there are limited additional supporting scientific analyses that utilize those data (e.g., analyses involving climate projections, trends, vulnerability, velocity, species distribution, or trophic interactions). Where such supporting analyses did exist (nine stocks), they were not commonly considered in the SAR (five stocks), sometimes “moderately/minimally” considered (three stocks), and only “fully considered” for three lobster stocks. It is not surprising that supporting analyses were not considered in the SAR given the intent of the SAR at the time of this pilot study. These results indicate that there are opportunities to include additional knowledge in assessment processes and frameworks for the benefit of the stock and fisheries management resilience to climate change.

4.3 FiMACC outputs support DFO’s fisheries management objectives

Fisheries management in Canada, as elsewhere around the world, is recognizing the value of a more comprehensive ‘ecosystem-based’ fisheries management approach, which goes beyond single-stock species assessments to include ecosystem and social-ecological considerations (Tyrrell et al. 2011; Long et al. 2015; Woods 2021; Pourfaraj et al. 2022). Ecosystem approaches represent a convenient means of meeting some of the objectives of further consideration of climate variables on stock assessment and associated management strategies. DFO has made progress towards ecosystem approaches to fisheries management (EAFM) through an EAFM national working group (Fisheries and Oceans Canada 2023), as well as through concentrated regional efforts on related topics (e.g., Maritimes Region ecosystem-based management working group; Daly et al. 2020; Bundy et al. 2021). The FiMACC framework and survey can help gauge regional progress toward implementing EAFM goals (Fisheries and Oceans Canada 2023). At its essence, the FiMACC output synthesizes information for all regional stocks to provide a snapshot of integration and implementation of deliverables (i.e., climate integration into fisheries management) that align with the general goals of EAFM. While we frame the FiMACC attributes and assessment criteria with respect to managing for resilience in the face of climate variability and uncertainty, they are also reflections of ‘ecosystem approaches’ or ‘ecosystem-based’ management. The FiMACC approach also aligns with successful reporting structures for the Sustainable Fisheries Framework, such as the Sustainable Survey for Fisheries, but goes further by providing a tool to assess institutional responses to stressors and identifying areas where effort and resources are already allocated.

Institutional efforts to support climate-resilient fisheries may benefit from prioritizing management adaptation and actions for stocks that are most at risk. Ecological and social vulnerability analyses are widely regarded as critical components of climate-informed management and essential to quantifying climate change impacts (Busch et al. 2016; FAO 2021; Boyce et al. 2024). As such, there is a great opportunity to leverage the results of the FiMACC survey by examining them in the context of information from existing climate change vulnerability assessments that DFO Science has led or contributed to (Hunter et al. 2014; Stortini et al. 2015; Boyce et al. 2023, 2024; Harper et al. 2023) as has been proposed previously (Boyce et al. 2023, 2024). In addition, while outside the scope of current Canadian

practices, these analyses could ideally be further paired with social vulnerability assessments, such as those used in the United States (e.g., Clay and Colburn 2020).

Pairing FiMACC components with climate change vulnerability analyses could help DFO to examine the degree to which data, analyses, and climate consideration are incorporated in management processes to support the resilience of stocks based on the prioritization of the most vulnerable species with particular relevance / importance to data-poor or resource-poor stocks. For example, groundfish in the Maritimes Region have a consistently high climate risk, according to the recently-developed Climate Risk for Biodiversity Index (Boyce et al. 2024, see also Stortini et al. 2015). Yet, our results suggest that groundfish stocks also tend to be low in their institutional climate consideration. For instance, several stocks had OCE data available, but limited scientific analyses using OCE variables; had multiple forms of climate risks, benefits, and uncertainty being communicated to managers; and predicted climate-related management actions will be required in the next five years. This places groundfish and stocks like these under increased pressure from uncertainty or shocks as they are subjected to both ecological and institutional gaps / vulnerabilities under climate change and thus could require a priority focus for climate adaptation resources. By contrast, crustaceans tend to score as moderate climate risk ecologically, indicating that science has fewer hypotheses for plausible impacts from OCE-related change. Crustaceans have also been identified here as having stronger attributes for climate-resilient management, specifically with respect to scientific and analytic capacity (Greenan et al. 2019). Leveraging FiMACC outputs alongside other climate vulnerability studies, including considerations of ecological and infrastructure vulnerability (per Boyce et al. 2023) and social vulnerability work (Howarth et al. 2021; Harper et al. 2023) could yield a more fulsome picture of climate risks and opportunities.

Identifying barriers to adaptation helps to advance understanding of factors which may stop, delay, or divert climate response efforts (Moser and Ekstrom 2010). Our survey results revealed insights into what enables and constrains climate consideration in the fisheries management system within the Maritimes Region. Some barriers identified here, such as those related to funding and human resources, originate at the higher-level 'strategic' scale within the organization. In contrast, others are highly stock-specific (e.g., certain data needs related to life history or habitat type) and are most relevant at the 'tactical' or 'operational' scale of fisheries management (Stephenson et al. 2017, 2018). Generally, barriers to collecting and analyzing data fell into two categories: 1) challenges inherent to doing new science necessary to fully capture (possible) climate impacts and 2) perceived capacity limitations stemming from the need for more staff, time, funding, or other resources. Science is continually evolving as efforts are made to understand linkages between OCE variables and population dynamics, however for many stocks there are inherent difficulties in sampling OCE variables at the correct geographic scale, as well as challenges in coupling population data with climate data (e.g., English et al. 2021; Thompson et al. 2023). In our surveys results, both scientists and resource managers identified the same top barrier – limited capacity in DFO Science to enable technical assessments – as constraining both the inclusion of OCE data in stock assessments and the ability of the department to take management actions in response to climate-related risks and / or uncertainties. This is consistent with previous findings from Kulka et al. (2022), in which

limited capacity (i.e., expertise, time, and money) to carry out the work was identified by 76% of Science respondents as the primary or second reason that environmental factors (i.e., OCE) were not integrated in their stock assessment. Structured evaluations like the FiMACC survey can map out enabling conditions to help chart a course toward climate resilience goals.

4.4 Limitations and learnings from the Maritimes Region pilot for future application

FiMACC was designed to assess factors that contribute to managing fisheries for resilience in the context of climate change impacts in Canada. While FiMACC is a valuable tool, the survey was not designed to be comprehensive, and there are important management considerations that were not included but would be indicative of fisheries resilience in a changing climate. For example, FiMACC did not examine departmental fisheries regulations or licencing despite these system components being mentioned frequently as adaptation options in climate-fisheries research (e.g. Ojea et al. 2017, Woods et al. 2021). While the institution can set such options, these aspects fall more appropriately under the assessment of social/human vulnerability where they have been considered as adaptive responses that impact fishery participants' resilience, not the functionality of the institution (Figure 1; e.g., Colburn et al. 2016).

Furthermore, like DFO's Sustainable Survey for Fisheries, the stocks assessed in our FiMACC survey were largely commercial stocks, and thus may not include some stocks of primary interest to recreational or Indigenous fishers, including some small-scale and non-commercial fisheries. However, one study found that while commercial and non-commercial stocks had similar climate risk in Atlantic Canada, commercial stocks tended to have increased climate sensitivity, lower adaptivity, and much higher exposure than non-commercial stocks (Boyce et al. 2024), supporting their prioritization for assessment. Finally, by focusing on individual harvested fish stocks, our work reflects current DFO fisheries management approaches, however we recognize that the assessment does not capture the full suite of institutional characteristics that could affect resilience to climate change at an ecosystem or regional scale. There are several possible next steps for FiMACC, and the future of FiMACC will involve refining the assessment to incorporate some of the learnings from this Maritimes Region pilot.

Through developing and analyzing the FiMACC survey, combined with feedback received from DFO staff and respondents before, during, and after survey administration, we gained several key insights that could improve future applications of the FiMACC framework. First, the survey responses were all provided by DFO staff, which was both an inherent strength and weakness. The FiMACC outputs are meant to capture what is within the sphere of DFO staff awareness at the time of the survey. However, the quality of responses may vary with individual staff experience and knowledge, which in turn may be influenced by factors such as whether staff are newer or more experienced with a given stock file, and by the degree of thoroughness with which the survey is completed. Repeated use of, and training related to, the framework and survey could improve efficiency and effectiveness of survey implementation. Additionally, not all criteria were explored in the survey in such a way that participant responses could be conveniently scored on the three-point scale that was eventually applied to enable our higher-level synthesis. This is the nature of a pilot study, where multiple rounds of iteration were

required to develop the assessment approach. In the future, the survey questions designed for each assessment criterion could be designed to be compatible with the scoring system from the beginning to enable all criteria to be included in the final synthesis.

Beyond several changes that could be made to refine some of the survey questions, optimize survey implementation, and streamline the survey-to-data-output process, an important future consideration is the absence of socio-economic considerations within institutional processes. For example, a more comprehensive understanding of “Information” assets and “Analysis and Integration” could also include a way to inventory social or economic information that DFO has available, along with any socioeconomic analyses that exist for commercial stocks and the human communities that harvest them. Although this was considered, one barrier was that socioeconomic information is held more centrally by a small regional DFO Economics team, and there are no dedicated stock-specific socioeconomic (i.e. Policy and Economics) personnel to act as survey respondents, as there were for Science and Resource Management. However, we are certain that future iterations of this survey could include some level of inventory for socioeconomic information and analyses, given the critical importance of managing for resilient fisheries in recognition of the entire social-ecological system (Colburn et al. 2016; Levin et al. 2016; Clay et al. 2020; Galappaththi et al. 2022; Harvey et al. 2025)

Despite some limitations in our pilot study, three key strengths of the FiMACC framework and survey emerged: 1) its broad scope of informational synthesis (i.e. range of attributes and assessment criteria), 2) its novel and multiple scales of analytical resolution (by resilience attribute, individual fish stock, and region), and 3) the repeatability of its design. By organizing information around resilience attributes, the FiMACC bridges sectors (i.e., Science and Resource Management), promoting a more integrated fisheries management approach essential for addressing complex social-ecological stressors affecting Canada’s oceans. The ability to analyze data at various scales enables comparisons that are locally relevant yet can also be aggregated to regional levels, reflecting the multi-layered impacts of climate change. Designed for use across Canada’s regions, FiMACC can support cross-jurisdictional learning and comparison, as well as tracking progress within a single region (such as the Maritimes evaluated here) over time. This also offers potential for FiMACC contribution to and compatibility with other climate tools proposed within DFO, such as the Risk Equivalency Framework (Roux et al. 2022) or the Climate Adaptation Framework for Fisheries (CAFF; Boyce et al. 2023). Ultimately, the FiMACC underscores the value of institutional self-assessment in support of resilient fisheries in an uncertain future.

5. CONCLUSION

Fisheries are complex social-ecological systems, requiring evaluation not only of ecological resilience, which is already relatively well-studied, but also of institutional elements, which have often been overlooked in vulnerability and resilience assessments. While variation and change are inherent to fisheries systems, the changing climate is producing increasingly unprecedented and overlapping stressors that require consideration of resilience across all dimensions of a fisheries management system. Tools that facilitate discussion, planning, and ultimately adaptation will best position institutions, such as DFO, to continue to pursue important

objectives in fisheries management, in light of both climate and decision uncertainty. The FiMACC framework and survey were developed to help resource managers and decision-makers identify key areas to prioritize for improving or enhancing fisheries resilience under climate change. Our work advances the academic literature by focusing on the underappreciated institutional aspect of climate resilience, and by adapting a resilience assessment framework in a practical setting. This pilot project evaluated the climate adaptation status of fisheries across the Maritimes Region; however, FiMACC was intentionally designed to be applicable nationwide in Canada, and with much scope for adaptation to other stressors or management issues. Moving forward, FiMACC could be expanded and repeated in other regions to facilitate a more comprehensive understanding of climate considerations across the country. Likewise, our institutional framework, survey, and synthesis output could be replicated over time to track progress towards enhancing climate adaptation and resilience in Canada's fisheries, or adapted to other institutional contexts or sectors within or beyond DFO. While acknowledging many other competing challenges facing contemporary fisheries, the persistent and compounding nature of climate change necessitates the need to coordinate efforts around this driver of change. By investing in reflection on the role of institutions in promoting climate resilience in fisheries, we are building capacity to support the goal of sustainable fishing in the face of emerging and accelerating climate-driven uncertainty.

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APPENDIX

Appendix 1: Possible actions to be taken by fisheries management agencies in support of climate-ready fisheries science and management (Adapted from Bell et al. 2020)

Climate-ready actions	Examples
Address cumulative impacts	• Ensure healthy spawning stock biomass • Maintain expanded age structure • Management for climate resilience
Prepare for emerging challenges	• Consider species-gear interactions • Plan for distribution shifts
Adjust reference points	• Include environment in assessments • Include changes in productivity / time-varying parameters in models • Implement risk policies, indicator frameworks in management
Conservation areas	• Developing / altering management areas • Establishing dynamic management areas
Evaluate range of scenarios	• Include deterministic projections • Implement scenario planning • Use management strategy evaluation
Integrate monitoring and evaluation of climate	• Link the environment with decision rules
Reduce barriers to adaptation	• Allow for framework adjustments • Support co-management • Invest in habitat restoration • Promote insurance programs • Allow for permit banking • Promote gear innovation • Invest in increasing product value • Support community/stakeholder initiatives • Engage in coastal zone management

Appendix 2: Flow charts for Fisheries Management Adaptation to Climate Change (FiMACC) survey questions for survey modules 1) Monitoring and Information Gathering, 2) Analysis and Generating Science Advice, and 3) Decision-making and Implementation

Module 1: Monitoring and Information Gathering

What this is trying to address: Whether fishery and ecosystem monitoring is available, dependable and accessible to support sustainable harvest of marine species.

Who: Directed to DFO scientists/biologists

1A

How would you characterize the overall level of data collected for this stock?

Data rich

Data moderate

Data poor

What types of data are collected for this stock? (please check all that apply and specify the type and the accessibility of the data)

Fishery-dependent

Fishery-independent

Data type

Total catch of target species

Age of catch

Weight of catch

Size (ie, length) of catch

Discards, target and non-target species

Protected species occurrence in catch

Fishing location (GPS)

Fishing date and times

Biological sample (Please, briefly explain)

(1) Other type of fishery data (Please, specify)

(2) Other type of fishery data (Please, specify)

(3) Other type of fishery data (Please, specify)

Accessibility

Data exists internally within DFO but is not shared across divisions/departments

Internally accessible and shared across divisions/departments (e.g., DFO analytic team)

Accessible to certain groups outside of DFO (e.g., First Nations, Industry, NGOs) through sharing agreements, or at advisory committees

Externally/publicly accessible (e.g., Posted online)

1B

With respect to climate and oceanographic data/observations collected, how would you characterize the overall level of data available for this stock?

Data rich

Data moderate

Data poor

What climate and oceanographic data/observations are collected for this stock? (please check all that apply and specify the source and of the accessibility of the data)

Are you aware of any barriers to collecting data on relevant climate and oceanographic variables associated with this stock?

Open/written answer

Data/observation type

Temperature

Oxygen

Carbonate chemistry (pH)

Salinity

Primary productivity

Nutrients zooplankton/Secondary productivity

Upwelling

Ocean currents

Sea ice

(1) Other (please specify)

(2) Other (please specify)

(3) Other (please specify)

Accessibility

Data exists internally within DFO but is not shared across divisions/departments

Internally accessible and shared across divisions/departments (e.g., DFO analytic team)

Accessible to certain groups outside of DFO (e.g., First Nations, Industry, NGOs) through sharing agreements, or at advisory committees

Externally/publicly accessible (e.g., Posted online)

1C

With respect to ecological data/observations collected, how would you characterize the overall level of data available for this stock? (see examples of data types in the following question)

Data rich

Data moderate

Data poor

What ecological data/observations are collected for this stock? (please check all that apply and specify the accessibility of the data)

Are you aware of any barriers to collecting data on relevant ecological variables associated with the stock?

Open/written answer

Data type

Geographic location (i.e., is the spatial structure of the stock monitored for its entire range?)

Abundance of potential prey, predators or competitors (Please, briefly specify)

Composition of potential prey, predators (Please, briefly specify)

Invasive species that interact with this stock

Physical habitat of the stock

(1) Other, Please specify

(2) Other, Please specify

(3) Other, Please specify

Accessibility

Data exists internally within DFO but is not shared across divisions/departments

Internally accessible and shared across divisions/departments (e.g., DFO analytic team)

Accessible to certain groups outside of DFO (e.g., First Nations, Industry, NGOs) through sharing agreements, or at advisory committees

Externally/publicly accessible (e.g., Posted online)

1D

Which of these options best describes how the existing monitoring program contributes to detect changes in the status of the stock (e.g. changes in productivity) that might be associated with climate or oceanographic events?

Real-time monitoring is occurring for this stock whereby changes observed on the water are immediately available to DFO enabling real-time tracking or shifts in stock status that could be associated with changing environmental variables.

(e.g., stock responses to an anomalously warm conditions, for example related to the onset of a heat dome or atmospheric river)

Short-term monitoring is occurring for this stock enabling DFO to detect changes in the status of the stock that might be associated with short-term environmental/oceanographic events (e.g., stock responses to an anomalously warm period, for example related to a heat dome or oceanographic rivers that occurs within a given season)

Annual monitoring is occurring for this stock enabling DFO to detect changes in the status of the stock associated with environmental variables on a given year or over a series of years.

(e.g., ENSOs or NAO)

Monitoring at intervals greater than 1 year is occurring for this stock, which does not enable DFO to detect year-to-year changes, but might enable DFO to detect changes in the stock status that are associated with longer term climatic or oceanographic events or patterns.

(e.g., ENSOs or NAO)

Insufficient monitoring occurs for this stock and DFO is not able at this time to detect how changes in the status of the stock might be associated with climate or oceanographic events

1E

Are you aware of any monitoring programs that provide climate, oceanographic or ecological data that is relevant to this stock?

Yes

No

Please, specify

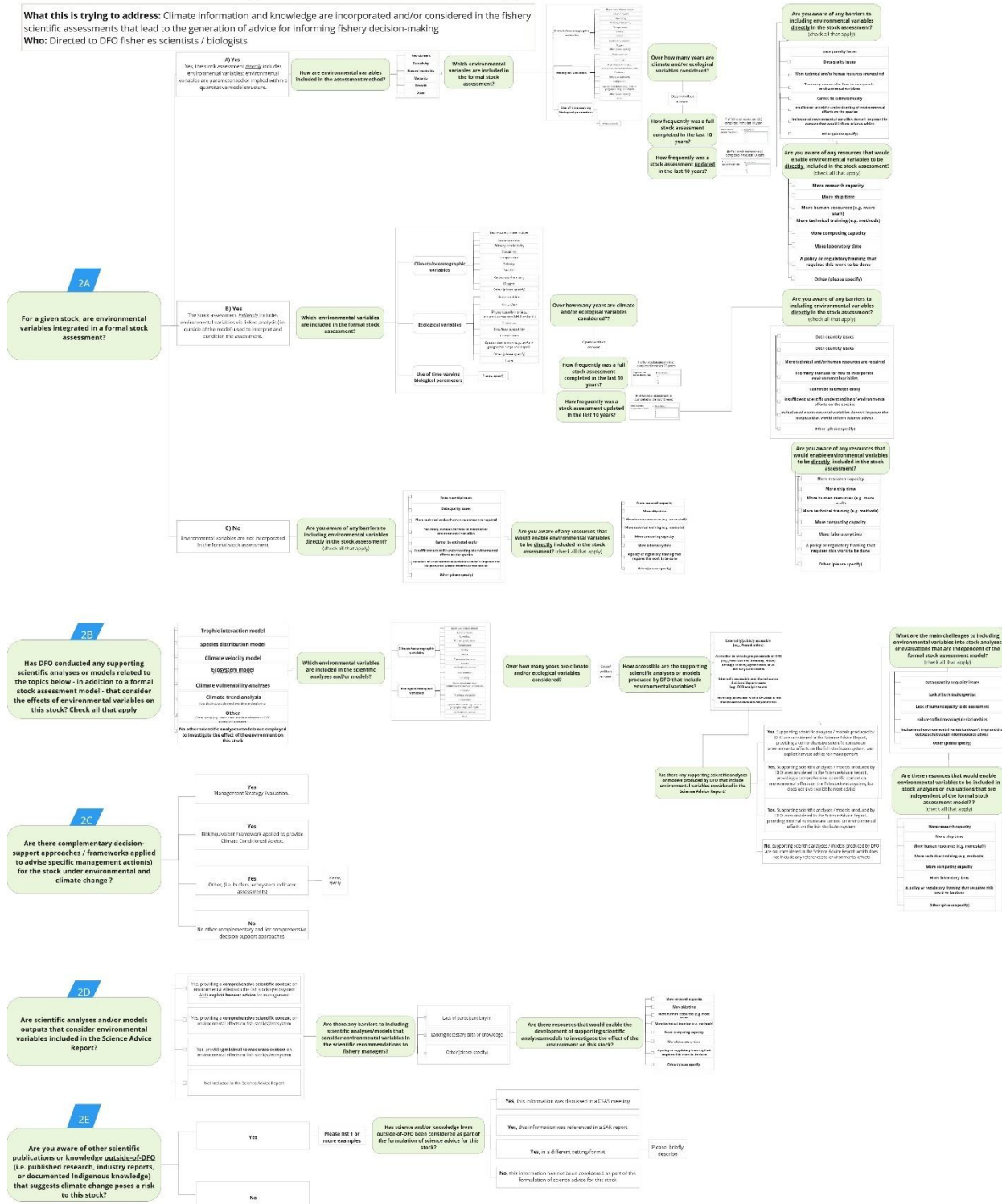
1F

What monitoring data would best assist you to include environmental variables (e.g. climate, oceanographic, ecological) when providing science advice for this stock?

Open/written answer

Module 2: Analysis & Generating Science Advice

What this is trying to address: Climate information and knowledge are incorporated and/or considered in the fishery scientific assessments that lead to the generation of advice for informing fishery decision-making
Who: Directed to DFO fisheries scientists / biologists



Module 3/4: Decision-making and Implementation

What this is trying to address: Managers are able to base decisions with an understanding of climate uncertainty in mind and have tools at their disposal to manage climate uncertainty when implementing fishery decisions
Who: Directed to DFO resource managers

A) Information about the stock and its management complexity

A.1

What type of fishery/ies operates on the stock? (check all that apply)

Recreational and Commercial (PQ)
 Commercial
 Recreational
 Other (specify):

A.2

Are there multiple gear types or fishing fleets that operate on this stock?

Yes (Please list them)
 No

A.3

What is the current status zone for this stock?

Stable
 Declining
 Increasing

A.4

What is the current trend of this stock?

Increasing
 Stable
 Declining

A.5

Is this stock caught as bycatch in other commercial fisheries?

Yes (Please list them)
 No

A.6

On average, how many times in a year does an advisory committee (or equivalent meeting with fishery stakeholders or rightsholders) meet to discuss and provide input into the management of the stock?

Provide periodic (1,2,3)
 Only once for the year of meeting

A.7

Is this stock, or some portion of it, co-managed?

Yes
 No

A.8

Is this stock managed internationally via treaty or major organization/institution?

Yes
 No

What stakeholders, rightsholders, and/or fishery participants take part in providing input into the management of this stock?

Other (specify):
 (1) Fishery
 (2) Government
 (3) Industry
 (4) Academia
 (5) Other (specify):

How many contracting parties are part of the co-management agreements?

Provide periodic (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,166,167,168,169,170,171,172,173,174,175,176,177,178,179,180,181,182,183,184,185,186,187,188,189,190,191,192,193,194,195,196,197,198,199,200,201,202,203,204,205,206,207,208,209,210,211,212,213,214,215,216,217,218,219,220,221,222,223,224,225,226,227,228,229,230,231,232,233,234,235,236,237,238,239,240,241,242,243,244,245,246,247,248,249,250,251,252,253,254,255,256,257,258,259,260,261,262,263,264,265,266,267,268,269,270,271,272,273,274,275,276,277,278,279,280,281,282,283,284,285,286,287,288,289,290,291,292,293,294,295,296,297,298,299,300,301,302,303,304,305,306,307,308,309,310,311,312,313,314,315,316,317,318,319,320,321,322,323,324,325,326,327,328,329,330,331,332,333,334,335,336,337,338,339,340,341,342,343,344,345,346,347,348,349,350,351,352,353,354,355,356,357,358,359,360,361,362,363,364,365,366,367,368,369,370,371,372,373,374,375,376,377,378,379,380,381,382,383,384,385,386,387,388,389,390,391,392,393,394,395,396,397,398,399,400,401,402,403,404,405,406,407,408,409,410,411,412,413,414,415,416,417,418,419,420,421,422,423,424,425,426,427,428,429,430,431,432,433,434,435,436,437,438,439,440,441,442,443,444,445,446,447,448,449,450,451,452,453,454,455,456,457,458,459,460,461,462,463,464,465,466,467,468,469,470,471,472,473,474,475,476,477,478,479,480,481,482,483,484,485,486,487,488,489,490,491,492,493,494,495,496,497,498,499,500,501,502,503,504,505,506,507,508,509,510,511,512,513,514,515,516,517,518,519,520,521,522,523,524,525,526,527,528,529,530,531,532,533,534,535,536,537,538,539,540,541,542,543,544,545,546,547,548,549,550,551,552,553,554,555,556,557,558,559,560,561,562,563,564,565,566,567,568,569,570,571,572,573,574,575,576,577,578,579,580,581,582,583,584,585,586,587,588,589,590,591,592,593,594,595,596,597,598,599,600,601,602,603,604,605,606,607,608,609,610,611,612,613,614,615,616,617,618,619,620,621,622,623,624,625,626,627,628,629,630,631,632,633,634,635,636,637,638,639,640,641,642,643,644,645,646,647,648,649,650,651,652,653,654,655,656,657,658,659,660,661,662,663,664,665,666,667,668,669,670,671,672,673,674,675,676,677,678,679,680,681,682,683,684,685,686,687,688,689,690,691,692,693,694,695,696,697,698,699,700,701,702,703,704,705,706,707,708,709,710,711,712,713,714,715,716,717,718,719,720,721,722,723,724,725,726,727,728,729,730,731,732,733,734,735,736,737,738,739,740,741,742,743,744,745,746,747,748,749,750,751,752,753,754,755,756,757,758,759,760,761,762,763,764,765,766,767,768,769,770,771,772,773,774,775,776,777,778,779,780,781,782,783,784,785,786,787,788,789,790,791,792,793,794,795,796,797,798,799,800,801,802,803,804,805,806,807,808,809,810,811,812,813,814,815,816,817,818,819,820,821,822,823,824,825,826,827,828,829,830,831,832,833,834,835,836,837,838,839,840,841,842,843,844,845,846,847,848,849,850,851,852,853,854,855,856,857,858,859,860,861,862,863,864,865,866,867,868,869,870,871,872,873,874,875,876,877,878,879,880,881,882,883,884,885,886,887,888,889,890,891,892,893,894,895,896,897,898,899,900,901,902,903,904,905,906,907,908,909,910,911,912,913,914,915,916,917,918,919,920,921,922,923,924,925,926,927,928,929,930,931,932,933,934,935,936,937,938,939,940,941,942,943,944,945,946,947,948,949,950,951,952,953,954,955,956,957,958,959,960,961,962,963,964,965,966,967,968,969,970,971,972,973,974,975,976,977,978,979,980,981,982,983,984,985,986,987,988,989,990,991,992,993,994,995,996,997,998,999,1000,1001,1002,1003,1004,1005,1006,1007,1008,1009,1010,1011,1012,1013,1014,1015,1016,1017,1018,1019,1020,1021,1022,1023,1024,1025,1026,1027,1028,1029,1030,1031,1032,1033,1034,1035,1036,1037,1038,1039,1040,1041,1042,1043,1044,1045,1046,1047,1048,1049,1050,1051,1052,1053,1054,1055,1056,1057,1058,1059,1060,1061,1062,1063,1064,1065,1066,1067,1068,1069,1070,1071,1072,1073,1074,1075,1076,1077,1078,1079,1080,1081,1082,1083,1084,1085,1086,1087,1088,1089,1090,1091,1092,1093,1094,1095,1096,1097,1098,1099,1100,1101,1102,1103,1104,1105,1106,1107,1108,1109,1110,1111,1112,1113,1114,1115,1116,1117,1118,1119,1120,1121,1122,1123,1124,1125,1126,1127,1128,1129,1130,1131,1132,1133,1134,1135,1136,1137,1138,1139,1140,1141,1142,1143,1144,1145,1146,1147,1148,1149,1150,1151,1152,1153,1154,1155,1156,1157,1158,1159,1160,1161,1162,1163,1164,1165,1166,1167,1168,1169,1170,1171,1172,1173,1174,1175,1176,1177,1178,1179,1180,1181,1182,1183,1184,1185,1186,1187,1188,1189,1190,1191,1192,1193,1194,1195,1196,1197,1198,1199,1200,1201,1202,1203,1204,1205,1206,1207,1208,1209,1210,1211,1212,1213,1214,1215,1216,1217,1218,1219,1220,1221,1222,1223,1224,1225,1226,1227,1228,1229,1230,1231,1232,1233,1234,1235,1236,1237,1238,1239,1240,1241,1242,1243,1244,1245,1246,1247,1248,1249,1250,1251,1252,1253,1254,1255,1256,1257,1258,1259,1260,1261,1262,1263,1264,1265,1266,1267,1268,1269,1270,1271,1272,1273,1274,1275,1276,1277,1278,1279,1280,1281,1282,1283,1284,1285,1286,1287,1288,1289,1290,1291,1292,1293,1294,1295,1296,1297,1298,1299,1300,1301,1302,1303,1304,1305,1306,1307,1308,1309,1310,1311,1312,1313,1314,1315,1316,1317,1318,1319,1320,1321,1322,1323,1324,1325,1326,1327,1328,1329,1330,1331,1332,1333,1334,1335,1336,1337,1338,1339,1340,1341,1342,1343,1344,1345,1346,1347,1348,1349,1350,1351,1352,1353,1354,1355,1356,1357,1358,1359,1360,1361,1362,1363,1364,1365,1366,1367,1368,1369,1370,1371,1372,1373,1374,1375,1376,1377,1378,1379,1380,1381,1382,1383,1384,1385,1386,1387,1388,1389,1390,1391,1392,1393,1394,1395,1396,1397,1398,1399,1400,1401,1402,1403,1404,1405,1406,1407,1408,1409,1410,1411,1412,1413,1414,1415,1416,1417,1418,1419,1420,1421,1422,1423,1424,1425,1426,1427,1428,1429,1430,1431,1432,1433,1434,1435,1436,1437,1438,1439,1440,1441,1442,1443,1444,1445,1446,1447,1448,1449,1450,1451,1452,1453,1454,1455,1456,1457,1458,1459,1460,1461,1462,1463,1464,1465,1466,1467,1468,1469,1470,1471,1472,1473,1474,1475,1476,1477,1478,1479,1480,1481,1482,1483,1484,1485,1486,1487,1488,1489,1490,1491,1492,1493,1494,1495,1496,1497,1498,1499,1500,1501,1502,1503,1504,1505,1506,1507,1508,1509,1510,1511,1512,1513,1514,1515,1516,1517,1518,1519,1520,1521,1522,1523,1524,1525,1526,1527,1528,1529,1530,1531,1532,1533,1534,1535,1536,1537,1538,1539,1540,1541,1542,1543,1544,1545,1546,1547,1548,1549,1550,1551,1552,1553,1554,1555,1556,1557,1558,1559,1560,1561,1562,1563,1564,1565,1566,1567,1568,1569,1570,1571,1572,1573,1574,1575,1576,1577,1578,1579,1580,1581,1582,1583,1584,1585,1586,1587,1588,1589,1590,1591,1592,1593,1594,1595,1596,1597,1598,1599,1600,1601,1602,1603,1604,1605,1606,1607,1608,1609,1610,1611,1612,1613,1614,1615,1616,1617,1618,1619,1620,1621,1622,1623,1624,1625,1626,1627,1628,1629,1630,1631,1632,1633,1634,1635,1636,1637,1638,1639,1640,1641,1642,1643,1644,1645,1646,1647,1648,1649,1650,1651,1652,1653,1654,1655,1656,1657,1658,1659,1660,1661,1662,1663,1664,1665,1666,1667,1668,1669,1670,1671,1672,1673,1674,1675,1676,1677,1678,1679,1680,1681,1682,1683,1684,1685,1686,1687,1688,1689,1690,1691,1692,1693,1694,1695,1696,1697,1698,1699,1700,1701,1702,1703,1704,1705,1706,1707,1708,1709,1710,1711,1712,1713,1714,1715,1716,1717,1718,1719,1720,1721,1722,1723,1724,1725,1726,1727,1728,1729,1730,1731,1732,1733,1734,1735,1736,1737,1738,1739,1740,1741,1742,1743,1744,1745,1746,1747,1748,1749,1750,1751,1752,1753,1754,1755,1756,1757,1758,1759,1760,1761,1762,1763,1764,1765,1766,1767,1768,1769,1770,1771,1772,1773,1774,1775,1776,1777,1778,1779,1780,1781,1782,1783,1784,1785,1786,1787,1788,1789,1790,1791,1792,1793,1794,1795,1796,1797,1798,1799,1800,1801,1802,1803,1804,1805,1806,1807,1808,1809,1810,1811,1812,1813,1814,1815,1816,1817,1818,1819,1820,1821,1822,1823,1824,1825,1826,1827,1828,1829,1830,1831,1832,1833,1834,1835,1836,1837,1838,1839,1840,1841,1842,1843,1844,1845,1846,1847,1848,1849,1850,1851,1852,1853,1854,1855,1856,1857,1858,1859,1860,1861,1862,1863,1864,1865,1866,1867,1868,1869,1870,1871,1872,1873,1874,1875,1876,1877,1878,1879,1880,1881,1882,1883,1884,1885,1886,1887,1888,1889,1890,1891,1892,1893,1894,1895,1896,1897,1898,1899,1900,1901,1902,1903,1904,1905,1906,1907,1908,1909,1910,1911,1912,1913,1914,1915,1916,1917,1918,1919,1920,1921,1922,1923,1924,1925,1926,1927,1928,1929,1930,1931,1932,1933,1934,1935,1936,1937,1938,1939,1940,1941,1942,1943,1944,1945,1946,1947,1948,1949,1950,1951,1952,1953,1954,1955,1956,1957,1958,1959,1960,1961,1962,1963,1964,1965,1966,1967,1968,1969,1970,1971,1972,1973,1974,1975,1976,1977,1978,1979,1980,1981,1982,1983,1984,1985,1986,1987,1988,1989,1990,1991,1992,1993,1994,1995,1996,1997,1998,1999,2000,2001,2002,2003,2004,2005,2006,2007,2008,2009,2010,2011,2012,2013,2014,2015,2016,2017,2018,2019,2020,2021,2022,2023,2024,2025,2026,2027,2028,2029,2030,2031,2032,2033,2034,2035,2036,2037,2038,2039,2040,2041,2042,2043,2044,2045,2046,2047,2048,2049,2050,2051,2052,2053,2054,2055,2056,2057,2058,2059,2060,2061,2062,2063,2064,2065,2066,2067,2068,2069,2070,2071,2072,2073,2074,2075,2076,2077,2078,2079,2080,2081,2082,2083,2084,2085,2086,2087,2088,2089,2090,2091,2092,2093,2094,2095,2096,2097,2098,2099,2100,2101,2102,2103,2104,2105,2106,2107,2108,2109,2110,2111,2112,2113,2114,2115,2116,2117,2118,2119,2120,2121,2122,2123,2124,2125,2126,2127,2128,2129,2130,2131,2132,2133,2134,2135,2136,2137,2138,2139,2140,2141,2142,2143,2144,2145,2146,2147,2148,2149,2150,2151,2152,2153,2154,2155,2156,2157,2158,2159,2160,2161,2162,2163,2164,2165,2166,2167,2168,2169,2170,2171,2172,2173,2174,2175,2176,2177,2178,2179,2180,2181,2182,2183,2184,2185,2186,2187,2188,2189,2190,2191,2192,2193,2194,2195,2196,2197,2198,2199,2200,2201,2202,2203,2204,2205,2206,2207,2208,2209,2210,2211,2212,2213,2214,2215,2216,2217,2218,2219,2220,2221,2222,2223,2224,2225,2226,2227,2228,2229,2230,2231,2232,2233,2234,2235,2236,2237,2238,2239,2240,2241,2242,2243,2244,2245,2246,2247,2248,2249,2250,2251,2252,2253,2254,2255,2256,2257,2258,2259,2260,2261,2262,2263,2264,2265,2266,2267,2268,2269,2270,2271,2272,2273,2274,2275,2276,2277,2278,2279,2280,2281,2282,2283,2284,2285,2286,2287,2288,2289,2290,2291,2292,2293,2294,2295,2296,2297,2298,2299,2300,2301,2302,2303,2304,2305,2306,2307,2308,2309,2310,2311,2312,2313,2314,2315,2316,2317,2318,2319,2320,2321,2322,2323,2324,2325,2326,2327,2328,2329,2330,2331,2332,2333,2334,2335,2336,2337,2338,2339,2340,2341,2342,2343,2344,2345,2346,2347,2348,2349,2350,2351,2352,2353,2354,2355,2356,2357,2358,2359,2360,2361,2362,2363,2364,2365,2366,2367,2368,2369,2370,2371,2372,2373,2374,2375,2376,2377,2378,2379,2380,2381,2382,2383,2384,2385,2386,2387,2388,2389,2390,2391,2392,2393,2394,2395,2396,2397,2398,2399,2400,2401,2402,2403,2404,2405,2406,2407,2408,2409,2410,2411,2412,2413,2414,2415,2416,2417,2418,2419,2420,2421,2422,2423,2424,2425,2426,2427,2428,2429,2430,2431,2432,2433,2434,2435,2436,2437,2438,2439,2440,2441,2442,2443,2444,2445,2446,2447,2448,2449,2450,2451,2452,2453,2454,2455,2456,2457,2458,2459,2460,2461,2462,2463,2464,2465,2466,2467,2468,2469,2470,2471,2472,2473,2474,2475,2476,2477,2478,2479,2480,2481,2482,2483,2484,2485,2486,2487,2488,2489,2490,2491,2492,2493,2494,2495,2496,2497,2498,2499,2500,2501,2502,2503,2504,2505,2506,2507,2508,2509,2510,2511,2512,2513,2514,2515,2516,2517,2518,2519,2520,2521,2522,2523,2524,2525,2526,2527,2528,2529,2530,2531,2532,2533,2534,2535,2536,2537,2538,2539,2540,2541,2542,2543,2544,2545,2546,2547

Appendix 3: Framework for Fisheries Management Adaptation to Climate Change (FiMACC) survey, listing institutional resilience attributes, assessment criteria, survey questions, and associated scoring levels for selected synthesis criteria, where scores of 3 = higher level, 2 = moderate level, 1 = lower level climate consideration. OCE refers to Ocean, Climate, and Ecological (data).

Institutional Resilience Attribute	Assessment Criteria	Survey Questions	Synthesis Levels and Scores
INFORMATION <i>Definition: Assets in the form of data or information, to provide the foundation for a comprehensive understanding of the fishery system</i> Rationale: Information assets are the foundation for understanding fishery systems and awareness of how they are changing with climate-related variability and impacts ⁹	Overall degree of monitoring data available	"How would you characterize the overall level of data collected for this stock?" / [As above] "...With respect to climate and oceanographic data" / [As above] "...With respect to ecological data"	N/A
	Data types available (Stock)	"What types of data are collected for this stock?" (E.g. Fishery-dependent and fishery-independent data)"	>2/3 of data types selected = 3
			1/3 - 2/3 of data types selected = 2
			< 1/3 of data types selected = 1
	Data types available (Ocean-Climate)	"What climate and/or oceanographic data are available to investigate the effects of environmental variables on this stock?" (E.g. temperature, pH, dissolved O ₂ , salinity, etc)	>2/3 of data types selected = 3
			1/3 - 2/3 of data types selected = 2
			< 1/3 of data types selected = 1
	Data types available (Ecological)	"What type of ecological data are collected for this stock?" (E.g. predator/prey, behaviour, spatial structure, habitat, etc)	>2/3 of data types selected = 3
			1/3 - 2/3 of data types selected = 2
			< 1/3 of data types selected = 1
	Existence of monitoring outside of DFO	"Are you aware of any monitoring programs outside of DFO that provide climate, oceanographic or ecological data that is relevant to this stock?" / "What monitoring data would best assist you to include environmental variables when providing science advice for this stock?"	N/A
ANALYSIS AND INTEGRATION <i>Definition: Assets in the form of capacity, tools,</i>	Incorporation of OCE data in stock assessment	"For your given stock, are environmental variables integrated in a formal stock assessment?"	"Yes. The stock assessment directly includes environmental variables; environmental variables are parameterized or implied within a quantitative model structure" = 3
			"Yes. The stock assessment indirectly includes environmental variables via linked analysis (i.e.

⁹ Pinsky and Mantua, 2014; Bell et al., 2020; Pepin et al. 2020; Dorn & Zador, 2020

<i>and approaches to analyse and contextualize information assets</i> Rationale: Turning data and information into shared knowledge and science outputs allows for a synthesized understanding of the fishery system and climate interactions upon which to make decisions and determine appropriate actions ¹⁰			outside of the model) used to interpret and affect the assessment" = 2
			"No. Environmental variables are not included in the formal stock assessment" = 1
	Supporting analyses that consider OCE data	"Has DFO conducted any supporting scientific analyses or models related to the topics below – in addition to a formal stock assessment model – that consider the effects of environmental variables on this stock? Check all that apply]"	>1 analysis selected = 3
			1 analysis selected = 2
			0 analysis selected = 1
	OCE data types in stock assessment or supporting analyses	"Which environmental variables are included in the formal stock assessment? Climate oceanographic variables" / [As above] "...Ecological variables"	N/A
	Use of complementary decision-support tools used	"Are there complementary decision-support approaches / frameworks applied to advise specific management action(s) for the stock under environmental and climate change?"	>1 analysis selected = 3
			1 analysis selected = 2
			0 analysis selected = 1
	Existence of scientific analyses or publications outside of DFO	"Are you aware of other scientific publications or knowledge <u>outside-of-DFO</u> (i.e. published research, industry reports, or documented Indigenous knowledge) that suggests climate change poses a risk to this stock?"	N/A
PARTICIPATION <i>Definition: The degree to which an institution empowers participants to share control in processes of decision-making,</i>	Advisory participants	"What stakeholders, rightsholders, and/or fishery participants take part in providing input into the management of this stock?"	>2/3 of participant types selected = 3
			1/3 - 2/3 of participant types selected = 2
			< 1/3 of participant types selected = 1
	Co-management of stock	"Is this stock, or some portion of it, co-managed?" / "How many contracting parties are part of the co-management agreements?" / "Have co-management terms or agreements been revised in response to climate-related risks, benefits, and/or uncertainties associated with the stock?"	N/A

¹⁰Mason et al. 2021

<i>-ranging from consultation to co-management</i> Rationale: Participation facilitates climate consideration and effective response by including diverse actors in knowledge-sharing, supporting legitimacy and compliance, and building trust among rightsholders and stakeholders ¹¹	Managed by international treaty/organizations	“Is this stock managed internationally via treaty or major organization/institution?” / “Have international treaty terms/agreements been revised in response to climate-related risks, benefits, and/or uncertainties associated with the stock?”	N/A
TRANSPARENCY <i>Definition: Openness and accessibility of timely information and decision-making procedures</i> Rationale: Transparency enables the free flow of fishery-related information to support learning and decision-making, which can support implementation and perceived trustworthiness and legitimacy of	Accessibility of monitoring data	“How accessible are the data collected?”	“Data are publicly accessible” = 3
			“Data are accessible to specific groups outside of DFO through data sharing agreements or advisory committees” = 2
			“Data are internally accessible and shared across divisions /departments” = 1
			“Data exists internally within DFO but is not shared across divisions / departments” = 1
		“How accessible are the data collected?” [Ocean-Climate data]	“Data are publicly accessible” = 3
			“Data are accessible to specific groups outside of DFO through data sharing agreements or advisory committees” = 2
			“Data are internally accessible and shared across divisions /departments” = 1
		“How accessible are the data collected?” [Ecological data]	“Data exist internally within DFO but is not shared across divisions / departments” = 1
			“Data are publicly accessible” = 3

¹¹ Coghlan and Brydon-Miller 2014, Leite and Pita 2016, Cvitanovic et al 2018, Fraser and Kirbyshire 2017, Hall-Arber 2005, Mason et al. 2021

decisions or actions that support responses to climate change ¹²			"Data are accessible to specific groups outside of DFO through data sharing agreements or advisory committees" = 2
			"Data are internally accessible and shared across divisions /departments" = 1
			"Data exist internally within DFO but is not shared across divisions / departments" = 1
	Accessibility of supporting analyses	"How accessible are the supporting scientific analyses or models produced by DFO that include environmental [i.e., OCE] variables?"	"Supporting scientific analyses/models are publicly accessible (e.g., posted online)" = 3
			"Supporting scientific analyses/models are accessible to specific groups outside of DFO through sharing agreements or advisory committees" = 2
			"Supporting scientific analyses/models are internally accessible and shared across divisions/departments" = 1
			"Supporting scientific analyses/models are internally accessible within DFO but is not shared across divisions/departments" = 1
	Rationale provided for decisions	"When a substantive decision is made regarding the allocations or harvest specifications for this stock, is there typically a rationale provided to help explain?"	N/A
	Decision rationale made accessible	"To what degree is the rationale provided made accessible?"	"Externally/publicly accessible (e.g., posted online)" = 3
			"Accessible to certain groups outside of DFO through sharing agreements, or at advisory committees" = 2
			"Internally accessible and shared across divisions/departments" = 1
			"Internally accessible within DFO but is not shared across divisions/departments" = 1
			8+ assessments / 10 years = 3

¹² Clark et al., 2015; Davis & Hanich, 2020; Mason et al. 2021

RESPONSIVENESS <i>Definition: The sensitivity, readiness, speed, and accuracy with which a system can detect, process, and react to a stressor or changing trend</i> Rationale: Responsive systems can resist and / or recover from disturbances by allowing for the timely deployment of strategies, tactics, and actions ¹³	Frequency of stock assessment completion + update	("How many times was a stock assessment completed in the last 10 years?") + ("How many times was a stock assessment updated in the last 10 years?")	2-7 assessments / 10 years = 2 0-1 assessments / 10 years = 1
	Frequency of advisory committee meetings	"On average, how many times in a year does an advisory committee (or equivalent meeting with fishery stakeholders or rightsholders) meet to discuss and provide input into the management of the stock?"	3+ meetings / year = 2
			2 meetings / year = 2
			1 meetings / year = 1
CAPACITY FOR ACTION <i>Definition: Support and development of actors who mobilize and direct responses to disruptions and who take responsibility to act as necessary</i> Rationale: Leadership and staff are empowered to make use of resources and catalyze action to maintain functionality in light of stressors, allowing	Consideration of supporting analyses in advice	"Are any supporting scientific analyses or models produced by DFO that include environmental [i.e., OCE] variables considered in the Science Advice Report?"	"Yes. Supporting scientific analyses/models produced by DFO are considered in the Science Advice Report, providing a comprehensive scientific context on environmental effects on the fish stock(s)/ecosystem, and explicit harvest advice for management" = 3
			"Yes. Supporting scientific analyses/models produced by DFO are considered in the Science Advice Report, providing a comprehensive scientific context on environmental effects on the fish stock(s)/ecosystem, but does not give explicit harvest advice" = 2
			"Yes. Supporting scientific analyses/models produced by DFO are considered in the Science Advice Report, providing minimal to moderate context on environmental effects on the fish stock(s)/ecosystem" = 2

¹³ Sheng 2009, Grafton 2010, Mason et al. 2021

for the achievement of objectives with fewer trade-offs ¹⁴			"No. supporting scientific analyses/models produced by DFO are not considered in the Science Advice Report, which does not include any reference to environmental effects on the fish stock(s)/ecosystem" = 1
	Consideration of external science and knowledge in advice	"Has science and/or knowledge from outside-of-DFO resources been considered as part of the formulation of science advice for this stock?"	Yes; referenced in a science advisory report (SAR) = 3
			Yes; discussed in the Canadian Science Advisory Secretariat meeting (CSAS) = 2
			Yes; considered in a different setting/format = 2
			I do not know if science/knowledge has been considered in the formulation of science advice for this stock = 1
	Data collection barriers	"Are you aware of any barriers to collecting data on relevant climate and oceanographic variables / ecological variables associated with this stock?"	N/A
	Barriers to including OCE data in stock assessment	"Are you aware of any barriers to including environmental [i.e., OCE] variables directly in the stock assessment?" / "Are you aware of any resources that would enable environmental [i.e., OCE] variables to be directly included in the stock assessment?"	N/A
COMMUNICATION	Barriers to taking management actions	"Are you aware of any barriers in the dept to taking management action(s) in response to climate-related risks / uncertainties?" / "What additional resources for the dept do you think could help overcome the identified barriers in responding to climate-related risks?"	N/A
	Manager awareness of climate issues	"In the last five years, have you been aware of any communications about climate-related risks, benefits, and/or uncertainties associated with the stock?" /	N/A
			3+ communication methods = 3

¹⁴ Crona et al. 2017, Ostrom 2009, Gutierrez et al 2011, Mason et al. 2021

<i>Definition: The transmission of knowledge and ideas to educate, establish a shared understanding, and/or mobilize the audience</i> Rationale: Communication (e.g., between scientists, managers, policymakers, fishery participants, and the public) is essential to building connections, collaboration, and consensus required to be responsive to climate change; Through regular and comprehensive communication channels, it is possible to establish shared visions, values, and pathways to operationalizing them¹⁵	Methods used for communicating climate risks	"In what form(s) was the information about climate-related risks, benefits, and/or uncertainties communicated to you?"	2 communication methods = 2 1 communication method = 1
	Nature of climate risks communicated	"Based on the information communicated to you, what is the nature of climate-related risks, benefits, and/or uncertainties associated with the stock?"	N/A
	Timeframe of climate risks communicated	"Based on the information communicated, what is your understanding of the timeframe of climate-related risks, benefits, etc?"	N/A
ADAPTATION <i>Definition: The ability to conduct an iterative process of continual innovation, testing, learning, and adjustment</i>	Climate-related management action response (taken or anticipated)	"In the last five years, have you been aware of any management actions taken by the department to mitigate climate-related risks and/or uncertainties associated with the stock? [check all that apply]" / "Are any of these management actions likely to be taken by the department in the next 5 years to help reduce climate-related risks and/or uncertainties associated with this stock? [Check all that apply]"	At least 1 past action AND at least 1 future action anticipated = 3
			At least 1 action anticipated regardless of past action = 2
			No past or anticipated actions = 1

¹⁵ Maltby et al. 2023

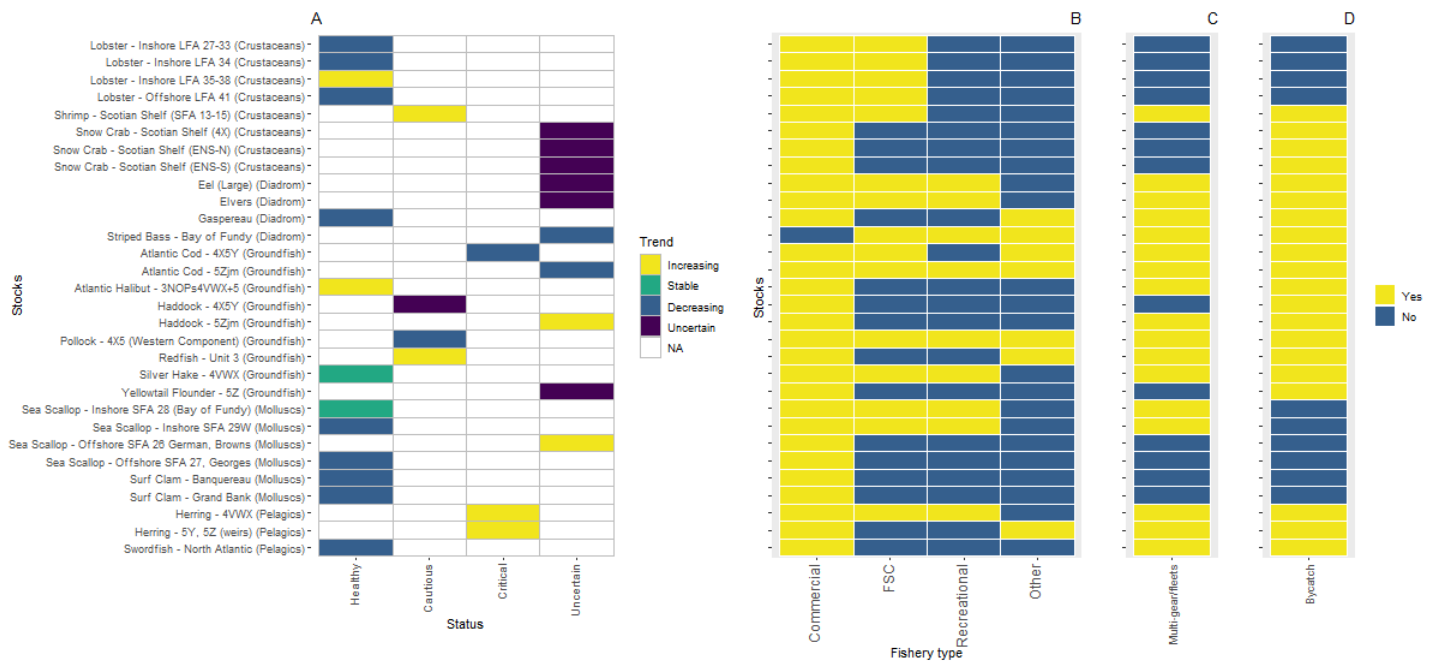
<i>that facilitates action toward an objective</i> Rationale: Adaptive processes in fisheries management allow for the institutional capacity to experiment and learn in the face of uncertainty and complexity ¹⁶	Process to review stock management at end of season	“Does the management of the stock include any sort of explicit process or meeting to review/assess harvest decisions or fishery outcomes after the fishing season has concluded?”	N/A
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¹⁶ Ojea et al 2017, Plaganyi et al 2011, Davidson et al 2013, Bell et al. 2020, Grafton 2010, Mason et al. 2021

Appendix 4: Summary of stocks assessed by the Fisheries Management Adaptation to Climate Change (FiMACC) survey

Stock Group	Species (Common)	Species (Scientific)	Stock Designation
Groundfish	Yellowtail flounder	<i>Pleuronectes ferruginea</i>	5Z
	Silver hake	<i>Merluccius bilinearis</i>	4VWZ
	Redfish	<i>Sebastes spp.</i>	Unit 3
	Pollock	<i>Pollachius pollachius</i>	4X5 (Western Component)
	Haddock	<i>Melanogrammus aeglefinus</i>	5Zjm
	Haddock	<i>Melanogrammus aeglefinus</i>	4X5Y
	Atlantic halibut	<i>Hippoglossus hippoglossus</i>	3NOPs4VWX+5
	Atlantic cod	<i>Gadus morhua</i>	5Zjm
	Atlantic cod	<i>Gadus morhua</i>	4X5Y
Diadromous	Gaspereau	<i>Alosa pseudoharengus</i>	
	Elvers	<i>Anguilla rostrata</i>	
	Eel (large)	<i>Anguilla rostrata</i>	
	Striped bass	<i>Morone saxatilis</i>	Bay of Fundy
Pelagics	Swordfish	<i>Xiphias gladius</i>	North Atlantic
	Herring	<i>Clupea harengus</i>	5Y, 5Z (Weirs)
	Herring	<i>Clupea harengus</i>	4VWX
Crustaceans	Snow crab	<i>Chionoectes opilio</i>	Scotian Shelf (ENS-N)
	Snow crab	<i>Chionoectes opilio</i>	Scotian Shelf (ENS-S)
	Snow crab	<i>Chionoectes opilio</i>	Scotian Shelf (4X)
	Shrimp	<i>Pandalus borealis</i>	Scotian Shelf (SFA 13-15)
	Lobster	<i>Homarus americanus</i>	Offshore LFA 41
	Lobster	<i>Homarus americanus</i>	Inshore LFA 35-38
	Lobster	<i>Homarus americanus</i>	Inshore LFA 34
	Lobster	<i>Homarus americanus</i>	Inshore LFA 27-33
Molluscs	Surf clam	<i>Spisula solidissima</i>	Grand Bank
	Surf clam	<i>Spisula solidissima</i>	Banquereau
	Sea scallop	<i>Placopecten magellanicus</i>	Offshore SFA 27, Georges

	Sea scallop	<i>Placopecten magellanicus</i>	Offshore SFA 26, German, Browns
	Sea scallop	<i>Placopecten magellanicus</i>	Inshore SFA 29W
	Sea scallop	<i>Placopecten magellanicus</i>	Inshore SFA 28 (Bay of Fundy)

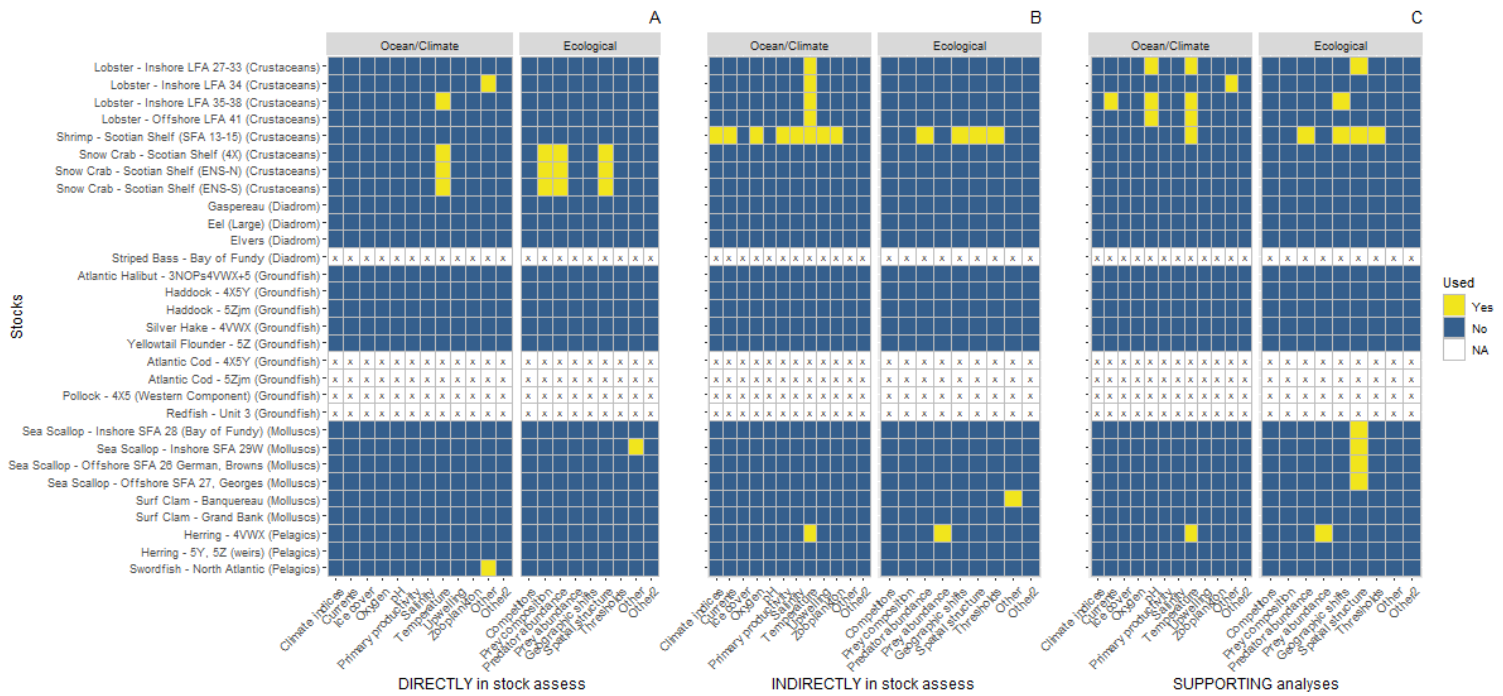


Appendix 5: Sustainable Fisheries Framework status and current trend (A) and fishery types (B, C, D) for 30 priority commercial stocks managed by Fisheries and Oceans Canada Maritimes Region.

Appendix 6: Outside monitoring awareness and monitoring data requested to best assist with including environmental variables when providing science advice for this stock for 30 priority commercial stocks managed by Fisheries and Oceans Canada Maritimes Region.

Stock	Outside monitoring available	Monitoring data to best assist
Gaspereau	eccc flow stations. precipitation	monitoring from dfo on stock sub units ranges from daily counts of abundance for some rivers, to no monitoring for decades on other rivers. with good monitoring, at seas temp, spring freshwater flows,
Eel (Large)	NA	we lack the resources to estimate eel productivity (e.g., standing stock, adult production etc.). it is accordingly difficult to propose means to include environmental monitoring.
Elvers	noaa?	environmental factors influencing the fishery are local (i.e., river temperatures and flows, etc.) we could probably begin to look for correlations between recruitment to the index river and data coll
Lobster - Inshore LFA 27-33	sometimes we use information from snow crab survey, but mostly the a	an inshore coastal monitoring program designed to collect data relevant to lobster.
Lobster - Inshore LFA 34	yes, we rely heavily on the us surveys, all the coastal monitoring i	temperature is currently an annual index from disparate surveys. a seasonal temperature index from a common survey would be better for process
Lobster - Inshore LFA 35-38	NA	more thorough surveys in lfa 36 and 38 are needed.
Lobster - Offshore LFA 41	us surveys	there are data but we have not had time to work on incorporating into sam
Shrimp - Scotian Shelf (SFA 13-15)	fishing industry runs survey and new program on monitoring disease a	seasonal monitoring of temperature, predators, shrimp catch would be ideal. currently have research program on temperature and catch through fishing industry
Snow Crab - Scotian Shelf (4X)	NA	high res space time of bottom azmp data
Snow Crab - Scotian Shelf (ENS-N)	NA	high res space time of bottom azmp data
Snow Crab - Scotian Shelf (ENS-S)	NA	high res space time of bottom azmp data
Haddock - 4X5Y	NA	temperature, salinity and currents.
Haddock - 5Zjm	NA	temperature, salinity and currents.

Yellowtail Flounder - 5Z	NA	temperature, salinity and currents.
Sea Scallop - Inshore SFA 28 (Bay of Fundy)	habitat mapping work at dalhousie.	habitat maps
Sea Scallop - Inshore SFA 29W	habitat mapping work at dalhousie.	habitat maps
Sea Scallop - Offshore SFA 26 German, Browns	habitat mapping work at dalhousie.	habitat maps
Sea Scallop - Offshore SFA 27, Georges	habitat mapping work at dalhousie.	habitat maps
Surf Clam - Banquereau	NA	the environmental variables would need to be available at the spatial scale of this fishery.
Surf Clam - Grand Bank	detailed oceanographic data is collected by industry	a novel approach to spatio-temporal stock assessment using high-resolution environmental variables is currently being developed for this stock. in 2023 we should have a better idea of which environmen
Herring - 4VWX	NA	most sources of monitoring exist already. the problem is linking these factors to actual cause-effect changes to the population. that is tricky.
Herring - 5Y, 5Z (weirs)	NA	current approaches are fine, but require research time and dedication to link these factors to population dynamics.
Swordfish - North Atlantic	noaa and organizations like it provide basin scale climate and ocean	psat data would help to describe swo distribution in relation to environmental variables and would address uncertainty related to catch rates when coupled with maps of the environmental data on the ap. diet and movement data.



Appendix 7: Inclusion of various ocean/climate and ecological data types in fishery analysis, including A) directly in stock assessment, B) indirectly in stock assessment, and C) via supporting analyses for 30 priority commercial stocks managed by Fisheries and Oceans Canada Maritimes Region. “Other” boxes allowed for the indication of up to two additional data types not otherwise listed.

Appendix 8: Awareness of science / knowledge from outside DFO for 30 priority commercial stocks managed by Fisheries and Oceans Canada Maritimes Region.

Stock	Outside source
Gaspereau	https://afspubs.onlinelibrary.wiley.com/doi/full/10.1002/mcf2.1
Lobster - Inshore LFA 27-33	There is knowledge that climate is impacting stock but currently it is not at risk
Lobster - Inshore LFA 34	There is knowledge that climate is impacting stock but currently it is not at risk
Lobster - Inshore LFA 35-38	There is knowledge that climate is impacting stock but currently it is not at risk
Lobster - Offshore LFA 41	There is knowledge that climate is impacting stock but currently it is not at risk
Shrimp - Scotian Shelf (SFA 13-15)	There is knowledge that climate is impacting stock but currently it is not at risk
Snow Crab - Scotian Shelf (4X)	Primaries
Snow Crab - Scotian Shelf (ENS-N)	Primaries
Snow Crab - Scotian Shelf (ENS-S)	Primaries
Eel (large)	Name something that is not attributed to climate change by one group or another.
Elvers	Name something that is not attributed to climate change by one group or another.