OCEANS NORTH

TURNING UP THE HEAT:

MANAGING THE IMPACTS OF CLIMATE CHANGE ON FISHERIES IN ATLANTIC CANADA & THE EASTERN ARCTIC

SUMMARY REPORT & RECOMMENDATIONS FOR ACTION

MAY 2021

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INTRODUCTION

> **Climate changes have and will continue to have large effects on the distribution, biomass, and productivity of commercially harvested species.**

The impacts of climate change on fisheries have been an increasing focus of scientific studies, and recently there have been calls to integrate climate directly into fisheries management. The Food and Agriculture Organization completed an overview of climate impacts on fisheries and aquaculture in 2018, concluding that adapting to and mitigating impacts of climate on fisheries will need to address environmental, social, cultural and economic factors. With the 2019 publication of the International Panel on Climate Change Special Report on Oceans and the Cryosphere, there is now a comprehensive compilation of existing data and forecasting of climate impacts on oceanic and ice-based ecosystems under various warming scenarios.

Oceans North's new report, "Incorporating climate change into fisheries management in Atlantic Canada and the Eastern Arctic," focuses exclusively on climate change and fisheries in the Atlantic Canadian and Eastern Arctic regions, building on global and national reports on climate change and the oceans. These issues are of critical importance to the productivity of fisheries in this region as climate changes have and will continue to have large effects on the distribution, biomass, and productivity of commercially harvested species. To make matters worse, many fish populations are already at low levels and in the "critical zone," with several groundfish species in particular never having recovered from overfishing in the early 1990s.

Fish populations in Atlantic Canada and the Eastern Arctic are already responding to climate impacts. Some of these impacts include:

- Warmer water temperatures, in particular in the Gulf of Maine, the Gulf of St. Lawrence and the Scotian Shelf which can lead to:
    - Increased threat of deoxygenation which can cause species death
    - Northward migration of species
    - More invasive species
- Earlier sea ice melting, impacting the timing of phytoplankton blooms and in turn spawning of commercially caught species
- Decrease in overall size of most species
- Impeded growth of shrimp, lobster and phytoplankton due to ocean acidification
- Increase in vulnerability to disease

The report looked at fisheries in Atlantic Canada and the Eastern Arctic within Canada's Exclusive Economic Zone, as show in the map above.

Fortunately, studies indicate that fisheries management measures, taken at the right time, can improve fish population status and can in part offset climate change effects. Management measures can compensate for the negative effects of climate change on the value of fisheries and possibly amplify the positive effects. This underscores the need to prioritize following science advice and taking into account ecosystem considerations as a matter of urgency in Canadian fisheries management.

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Canada lacks a clear and holistic climate change adaptation strategy for its fisheries, and climate change has yet to be adequately considered in fisheries management decisions. Immediate changes are needed to Canada's approach to fisheries management to ensure that climate change is being effectively considered in a proactive manner. As Canada embarks on the development of a Blue Economy Strategy, it is of vital importance that the impacts of climate change on the resources and communities who depend upon them are fully embedded in any future plans for an ocean-based economy.

This report provides key findings and recommendations that should be considered as Fisheries and Oceans Canada (DFO) moves towards incorporating ecosystem and climate considerations into fisheries management, and it can also be used to ensure that existing management practices follow precautionary principles.

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We summarize the report into the following sections:

HOW HEALTHY ARE FISHERIES IN ATLANTIC CANADA AND THE EASTERN ARCTIC, AND HOW IS CLIMATE CHANGE IMPACTING THEM?

FISHERIES IN ATLANTIC CANADA AND THE EASTERN ARCTIC

Understanding current and historic stock status trends is important for understanding species changes and for prioritizing actions on climate change adaptation. Following the groundfish collapse in the early 1990s, forage fishes and invertebrates became of greater importance and constituted the majority of all fishery landings in Atlantic Canada and the Eastern Arctic. Invertebrates now make up 65% of Atlantic Canadian fisheries landings, with lobster, shrimp, crab, and scallop being the most valuable, while groundfish make up 12%. The volume of fisheries landings has been decreasing since 2005, dropping to the lowest levels in the time series in 2018 (Figure 1).

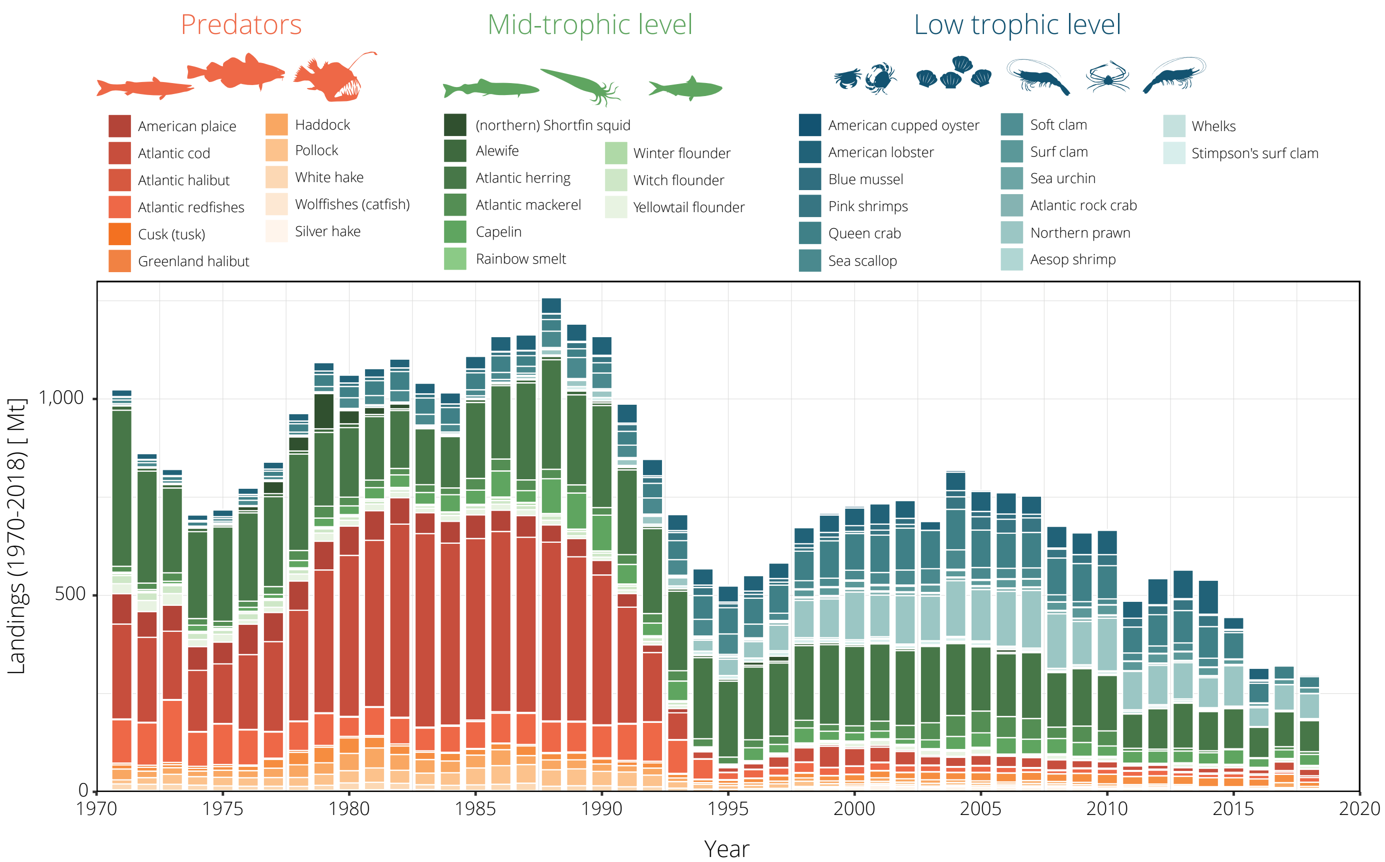


Figure 1: Officially reported commercial landings by species, functional group and year across Atlantic Canada and the Eastern Arctic. *Shaded bars depict the total reported commercial landings of the 35 top species by their functional group (indicated by colour) between 1970 and 2018. Orange depicts high trophic level (T.L.), green mid-T.L., and blue low T.L. species.*

Fishery stock assessments suggest declining abundance trends over time for most large predator species, including American plaice (-63%), Atlantic cod (-46%), cusk (-86%), deep-water redfish (-35%), Greenland halibut (-92%), porbeagle shark (-56%), spiny dogfish (-45%), white hake (-95%), winter flounder (-39%), and witch flounder (-76%). Increasing trends were evident for low trophic level species, including northern shrimp (41%) and sea scallop (35%) as well as Acadian redfish and Atlantic halibut (Figure 2).

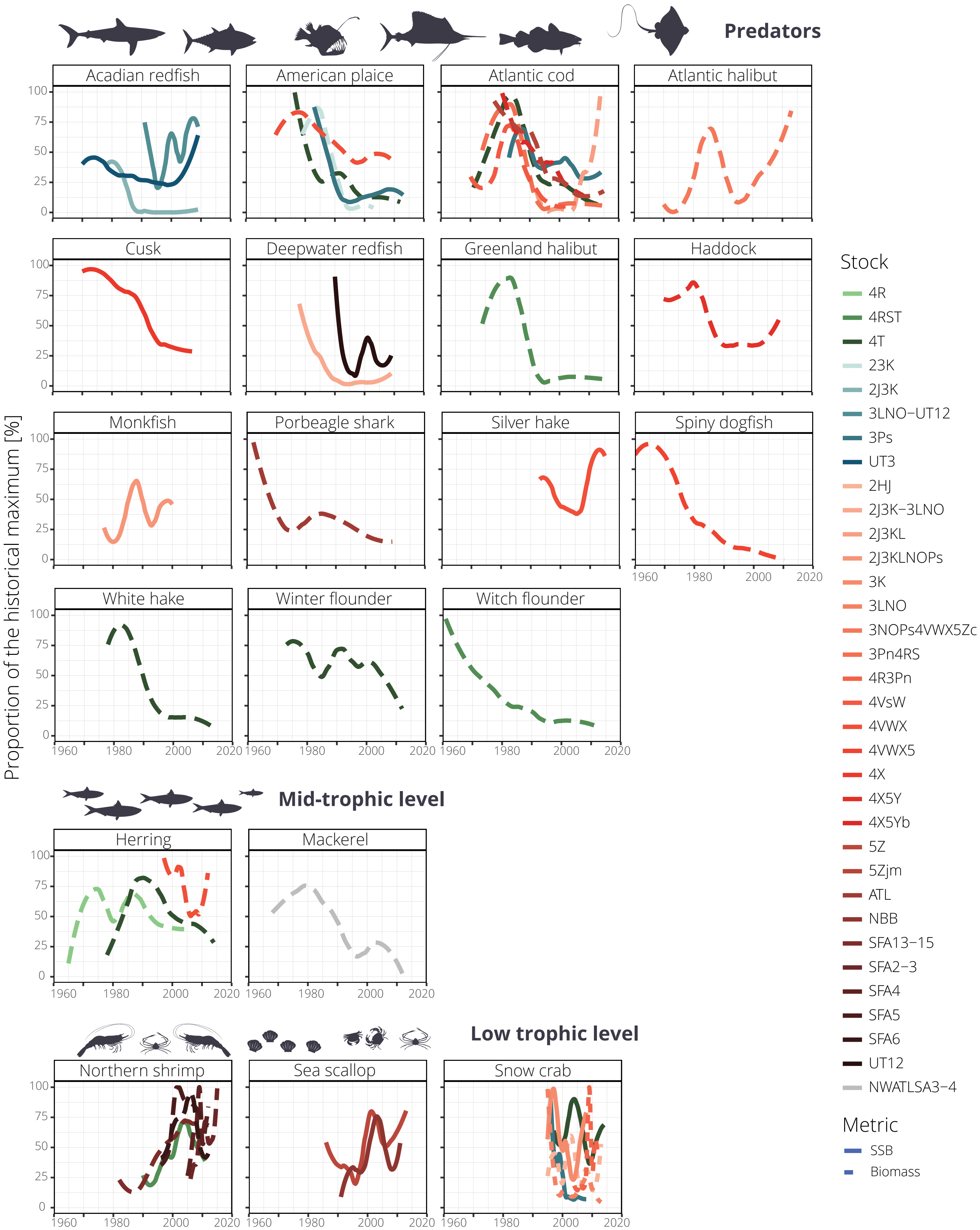


Figure 2: Stock assessment time trends within Atlantic Canada and the Eastern Arctic. *Trends in estimated stock abundance (SSB=solid lines, biomass= dashed lines) over time for all exploited species within the area. The bioregion and geographic identifier of the stocks are depicted in colours: Purple = Eastern Arctic, green = Gulf of St. Lawrence, blue = Newfoundland and Labrador, and orange = Scotian Shelf and Bay of Fundy. All time-series were standardized to units of percentage (%) of the time-series maximum. Lines are estimated from loess models (span = 0.25).*

The Sustainability Survey for Fisheries, completed by DFO and publicly available since 2016, suggests that nationally, almost half (44%) of stocks within the Atlantic Canada and the Eastern Arctic were classified as uncertain, 22% as cautious/critical, and only 34% as healthy (Figure 3). Only 15% of the populations in the Gulf region were healthy, whereas 69% were categorized as cautious or critical. Newfoundland and Labrador and the Eastern Arctic had low proportions of healthy stocks (19–25%) and high degrees of uncertainty (58–75%). Stocks within the Maritimes had 55% of stocks classified as healthy and a relatively low degree of uncertainty (23%).

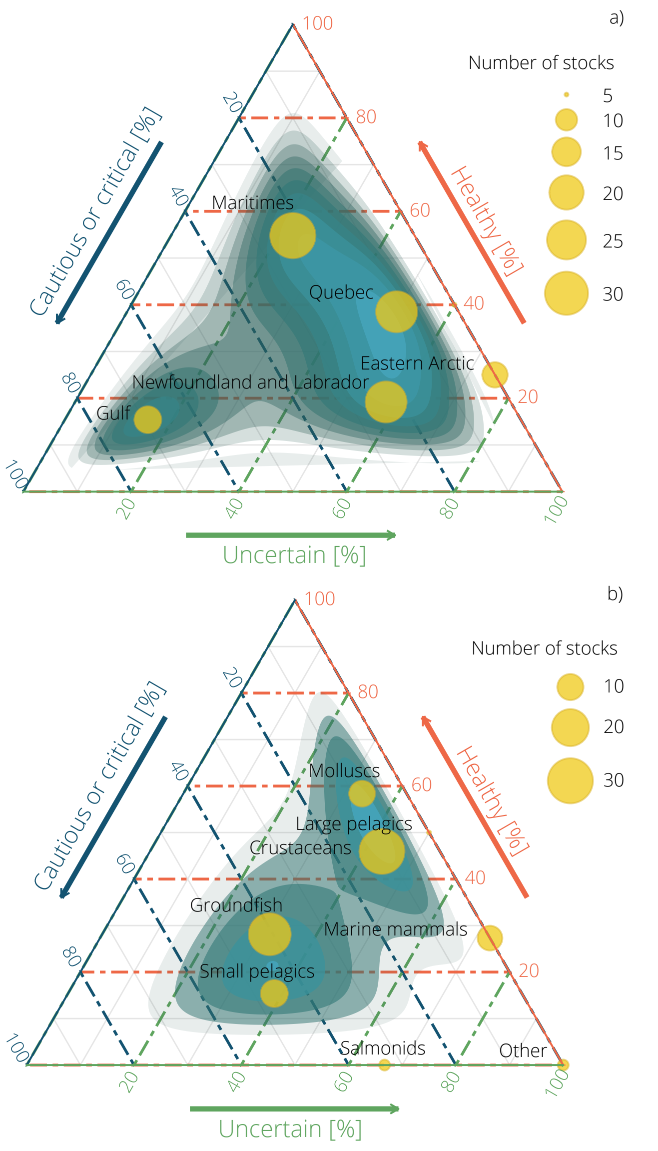


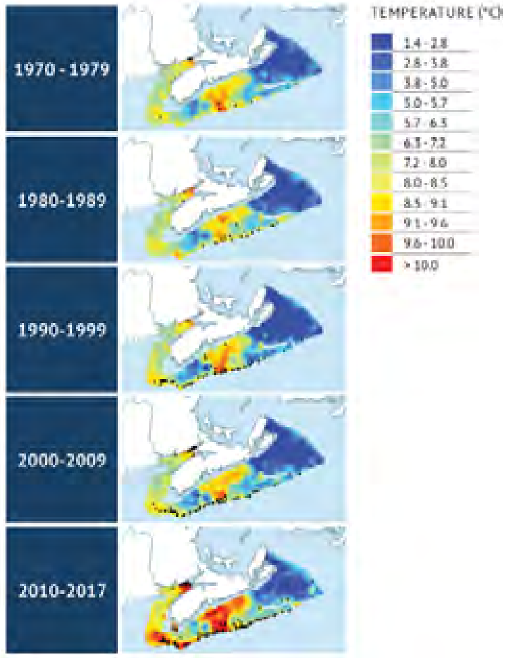
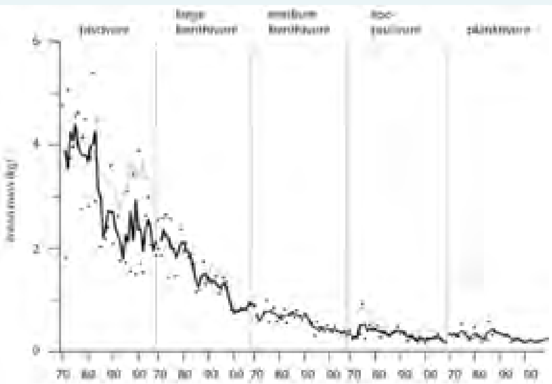
Figure 3: Sustainability survey of Canadian fisheries. *Points and shading depict the proportion of exploited populations classified as healthy, cautious or critical, or uncertain by region (a) and species group (b). Points in the bottom left have a high proportion of cautious/critical stocks, in the bottom right have a high percentage of uncertain stocks, and in the upper corner have a high proportion of healthy stocks. The size of the symbol depicts the number of stocks in the region (a) or species group (b). Shading shows the kernel density of the distributions.*

PROJECTED CLIMATE CHANGE IMPACTS ON FISHERIES

Climate change affects fisheries through a multitude of direct and indirect pathways, creating winners and losers, with some species benefitting and others declining as a result of temperature changes. These changes are associated with increasing magnitude and frequency of extremes both in the environment and in animal populations. More severe climate effects can occur when overlaid by additional stressors, whereas greater climate resistance and resilience have been observed in highly diverse ecosystems. Climate change is also reconfiguring ecosystems and altering population dynamics in ways that are not yet fully understood, but which certainly have implications for the productivity and management of fish populations.

A range of climate change effects have been reported both globally and across Atlantic Canada and the Eastern Arctic, including: warming; reduced mixing and surface nutrient supply; modified freshwater flux; widespread deoxygenation; acidification (e.g. in the Gulf of St. Lawrence); loss of sea ice (e.g. in the Eastern Arctic); reduced primary production (except in the Arctic); reduced size structure; altered community composition; altered species ranges and depth distributions; increased disease transmission; modified growth, metabolism, and condition; and seasonal development (see Table 1). Climate effects on marine microorganisms, including bacteria, viruses, and plankton, and their impacts on fisheries is not well understood but likely great.

Table 1: Observed climate change trends within Atlantic Canada and the Eastern Arctic.

Phenomenon	General observed pattern
Range expansion or contraction	• By mid century, water will be too warm for many species in southern Canadian waters.  ***Figure 4: Climate-driven species redistributions.*** *Points depict the occurrence of novel species in the DFO summer bottom trawl survey within each decade (1970–2017). Colours depict the average bottom water temperature. The figure is from Bernier et al. (2018).[1]*
Latitudinal range shifts	• Northward range shifts • 'Borealization' of Arctic, 'tropicalization' of temperate ecosystems • A shift in the spatial distribution of larvae for 43% of taxa in the northeastern US; mostly northward
Depth distribution	• A shift towards inhabiting deeper, colder waters
Species invasions	• New arrivals from US waters on the Scotian Shelf associated with latitudinal range shifts • New arrivals in the Arctic from the south, with effects on low diversity ecosystems there
Seasonal	• A shift in seasonal timing of larval occurrence for 49% of taxa in the northeastern US shelf • Earlier melting of sea ice in the year
Trophic	• Increased consumption of phytoplankton by zooplankton • Increased predation of ectotherms (such as marine fish) relative to endotherms (such as marine mammals)
Size structure	• Reduction in size of primary and secondary producers  ***Figure 5: Reduced size of marine species on the western Scotian Shelf.*** *Average mass (kg) for fish functional groups (1970–2008). Points are annual values, and lines are the 3-year moving averages. Grey lines are the mass at age six as weighted by species biomass within the functional groups. The figure is from Shackell et al. (2010).[2]*

1 Bernier, R. Y., Jamieson, R. E., and Moore, A. M. 2018. State of the Atlantic Ocean Synthesis Report. Canadian Techical Reports of Fisheries and Aquatic Sciences, 3167: 149.

2 Shackell, N. L., Frank, K. T., Fisher, J. A. D., Petrie, B., and Leggett, W. C. 2010. Decline in top predator body size and changing climate alter trophic structure in an oceanic ecosystem. Proceedings of the Royal Society B-Biological Sciences, 277: 1353–1360. ROYAL SOC, London, UK.

Phenomenon	General observed pattern
Temperature	• Warming almost everywhere • Rapid warming in the Gulf of Maine, Gulf of St. Lawrence, Scotian Shelf
Freshwater flux	• Increased at high latitudes from hydrological cycle intensification
Melting sea ice	• Melting Arctic ice and Greenland ice sheet, leading to a freshening of the Arctic • Spatially variable changes in sea ice type (old versus seasonal), thickness, and extent in the Arctic
Stratification	• Increased, especially at low latitudes • Associated with nutrient limitations at low to mid latitudes
Acidification	• Increasing, especially in the Gulf and Arctic • Negative effects on calcifying species
Deoxygenation	• Widespread increases, especially in the Gulf of St. Lawrence
Primary production	• Spatially variable, but generally declining, especially at lower latitudes • Complex responses in the Arctic including changes from ice algae to phy-toplankton; moderate declines in some areas but increases in others
Disease transmission	• Increased, especially in the Arctic

CUMULATIVE HUMAN IMPACTS

To explore how stressors are distributed globally and across Atlantic Canada and the Eastern Arctic, spatial patterns in the cumulative human impact index developed by Halpern et al. (2008) were evaluated. The index synthesizes 17 global datasets of human drivers of ecological change to estimate spatial patterns of human impacts.

Across Atlantic Canada and the Eastern Arctic, the human health index indicated that the most impacted areas were located in nearshore waters, particularly in the Gulf of St. Lawrence and Newfoundland and Labrador (Figure 6). Virtually all of the grid cells in the Gulf of St. Lawrence, Newfoundland and Labrador, and Scotian Shelf were more heavily impacted than the global average. The Eastern Arctic was less impacted by human activities than the other bioregions, likely due to its inaccessibility, sparse population, less productive fisheries and a reduced history of exploitation. However, due to the rapid warming and projected expansion of commercial fishing activities, human impacts in the Arctic are expected to increase.

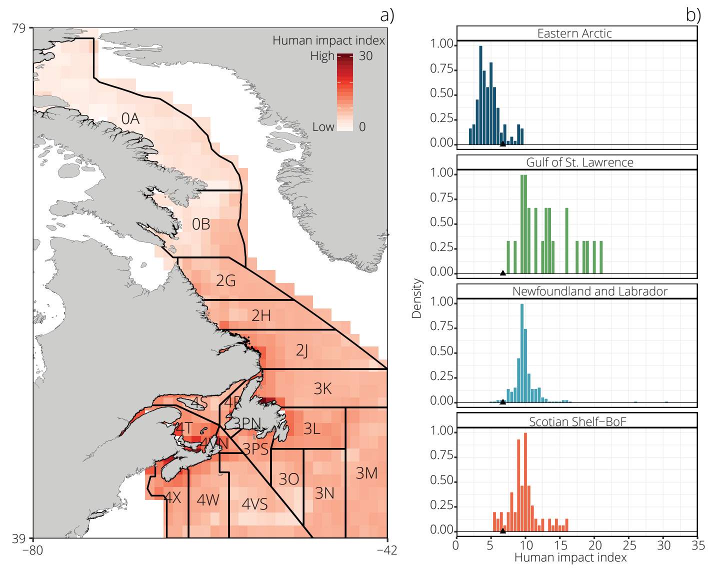


Figure 6: Cumulative human impacts across the area. *Cumulative human impact index estimated by Halpern et al. (Halpern et al., 2008)[3] within each 1x1° cell within Atlantic Canada and the Eastern Arctic (a) and within each bioregion (b). (a) Cumulative impacts are depicted as colours: dark red shows the most heavily impacted areas. (b) The density distribution of impacts within each bioregion region is shown as colours with the black triangle showing the global average.*

3 Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, K. V, Micheli, F., D'Agrosa, C., Bruno, J. F., et al. 2008. A global map of human impact on marine ecosystems. Science, 319: 948–952. http://www.sciencemag.org/content/319/5865/948.short (Accessed 6 November 2013).

Climate projections across Atlantic Canada and the Eastern Arctic under a worst-case emission scenario indicate widespread surface warming and decreased oxygen. They also indicate declining primary productivity, zooplankton biomass, and animal biomass (but increasing in the Eastern Arctic) (Figure 7).

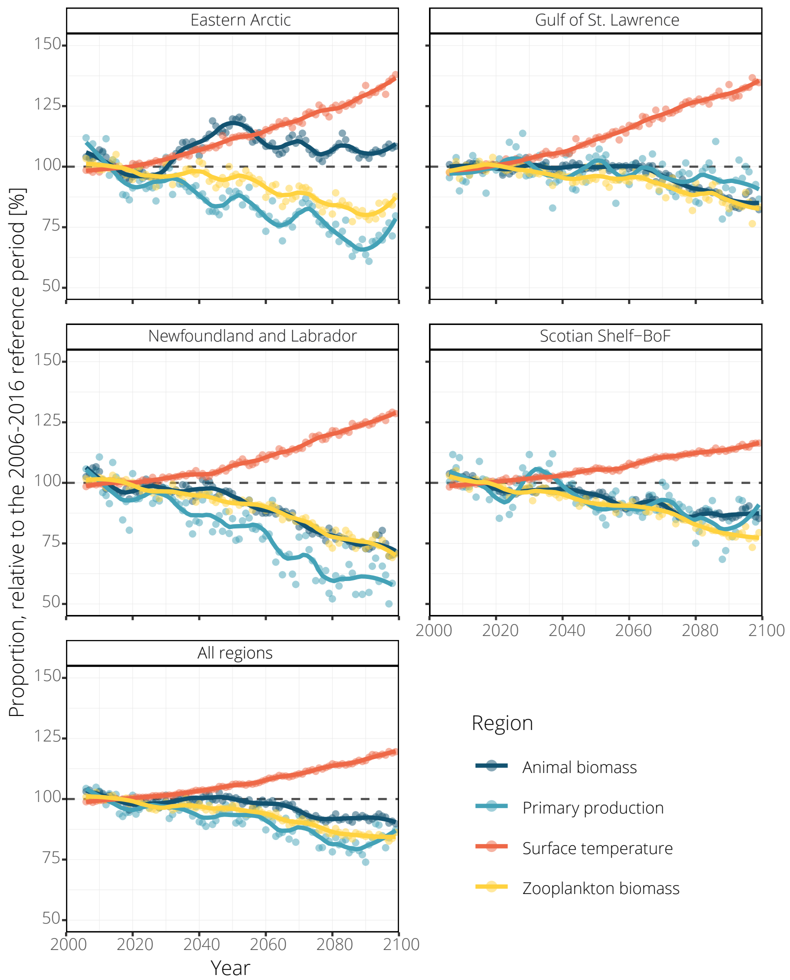


Figure 7: Projected time-series under a worse-case emission scenario (RCP8.5) within and across the area's bioregions. *Multi-model averaged time-series of projected SST (orange), Net Primary Productivity (light blue), zooplankton biomass (yellow), and animal biomass (dark blue) across the regions within the time-series are relative to the reference period (2006–2016) under a worst-case RCP8.5 emission scenario.*

Major changes include:

- New climate conditions in surface temperature and dissolved oxygen have already emerged in many locations within the area.
- Climate-driven changes in the area are projected to be abrupt and to occur in the next 20–30 years, with the most rapid changes projected on the Scotian Shelf and nearshore Newfoundland and Labrador.
- Fifty-five per cent of species in the area south of 45°N are projected to lose thermal habitat by 2060, and 21% to gain habitat.
- Under both a worst-case and strong mitigation emission scenario, climate-projected declines in animal biomass would be more severe in areas that currently support the largest fishery landings, a trend that has also been reported globally.
- Globally and across Atlantic Canada and the Eastern Arctic , climate-driven declines in animal biomass will be more severe in areas that are presently more impacted by cumulative human impacts (e.g. pollution), suggesting that climate effects on fisheries may be aggravated by additional stressors.

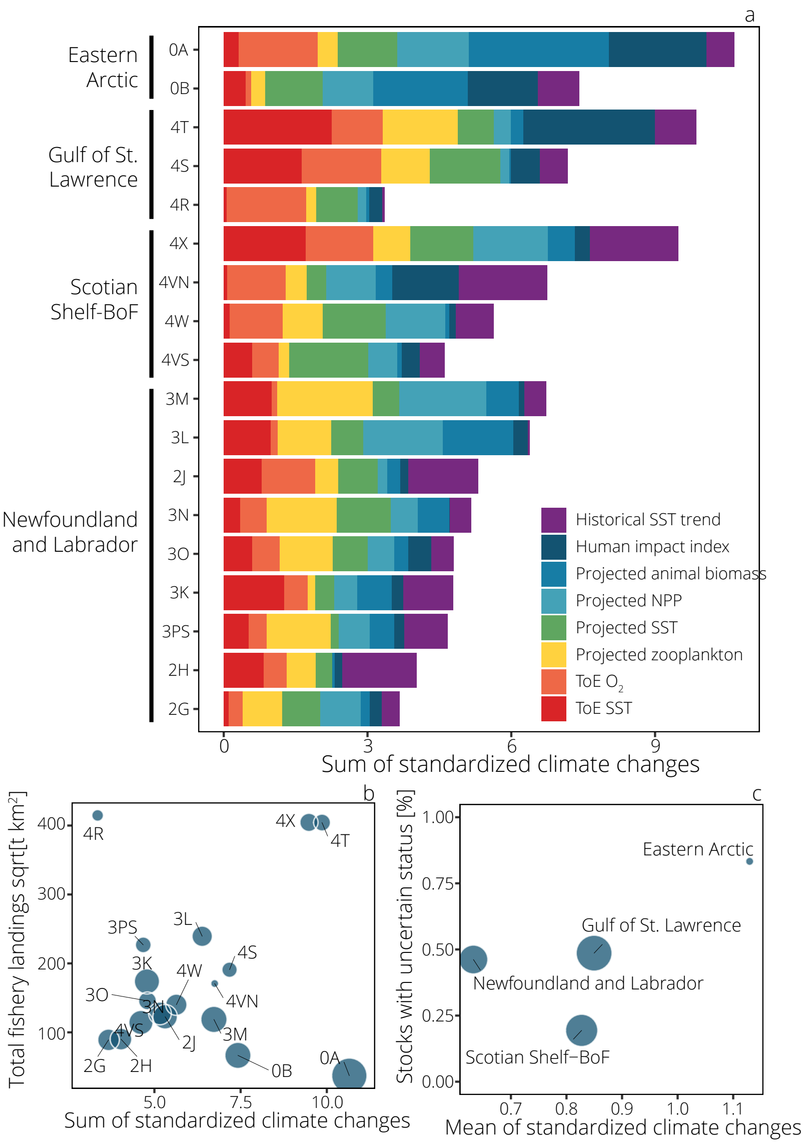


Figure 8 Cumulative climate impacts in relation to fisheries productivity and status across the area. *(a) Sum of standardized historical and future climate changes across NAFO divisions and bioregions within the area. Colours depict the climate change variable. (b) Sum of the standardized climate changes against the total reported fishery landings within each division. (c) Mean of standardized climate changes against the proportion of all stocks that have uncertain status. Symbol sizes depict the geographic area (b) and the number of stocks (c).*

An index of cumulative climate change was calculated by integrating the historical and projected future trends reported here with the Human Health Index. While cumulative climate changes were found across the entirety of the area studied , they were largest in the Eastern Arctic, followed by the Gulf of St. Lawrence, Scotian Shelf–Bay of Fundy, and Newfoundland and Labrador (Figure 8a). In particular, NAFO divisions 0A (high Arctic), 4T (Southern Gulf of St Lawrence) and 4X (western Scotian Shelf and Bay of Fundy) had the greatest cumulative climate changes, while 2G and 2H (northern Labrador) had the lowest. Examining these cumulative climate changes in relation to fishery productivity (Figure 8b) and status (Figure 8c) could be useful in identifying regions and/or species that are most in need of climate-relevant management responses. For example, areas subjected to large climate changes that also support the currently most productive fisheries (e.g. NAFO divisions 4X, 4T) or that have high stock-status uncertainty (e.g. Eastern Arctic) could potentially be focal areas for the incorporation of climate and ecosystem considerations. Alternatively, areas subjected to large climate changes that currently have low fishery landings (e.g. divisions 0A, 0B) could be identified as priority areas to apply the precautionary approach with new fisheries and adaptive management. Although climate and ecosystem considerations should be incorporated into all Canadian fisheries, locations that have lower relative climate impacts and that are less intensively fished (e.g. divisions 2G, 2H) could potentially be of lower priority.

WHAT ARE THE BEST TOOLS AND APPROACHES TO ADAPT FISHERIES MANAGEMENT TO CLIMATE CHANGE?

Whereas climate change considerations are not currently specified in Canada's *Fisheries Act*, incorporating them into management will be essential to meet DFO's mandated objectives of ensuring healthy and sustainable fisheries. The following section reviews fisheries management objectives, principles, and priorities that could help integrate climate change into the fisheries management process.

Minimizing abatable stressors and promoting healthy fisheries

Reducing abatable stressors, such as pollution overfishing, bycatch, and habitat alteration, and instituting effective and sustainable fisheries management can build resilience in the ecosystem and counter the deleterious effects of climate change on fisheries productivity.

Precautionary approaches

When there is uncertainty regarding stock status and climate impacts, erring on the side of caution can improve outcomes. Such measures could include lowering quotas or instituting moratoria until the uncertainty is reduced. A "precautionary approach" to fisheries management is official DFO policy; however, factors besides the recovery or rebuilding of a population often inform short-term decision making.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Enhancing ecological stability

Maintaining or improving biodiversity at genetic, species and ecosystem scales has been widely associated with increased resilience and productivity in marine ecosystems. Conversely, declining species diversity had been associated with increased resource collapse and exponential declines in population recovery potential and stability. Thus, avoiding species collapses and preserving biodiversity are key elements in ensuring that fisheries are best positioned to withstand the harmful effects of climate change.

An ecosystem approach to fisheries

According to the FAO, "an ecosystem approach to fisheries strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries." Canada committed to an ecosystem based-approach in 2004 but continues to manage most fisheries on a single-species basis.


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DATA AND INFORMATION GATHERING

Ecosystem monitoring

As climate change continues, it will be important to collect frequent information related to environmental conditions, predator and prey abundances, and human impacts, and to incorporate this data into fisheries management.

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Multispecies stock assessment models

Multispecies models that incorporate species interactions and ecosystem dynamics have existed since the early 1980s. These models can support an ecosystem approach to fisheries and help managers understand the impacts of changes to ecosystem structure and population dynamics.

Management strategy evaluation

MSE is a quantitative modelling approach that embodies the principles of uncertainty and risk management in the estimation of climate-considered reference points and harvest strategies. The approach is now capable of incorporating climate forecasts and ecosystem-based considerations.

Risk-based approaches

In risk-based approaches, climate change variables are identified and related to the risk assessment component of advice through assumed modelled response dynamics. 'Buffers' are factored into management advice such that with increasing risk, the recommended level of activity decreases.

QUANTITATIVE STOCK ASSESSMENTS, KNOWLEDGE GENERATION AND ADVICE

Climate-considered stock assessment models

As climate change continues to create novel and extreme climate and ecosystem conditions, estimating baseline conditions and reference points for fisheries, which form the basis for most fisheries management decisions, will become increasingly challenging and uncertain. Fortunately, assessment methods are available that are better suited to such circumstances. These models can evaluate dynamic changes in biological patterns and the robustness of different harvest strategies to a broad range of assumptions and uncertainties.

Non-stationary stock-recruitment parameters and biological reference points

Whereas traditional assessment methods often assume that population parameters (e.g. mortality, growth) and fishery attributes (e.g. selectivity, catchability) are temporally stationary, there is growing evidence that such attributes can vary over time in response to temperature regime shifts, the level and nature of exploitation, ecosystem factors such as predator/prey dynamics and stock distribution. Consequently, fisheries models with time-varying parameters are increasingly used, particularly as an approach to incorporating climate variability and change.

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Climate vulnerability of fisheries

Climate change can have a range of impacts on exploited species, ecosystems, and coupled human communities across a range of scales. Our current scientific understanding suggests that these effects will not be uniform or consistent across species or ecosystems—there will be winners and losers, and some areas will experience gradual change while in others change will be abrupt. Vulnerability estimates are used by decision-makers to identify priorities for scientific and management efforts in order to implement proactive management measures, reduce impacts, increase resilience, and advance the adaptive capacity of fisheries (Figure 9).

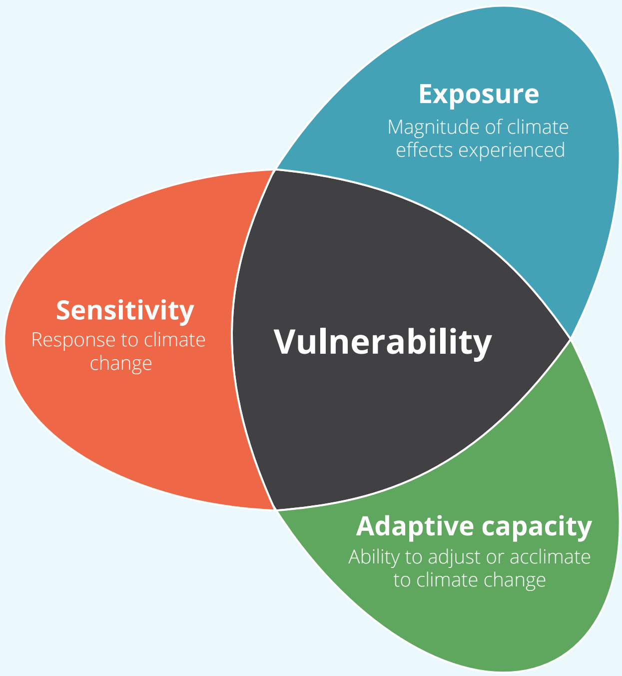


Figure 9: Climate change vulnerability. *Vulnerability of species to climate change is defined by its exposure (blue), sensitivity (orange), and adaptive capacity (green). Source: Adapted from IPCC, 2007, 2014*[4]

Climate forecasts and projections

The use of climate forecasting and projecting to understand how climate change will impact species and ecosystems is growing. The difference between projections and forecasts is subtle: whereas projections explore possible future outcomes under different climate scenarios, forecasts represent the expected future outcomes based on realistic assumptions and expectations. In consequence, forecasts are often restricted to shorter time intervals (e.g. weeks, months) and spatial domains (e.g. local, regional) than are projections (Figure 10).

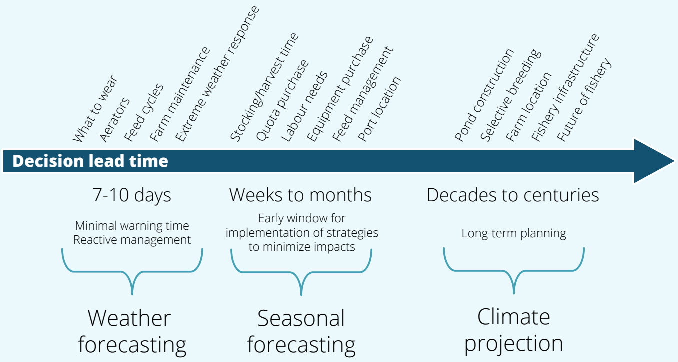


Figure 10: Time-scales at which information on climate projections and forecasts are relevant. *Source: (Hobday et al., 2016).*[5]

Climate change research

To fully integrate climate change considerations into fisheries management, a foundational understanding of the mechanisms by which climate change affects marine ecosystems, habitats, species, and fish stocks, as well as humans, is required.

DECISION MAKING: IMPLEMENTATION OF TOOLS & ACTIONS

Spatial management

The International Union for Conservation of Nature and Natural Resources (IUCN) has promoted the use of spatial protection tools to reduce the impacts of stressors on species and ecosystems, thereby increasing stability and resilience.

Dynamic ocean management

In contrast to static management, DOM refers to "management that changes rapidly in space and time in response to the shifting nature of the ocean and its users based on the integration of new biological, oceanographic, social and/or economic data in near real-time" (Maxwell *et al.*, 2015).[6]

4 IPCC. 2007. Climate change 2007: synthesis report. Summary for policymakers. Fourth Assessment Report. Intergovernmental Panel on Climate Change, Gland, Switzerland.
IPCC. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland. 151 pp

5 Hobday, A. J., Spillman, C. M., Eveson, P. J., and Hartog, J. R. 2016. Seasonal forecasting for decision support in marine fisheries and aquaculture. Fisheries Oceanography, 25: 45–56.

6 Maxwell, S. M., Hazen, E. L., Lewison, R. L., Dunn, D. C., Bailey, H., Bograd, S. J., Briscoe, D. K., et al. 2015. Dynamic ocean management: Defining and conceptualizing real-time management of the ocean. Marine Policy, 58: 42–50.

TO WHAT EXTENT IS CLIMATE CHANGE BEING CONSIDERED IN FISHERIES MANAGEMENT IN CANADA?

Currently, there is no public reporting of decision making on fisheries management measures. As such, we conducted an analysis of available fisheries science and management documents to determine whether climate change is being adequately considered.

We compiled a database of documents related to the science and management of marine species in Quebec, the Atlantic Provinces and Eastern Arctic published between 2000 and 2020. We used three publicly available DFO document types: DFO research documents (RES-DOCs) that form the scientific basis for management (n=729), DFO integrated fisheries management plans (IFMPs) (n=68) and peer-reviewed publications (PR-DOCs) related to fisheries dynamics authored or co-authored by DFO scientists (n=108) and published in scientific journals.[7] A similar analysis on DFO science advisory documents was completed by others in 2019.[8] The text within the documents was analyzed to understand how eight primary and secondary themes were represented in fisheries research and management in Canada. The three primary themes included **climate change**, **ecosystem approaches to fisheries (EAF)**, and **the precautionary approach**. The five secondary themes included **oceanographic factors**, **trophic dynamics**, **exploitation**, **climate vulnerability**, and **forecasting**. We searched the text of the documents for these terms, and upon occurrence, were associated with the fishing theme. The frequency with which these themes appeared in the documents was then analyzed to understand patterns in theme occurrence in relation to document types (RES-DOCs, IFMPs, PR-DOCs), species groups, regions, and over time.

> **This review suggests that of the primary themes considered, climate change and ecosystem approach to fisheries are currently the least frequently considered in the science and management of Canada's fisheries.**

Climate change was explicitly discussed with increasing frequency in almost a third (29%) of PR-DOCs, suggesting that it is a factor of importance to fisheries, and in one-quarter of IFMPs, suggesting that it is also on the radar of DFO managers. However, climate change was incorporated in only 11% of RES-DOCs, indicating that it is not routinely considered in the DFO science basis that informs the advisory process (Figure 11).

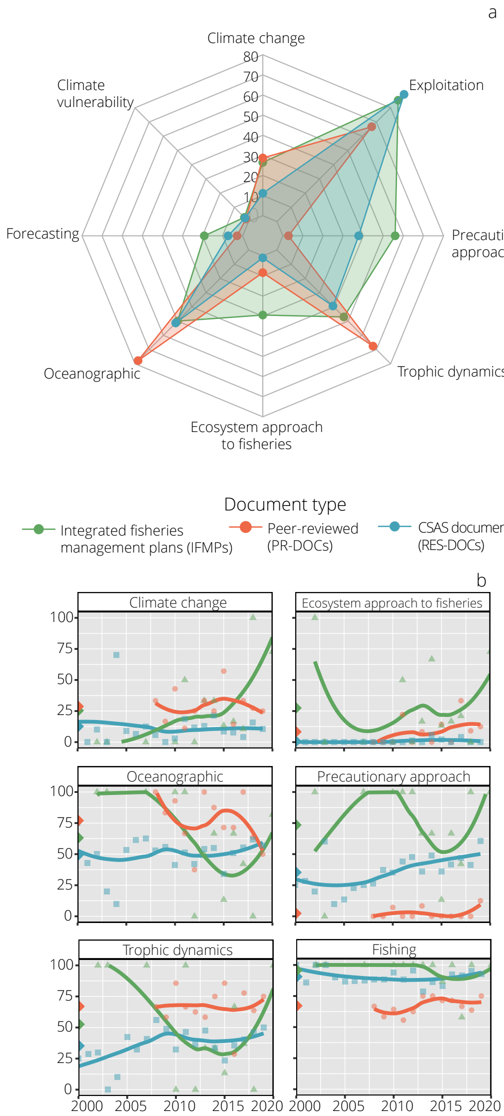


Figure 11: Frequencies of themes occurring across documents (a) and over time (b). (a) The average frequency of occurrence of the themes for each document type; axes begin at the centre of the plot and extend outward. (b) Time trends in the frequency of occurrence for themes of interest. Average frequencies over the time-series are displayed as points along the y-axes. (a–b) Colours denote the document types: RES-DOCs are blue, IFMPs are green, and PR-DOCs are orange.

7 Boyce, D.G; Karbowski, C; Fuller, S.D; Schleit, K; & Worm, B. (2021)..Leading or lagging: How well are climate change considerations being incorporated into Canadian fisheries management? CJFAS. In press.

8 Pepin, P., King, J., Holt, C., Gurney-Smith, H., Shackell, NL, Hedges, K., & Bundy, A. (2019). Incorporating climate, oceanographic and ecological change considerations into population assessments: A review of Fisheries and Oceans Canada's science advisory process. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/043.

Furthermore, on close inspection, it was found that most of the references to climate change in the RES-DOCs expressed that there was a lack of understanding of how climate change would impact the dynamics of the stock. For example, the SAR for American plaice (*Hippoglossoides platessoides*) in the Gulf of St. Lawrence for 2011 stated that "The impact of global warming is yet unknown on the biology of American Plaice" (DFO, 2011).[9] Statements of this nature are useful in identifying knowledge gaps but also emphasize that reference to climate change and other themes do not constitute knowledge or quantitative incorporation of them.

The frequency with which climate change and EAF occurred has increased over time in IFMPs but not in the RES-DOCs. The co-occurrence analyses indicated that fishing, oceanography, and trophic dynamics were 'core' themes across all document types, but climate change and EAF were not (Figure 12).

This low representation of climate change and EAF in RES-DOCs contrasts sharply with the precautionary approach theme, which arose in 56% of IFMPs and 38% of RES-DOCs and was discussed more frequently over time in both document types. The increasing frequency of reference to the precautionary approach in RES-DOCs coincided with the 2006 release of a framework for its incorporation into management (DFO, 2006).[10] This may suggest that priorities could be more effectively incorporated into science and management when there are explicit guidelines for how to do so. In conclusion, although the precautionary approach is being increasingly considered in the management of Canada's fisheries, other key priorities, such as the ecosystem approach to fisheries and climate change, are not.

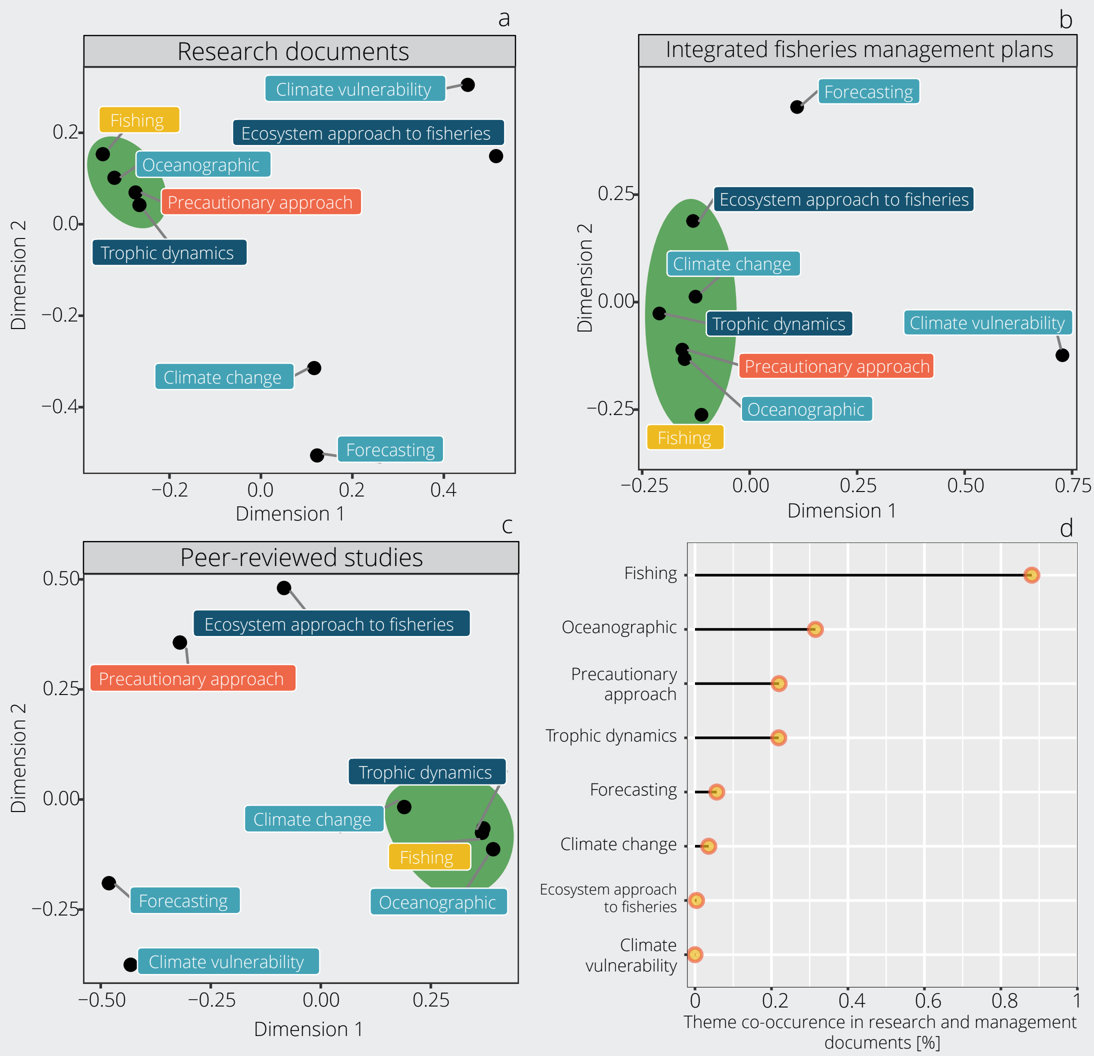


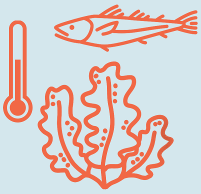
Figure 12: Patterns of co-occurrence across management themes. *(a) Non-metric multidimensional scaling results depicting the associations between the themes; themes that are closer are more strongly associated. The colour labels depict the type of theme: light blue is climatological, dark blue is ecological, yellow is fishing, and orange is precautionary. Green ellipses denote the core cluster of themes for each document type. (b) The probability that a theme occurs, or does not occur, together in both IFMPs and their matching RES-DOCs. Statistically significant co-occurrence differences are depicted as opaque orange symbols.*

9 DFO. 2011. Recovery potential assessment of the Maritime designatable unit of American plaice (Hippoglossoides platessoides). Canadian Science Advisory Secretariat Science Advisory Report, 2011/043: 1–30.

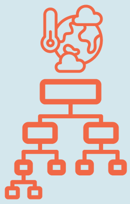
10 DFO. 2006a. A harvest strategy compliant with the precautionary approach. Canadian Science Advisory Secretariat science advisory report, 2006/023: 1–7.

RECOMMENDATIONS AND PRIORITIES FOR ACTION

As an overall approach, DFO should:



1. Take steps to assess nature-based solutions to climate change in the marine environment.



2. Develop a national fisheries and climate framework that clearly identifies a process for how climate information can go from data to decision making.

Based on the overview of fish populations, the known impacts of climate change, and the fact that DFO has yet to integrate climate change into fisheries management, we offer the following recommendations.

Given the current and projected impacts of climate change on fisheries, **DFO should take steps to assess the ways in which the ocean can effectively sequester carbon, including nature-based solutions, in the marine environment**. Canada has an opportunity to include fisheries and ocean management factors into its Nationally Determined Contributions (NDCs) under the United Nations Framework Convention on Climate Change (UNFCCC). DFO and Environment and Climate Change Canada must work together to ensure that the marine environment is fully part of Canada 's next submission in advance of the UNFCCC Conference of Parties (scheduled for Fall 2021). Such a high level commitment would enable climate based management decisions at the regional and ecosystem level.

To ensure that the impacts of climate change are being incorporated effectively into fisheries management, **DFO should develop a national fisheries and climate framework that clearly identifies a process for how climate information can go from data to decision making**. Climate change should be explicitly considered in Section 2.1 of the *Fisheries Act* and when the *Act* is reviewed. The framework should be based on enabling conditions and key initiatives that contain the following elements.

DFO should also take the actions listed below. We have prioritized these recommendations and advocate for a time frame within which they could happen, based on resources needed.

3. Improving transparency & accountability for science-based decision making by:

a. Publicly posting all fisheries management decisions, including which factors under 2.1 of the *Fisheries Act* were considered and weighted.

b. Making available Integrated Fisheries Management Plans (IFMPs) upon completion and updating the IFMP template to incorporate climate considerations and vulnerability of the target species.

c. Where there is uncertainty related to environmental factors in the population assessment or growth trajectory, this uncertainty should be clearly stated in stock and recovery potential assessments.

Timeframe: June – December 2021
Resources Needed: **Low**

4. Reducing non-climate stressors on Canada's fish populations by:

a. Making management decisions using the best available science advice and erring on the side of caution in order to maintain a resilient population.

b. Putting a stop to fishing on populations that are in the "critical zone" of the Precautionary Approach Framework, and rebuilding them into the "healthy zone."

c. Rebuilding forage fisheries, which support the rest of the ecosystem, and not authorizing commerical fisheries for new forage fish species.

d. Working with other Departments and jurisdictions to identify and, where possible, mitigate threats to fish populations, particularly those most vulnerable to climate change.

e. Including timelines, targets and probabilities in the regulatory process for rebuilding fisheries, as now required by Section 6 of the *Fisheries Act*, with a view towards reaching healthy levels so that populations are more resilient to climate change.

Timeframe: Long term
Resources Needed: **Medium**

5. Implementing more adaptive fisheries management measures, by:

a. As best as possible, evaluating the current and future spatial shifts in marine species as a result of climate factors.

b. Coupling social and economic models to climate models to better understand how different climate scenarios could impact human communities and economies. Efforts should be made to do this across all fisheries so that adaptation in licensing and access to fish can accommodate coastal communities and does not undermine Indigenous treaty rights to fish.

c. Assessing the needs and feasibility of opening new commercial and recreational fisheries.

d. Creating license and sharing policies that are flexible to projected climate change impacts, particularly with regards to distribution and biomass.

e. Prioritizing Indigenous fishing rights in areas where new species ranges are projected (e.g. species expansion to the North).

Timeframe: Long term
Resources Needed: **Medium**

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6. Complete comprehensive climate vulnerability assessments of Canadian and transboundary fish species, including identifying where there are data gaps that preclude such assessments.

Initial steps towards achieving this include:

a. Developing and agreeing to scientific methods to assess the climate vulnerability of marine species in Canada.

b. Prioritizing research funding and capacity to conduct climate vulnerability assessments.

c. Strengthening partnerships and coordination with non-DFO academic institutions and with NOAA, such as the existing collaborative framework to monitor and research ocean acidification.[11]

d. Facilitating citizen monitoring, traditional and community ecological knowledge systems, and fisheries co-management, particularly in data-deficient regions such as the Arctic.

Follow up steps include:

e. Enhancing knowledge through targeted research funding opportunities that require communication of results to managers and assessment communities.

f. Effectively communicating climate change and ecosystem studies funded by DFO to fisheries scientists, managers, rights holders and stakeholders. This could include workshops to communicate and share developments, methodologies and approaches to climate change integration into fisheries.

g. Requiring climate vulnerability assessments as a component of fishery stock assessments, CSAS documents and IFMPs.

h. Reviewing the effectiveness of climate change management measures at intervals that align with the biological timelines of focus species and fisheries.

Timeframe: Long term
Resources Needed: **High**

7. Enhance opportunities for ecosystem monitoring and data sharing by:

a. Ensuring that government efforts to design surveys, manage data and analyses are fully recognized by non-government partners and that projects are developed collaboratively with shared outcomes.

b. Creating a centralized repository of data and agreed indices used to produce annual ecosystem reports, available upon request to approved researchers and fishery scientists.

c. Streamlining and simplifying the process of requesting and using monitoring data maintained by DFO to improve prospects of collaboration with non-government partners.

d. Identifying and digitizing existing data relevant to climate change and fisheries and making these data available.

e. Collaborating with non-government partners on compiling relevant knowledge about climate change effects on fisheries from studies and reports.

f. Creating a publicly available database of Canadian fisheries data, including relevant time-series (e.g. SSB, f, recruitment), reference points, and assessment model information.

Timeframe: Near to medium term
Resources Needed: **Medium**

11 https://www.dfo-mpo.gc.ca/science/publications/accasp-psaccma/noaa-collaborative/index-eng.html


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> Climate risk to future fisheries should be openly discussed at fisheries management processes.

8. Introduce climate science and decision making into fisheries management processes:

a. For fisheries representatives and fishers to engage proactively in decisions regarding climate change and impacts on their livelihoods, climate impacts should be made clear during science and management processes.

b. Climate risk to future fisheries should be openly discussed at fisheries management processes.

c. Fisheries representatives and fishers should be engaged in any socioeconomic assessments of future fisheries resource access and distribution.

d. In management decisions, climate impacts should not be used as a reason to not limit fishing activity when populations are at low levels.

Timeframe: Immediate
Resources Needed: **Medium**

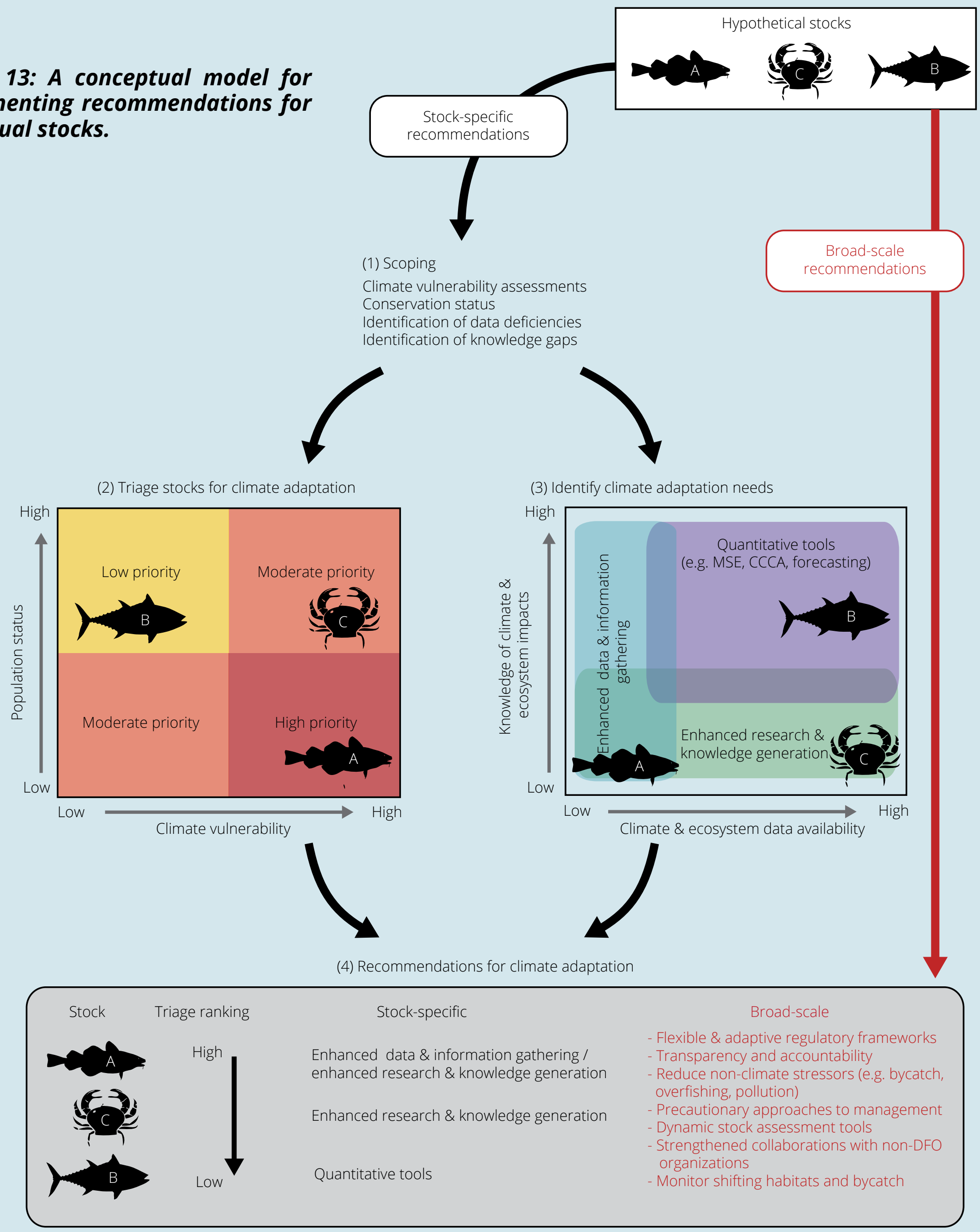
We recognize that incorporating climate and ecosystem considerations into fisheries science and management is, to a large extent, a stepwise progression that requires as a starting point adequate data and information gathering. Given the many recommendations listed here, and the finite resources of DFO, we propose a conceptual model to prioritize stocks and regions that are most in need of climate adaptation resources, and to identify what resources and tools would most effectively move them towards greater climate and/or ecosystem integration based on how they are currently managed. This approach does not imply that the recommendations need only apply to certain species, but rather that it may not be realistic, given the practical constraints under which DFO operates, to apply all recommendations to all species simultaneously. The approach also acknowledges that some of these recommendations are already being incorporated into the management of some species (e.g. ecosystem monitoring, knowledge generation), but that the extent of the incorporation differs between stocks and regions.

The model presented (Figure 13) distinguishes recommendations that can be broadly applied to all fisheries ('broad-scale' recommendations; red in Figure 13) from those that may instead apply to specific stocks and/or regions ('stock-specific' recommendations; black in Figure 10). The framework identifies stock-specific recommendations by identifying where individual stocks fall on this continuum, thus identifying which resources could be most effective in furthering climate adaptation into management.

Here are the proposed steps:

- **STEP 1** (scoping): Assess the data and knowledge available for stocks and conduct vulnerability assessments to estimate their risk of adverse effects of climate change.
- **STEP 2** (triage stocks for climate adaptation): Rank stocks by their climate vulnerability and conservation status.
- **STEP 3** (identify climate adaptation needs): Identify resources to facilitate climate adaptation for the stock based on the availability of climate and ecosystem data and knowledge.
- **STEP 4** (recommendations for climate action): When this information is combined, make recommendations for actions to move individual stocks towards climate change integration: rank stocks according to the urgency of climate adaptation resources and identify the global (red) and stock-specific (black) resources.

Figure 13: A conceptual model for implementing recommendations for individual stocks.



ABOUT OCEANS NORTH

Oceans North is a charitable organization that fosters science- and community-based conservation in the Arctic and Atlantic regions of Canada, as well as western Greenland. Our goal is to promote policies and programs that address the unprecedented environmental changes taking place in northern marine ecosystems and ensure that they are protected within the framework of Indigenous knowledge, rights and consultation.

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