Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2026/052

Gulf and Québec Regions

Defining an Ecosystem Summary for Mid and Offshore Waters of the Estuary and Gulf of St. Lawrence in Support of Fisheries and Oceans Canada's Ecosystem Approach to Fisheries Management

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August 2026

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
DFO.CSAS-SCAS.MPO@dfo-mpo.gc.ca

ISSN 1919-5044
ISBN 978-0-662-79568-1 Cat. No. Fs70-5/2026-052E-PDF

Correct citation for this publication:

Benoît, H.P., McDermid, J.L., Blais, M., Bordeleau, X., Burbank, J., Chassé, J., Duplisea, D., Galbraith, P.S., Isabel, L., Lavoie, D., Lizotte, M., Roux, M.-J., Sutton, J.T., and Turcotte, F. 2026. Defining an Ecosystem Summary for Mid and Offshore Waters of the Estuary and Gulf of St. Lawrence in Support of Fisheries and Oceans Canada's Ecosystem Approach to Fisheries Management. DFO Can. Sci. Advis. Sec. Res. Doc. 2026/052. v + 101 p.

Aussi disponible en français :

Benoît, H.P., McDermid, J.L., Blais, M., Bordeleau, X., Burbank, J., Chassé, J., Duplisea, D., Galbraith, P.S., Isabel, L., Lavoie, D., Lizotte, M., Roux, M.-J., Sutton, J.T., et Turcotte, F. 2026. Définir un résumé écosystémique pour les eaux intermédiaires et au large de l'estuaire et du golfe du Saint-Laurent en appui à l'approche écosystémique de la gestion des pêches de Pêches et Océans Canada. Secr. can. des avis sci. du MPO. Doc. de rech. 2026/052. vi + 111 p.

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ABSTRACT

Fisheries and Oceans Canada (DFO) is advancing implementation of the Ecosystem Approach to Fisheries Management (EAFM), motivated by recent legislative requirements under the amended *Fisheries Act* and international commitments such as the Kunming–Montreal Global Biodiversity Framework. A central tool supporting this transition is the development of Ecosystem Summaries, which are concise, routinely updated syntheses of environmental and ecological conditions relevant to fisheries assessments and management. This framework establishes the scientific foundation, indicators, and methodological approach for producing an Ecosystem Summary for the midshore and offshore (hereafter, simply “offshore”) waters of the Estuary and Gulf of St. Lawrence (EGSL). The framework placed particular emphasis on identifying indicators that are ecologically meaningful, broadly relevant to multiple harvested stocks, and supported by sufficiently long, reliable time series to allow consistent annual updates.

The EGSL is undergoing rapid and significant environmental change. Warming trends are evident throughout the water column with sea-surface, cold-intermediate layer, and deep water temperatures reaching record highs in the 2020s. At the same time, sea ice volume has reached some of its lowest levels on record. Dissolved oxygen levels in deep water have declined sharply since 2016, producing new hypoxic zones in the central and northern Gulf of St. Lawrence and near-lethal conditions in the Lower Estuary. Acidification has intensified, with deep waters exhibiting declining pH, elevated partial pressures of CO_2, and persistent hypercapnia since 2020.Trends in these various oceanographic characteristics are projected to persist through to the end of the century under business as usual greenhouse gas emissions climate scenarios.

Biological indicators reflect ecosystem-level response to these shifts. Zooplankton biomass has declined consistently since 2001, driven by a transition from large lipid-rich copepods to smaller taxa. Mid-trophic forage species (Atlantic Herring, Atlantic Mackerel, and Northern Shrimp) have declined by roughly two-thirds since 1990. Concurrently, several apex predators (grey seals, Atlantic Bluefin Tuna, and northern gannets) are at or above long-term median abundances, intensifying predation pressure on depleted prey communities.

Community-level indicators show persistent trophic imbalance, increases in small pelagic biomass largely driven by Redfish spp., and declines in size and condition across many demersal taxa. Approximately half of assessed offshore harvested stocks remain in the Critical Zone of the Precautionary Approach framework, with limited prospects for rebuilding without improvements in productivity. Fisheries landings have declined by an order of magnitude since the mid 1980s, reflecting long-term changes in stock status and ecological capacity.

The compiled indicators provide an integrated, climate-informed summary of ecosystem state and trends in the EGSL. They form the basis for an operational framework that will support regularly updated Ecosystem Summaries, strengthening EAFM implementation, ecological risk assessments, and fisheries decision-making across the Quebec and Gulf Regions.

INTRODUCTION

Fisheries and Oceans Canada (DFO) is committed to implementing an Ecosystem Approach to Fisheries Management (EAFM), which aims to enhance understanding of harvested stock abundance and dynamics by incorporating environmental information into fisheries management decisions. To date, EAFM has been implemented opportunistically and incrementally, partly through case studies in some fisheries (Pepin et al. 2023). However, recent legislative and policy changes are motivating an enhanced and accelerated implementation of EAFM in Canada. Amendments to the *Fisheries Act* in 2019, specifically the Fish Stock Provisions, require that environmental conditions affecting major fish stocks be taken into account in the management of fisheries harvesting them (DFO 2022a). More recently, the Kunming-Montreal Global Biodiversity Framework from the Conference of the Parties (COP 15) to the United Nations Convention of Biodiversity explicitly includes the adoption of the ecosystem approach to help ensure the sustainable harvest of wild stocks and to provide social, economic, and environmental benefits to people (United Nations 2022; DFO 2025a). Meanwhile, Canadian Science Advisory Secretariat (CSAS) advisory reports now include a mandatory section on Ecosystem and Climate Change Considerations in the provision of science advice on fisheries stock assessments. Furthermore, national and regional DFO working groups are stiving to motivate, facilitate, and guide further implementation of EAFM, with the long-term goal of laying the foundation for advancing toward broader Ecosystem-Based Fisheries Management and Ecosystem-Based Management.

Ecosystem Summaries are a key deliverable of EAFM. These reports are intended to provide regular, likely annual, summaries of key indicators describing the state of an ecosystem and trends in its components that may drive the dynamics of harvested stocks. By synthesizing ecosystem descriptions and analyses, these reports will consolidate information needed by DFO Science, Fisheries Management, decision-makers, rightsholders, and external stakeholders to better meet management objectives while also providing indicators and context for ecological risk assessments and the implementation of EAFM. Ecosystem Summaries for EAFM (hereafter, simply Ecosystem Summaries) will be valuable tools for communicating trends and pressures affecting species and stocks, and for developing a more comprehensive understanding of indirect and cumulative impacts within the ecosystem. The development and delivery of Ecosystem Summaries are planned for all of Canada’s major marine ecosystems. The manner in which they differ from, and ultimately complement, other DFO ecosystem reporting initiatives is described in the Context section below.

This document presents a framework to identify the requirements for an Ecosystem Summary for the Estuary and Gulf of St. Lawrence (EGSL) ecosystem (Figure 1). This framework identifies the relevant indicators that can be routinely reported to support EAFM implementation in the EGSL, and more generally to provide an overview of the status of harvested resources and the ecosystem pressures and drivers affecting them. This research document presents the necessary background and rationale supporting the selection of indicators for this Ecosystem Summary, along with descriptions and references to methodological details for calculating the key indicators. The inaugural Ecosystem Summary for the EGSL is presented in an appendix (Appendix A). This document reflects the conclusions of an inter-regional peer review process held on March 30, 2026 by the CSAS.

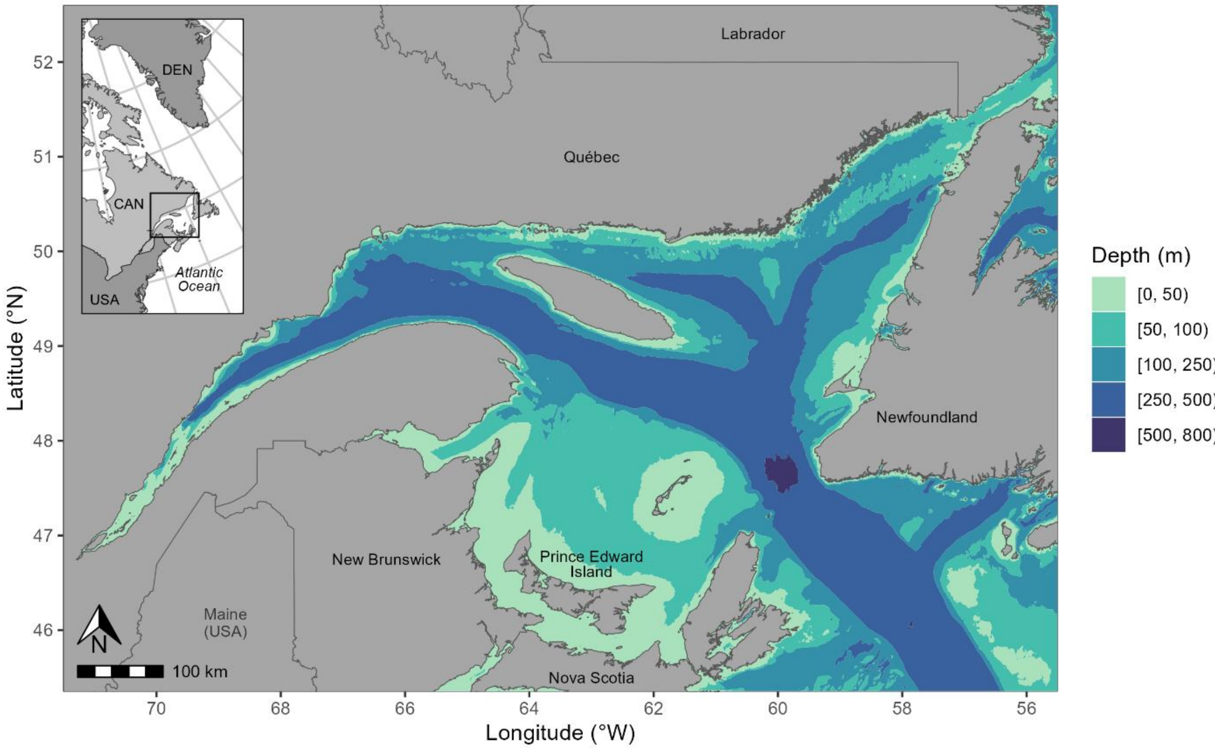

Figure 1. Map of the Estuary and Gulf of St. Lawrence (EGSL), including bathymetric contours. Note that the area south of Newfoundland and east of Nova Scotia (Cape Breton) is not part of the EGSL.

CONTEXT

DFO undertakes or contributes to several types of reporting for Canadian marine ecosystems. Understanding how the Ecosystem Summaries will differ from other initiatives is important to minimize duplication in their terms of reference and content, to identify key issues not adequately addressed in existing reporting, and to indicate where complementary information can be found. A brief overview is provided below.

State of the Ocean (SOTO) reports provide indicators and information spanning a broad range and large diversity of physical, chemical and biological characteristics, as well as focused reporting on specific issues of interest (Benoît et al. 2012; Bernier et al. 2018). Similarly, *Ecosystem Status and Trends* reporting (ESTR) produced under the Canadian Councils of Resource Ministers' Biodiversity Outcomes Framework provided information across numerous indicators (DFO 2010; Dufour et al. 2010). In both cases, reporting has been periodic, resource-intensive efforts covering a wide diversity of topics. In contrast, the Ecosystem Summaries are intended to be produced more frequently (annual), and thus need to be produced efficiently using existing resources, and focused on supporting the operationalization of EAFM.

Similar to the SOTO and ESTR processes, DFO also produced a number of *Ecosystem Overview and Assessment reports* (EOAR) during the 2000s and 2010s for various marine ecosystems, including the EGSL (Dufour and Ouellet 2007). The principal objective was to provide a descriptive overview of the components, structure and functioning of the ecosystem, and a preliminary evaluation of the main pressures exerted by human activities. These products were designed to inform strategic integrated oceans management, a much broader objective than the management of fisheries and harvested resources. EOARs were never intended to provide regular reporting on status and trends.

The National General Status Working Group, which includes representatives from all Canadian provincial and territorial governments, and the federal government (including DFO), produces quinquennial *General Status of Species in Canada* reports (accessed 2026-02-20). These reports provide summaries of the conservation status of all wild species in Canada to help identify priorities for additional conservation measures. Although much of the reporting is based on expert judgements, reporting on some taxa in some reports has been based on detailed quantitative or semi-quantitative reviews (e.g., Benoît et al. 2003; Sawatzky et al. 2018). While these reports offer a comprehensive overview of species-level conservation status, they typically do not provide status at the population or ecosystem level, nor do they examine in detail potential drivers.

Since 1999, the Atlantic Zonal Monitoring Program (AZMP) has provided detailed and comprehensive annual reporting on physical, chemical and biological oceanographic conditions in Atlantic Canadian ecosystems (e.g., Blais et al. 2025; Galbraith et al. 2025a,b), and more recently on acidification and related conditions (Lizotte et al. 2026). The suite of indicators and metrics presented in annual AZMP reports are directly relevant to understanding the environmental conditions experienced by harvested species and the potential drivers of their productivity and dynamics. These reports are, and will remain, a key source of information for stock-specific implementation of EAFM (e.g., EGSL northern shrimp, DFO 2025b). Ecosystem Summaries intend to reprise and distill information produced by AZMP into a small set of key indicators that adequately and parsimoniously describe trends in oceanographic variables. Presenting these key indicators alongside ecological and fishery resource indicators will facilitate and clarify linkages among ecosystem components and provide an integrated overview of interannual variation and directional changes in the ecosystem.

Finally, DFO’s Quebec Region produces an annual report on the results of the multi-species research vessel survey (RV) of the Estuary and northern Gulf of St. Lawrence (nGSL) (Chamberland et al. 2025). This report presents results related to trends in abundance and distribution of key species, along with other ecological and environmental indicators based on data collected during the survey. Similar annual reports were historically produced for surveys in the southern Gulf of St. Lawrence (sGSL) (e.g., Savoie 2014a, 2014b). For the Estuary and nGSL, species traits information and a first set of ecological indicators to monitor changes in the structure and functions of fish and invertebrate offshore communities based on RV survey data were also published in 2025, aiming for an annual or bi-annual update (Isabel et al. 2025a,b). Data from the RV surveys in the northern and southern Gulf of St. Lawrence (GSL) are used in a number of community-level indices to be included in the Ecosystem Summary, in addition to being a key input to numerous stock assessments.

In addition to the concerted reporting described above, ecosystem information has often been presented during individual stock assessment processes across DFO to foster an EAFM (e.g., Mowbray et al. 2023; Pantin et al. 2025; Surette and Chassé 2025; Tam et al. 2025). The production of regional Ecosystem Summaries will streamline this approach and facilitate cross-regional sharing and comparison of key indicators. Furthermore, it should reduce some redundancy for as indicators that are relevant to more than one region can be presented in the Ecosystem Summary for the most relevant region and referred to as required.

BACKGROUND FOR AN EGSL ECOSYSTEM SUMMARY

The EGSL (Figure 1) is defined by its distinct oceanography as a semi-enclosed inland sea (Loder et al. 1998; DFO 2009a). The southern Gulf is dominated by the Magdalen Shallows and the northern Gulf by deep channels. The waters of the EGSL are largely subpolar with a large freshwater input from the St. Lawrence River and warm Atlantic water found in the deep channels (DFO 2013; Chabot and Gilbert 2013). Seasonal changes in sea ice, near-surface temperatures and freshwater run-off are important drivers in this ecosystem (Loder et al. 1998; DFO 2009a), since they are important in determining freshwater input and the timing of phytoplankton blooms. The EGSL has been heavily exploited by commercial fisheries leading to the collapse of several demersal fish species. Only a small portion of demersal species have increased in recent years. As a whole, the state of knowledge for this ecosystem is considered rich, however important gaps remain for nearshore and coastal environments where survey coverage is less comprehensive.

To provide a tractable, routinely updateable summary, the following seven key scoping and scaling decisions were made to guide the coverage and content of the EGSL Ecosystem Summary.

First, the Summary will focus on the mid and offshore (hereafter offshore) components of the ecosystem, roughly defined as waters farther than 10 km from shore and at depths generally exceeding 30 m. This excludes the coastal zone, where environmental conditions are spatially and temporally more variable (e.g., Gendreau et al. 2025), and where monitoring has historically been more localized and of shorter duration (e.g., St-Denis et al. 2025). Recent efforts to increase the extent of coastal environmental monitoring, and importantly to consolidate the diversity of data sources into common databases will facilitate the production of an Ecosystem Summary for the coastal zone in the future (e.g., St-Denis et al. 2025). Selection of environmental variables and taxa to consider for the offshore EGSL Summary aligns with the scientific survey platforms and the waters the taxa occupy, rather than strict depth and distance thresholds.

Second, the EGSL Ecosystem Summary will focus on indicators at the scale of the entire ecosystem, or where relevant, at the scale of the sGSL (area south of the Laurentian Channel), the nGSL (Laurentian Channel and areas to the north, as well as the Estuary) and for a few indicators, the Estuary. The sGSL and nGSL split is both practical and ecologically relevant, as the macroscopic ecological communities have historically been sampled in separate surveys using different gear with different selectivity and the areas are largely characterized respectively by a shallow shelf and deep channels. Meanwhile, the Estuary is a hotspot, notably for hypoxia and acidification. Reporting trends for the Estuary separately from those in the Gulf will better reflect the severity of changes in the former, while clearly illustration changing condition in the remainder of the ecosystem. Environmental indicators at finer spatial scales than these that may be more appropriate for EAFM for specific stocks, are available in reports produced by the AZMP and in the *gslea* R package (Duplisea et al. 2024).

Third, the EGSL Ecosystem Summary will address EAFM-relevant content and indicators that are known or presumed relevant for multiple stocks. Indicators pertinent only to single stocks or non-harvested species of conservation concern, such as beluga (*Delphinapterus leucas*) and North Atlantic right whales (*Eubalaena glacialis*), are excluded from this routine reporting, although emerging factors with potential stock-level implications may be flagged in the appropriate section of the Summary.

Fourth, and following from the previous consideration, only indicators that have an extended time series, reliably indicate a pressure on harvested fish stocks or fisheries, and for which routine updates are expected will be routinely reported.

Fifth, the EGSL Ecosystem Summary will exclude indices mainly related to other ecosystems and that are reported elsewhere. For instance, the Newfoundland and Labrador (NL) climate index may influence some EGSL components similarly to the impacts on the productivity of numerous ecological components in offshore NL waters (Cyr et al. 2025), but this index is expected to be covered within the NL Ecosystem Summary.

Sixth, the content of the EGSL Ecosystem Summary is expected to evolve as methods and indicators are refined, and understanding of stock-environmental linkages improves. Progression towards broader Ecosystem-Based Fisheries Management and Ecosystem-Based Management is likely to motivate inclusion of new types of indicators, including those related to fishing effects on benthic habitats and non-target species.

Finally, the offshore EGSL Ecosystem Summary is intended to inform stock assessment and indicator updates in the Quebec and Gulf Regions, which typically occur during winter of the fiscal year (December-March). Acknowledging that the Ecosystem Summaries will be produced using existing resources and workflows, the terminal year presented in the Summary will vary to some extent amongst indicators. Many indicators will only be current to the previous year while others, including the indicators for particular taxa, such as apex predators, will be current to their last assessment (e.g., every 5 years for seals).

To enhance efficiency and reproducibility, indicator production and annual compilation are being automated to the extent possible. This will be achieved by making access to data and indicators via the *gslea* R package (Duplisea et al. 2024). A separate R package, *EAgraphics* was developed to produce the standard figures for the Summary using output from *gslea*. Separating data bundling from output production was in keeping with the objective of *gslea* (Duplisea et al. 2024) to maintain simplicity, reduce dependencies (e.g., graphing functions in third-party R packages), and preserve stability. Although not implemented for the production of the EGSL Ecosystem Summary in Appendix A, subsequent EGSL Ecosystem Summaries will likely use R-Markdown capabilities to standardize document generation and layout across years.

IDENTIFYING APPROPRIATE INDICATORS

The selection of environment and ecosystem variables (EVs) for inclusion in the offshore EGSL Ecosystem Summary was informed by a review of all CSAS Science Advisory Reports and Science Responses published by Quebec and Gulf Regions in 2021 through October 10, 2025. The review included all assessed EGSL stocks/populations, including diadromous and coastal stocks to ensure extensibility for future Ecosystem Summaries of the EGSL coastal zone and possibly key watersheds. For each stock, EVs in the published CSAS documents were identified, regardless of whether they were linked to the advice or mentioned as part of the environmental context for the stock. Stocks for which there was no mention of EVs in the advice were also retained and duly noted.

The results of the review are summarized in two tables. Table 1 summarizes stock-specific EVs and their purported or demonstrated effect on stock productivity, dynamics, or habitat, when specified. This information was then further summarized by EV or EV-class, to identify the ensemble of EVs relevant to EGSL stocks (Table 2). This tabulation shows the number of stocks for which particular EVs have been identified as relevant, revealing, for instance, that various facets of ocean temperature are cited for 11 stocks, that sea ice and hypoxia are each identified for four stocks, and that grey seals, are identified as a known or suspected important source of mortality for nine stocks. Table 2 also indicates the availability of each EV indicator and a comment with respect to considerations used in the selection of an indicator for each EV. These considerations are not discussed further here, although more justification is provided later in the document when discussing some specific indicators.

Draft National EAFM guidance on Ecosystem Summaries also identified that composite indicators were important when characterizing ecosystem state and trends relevant to fish stock statuses and fisheries. Specifically noted were:

1. Food web components and trophic state indicators,

2. Biodiversity indicators,
3. Habitat indicators and considerations,
4. Aggregated fisheries metrics, and
5. Perspectives on climate change impacts.

Considerations for the EGSL associated with each of these, along with reflections on the relevance of presenting indicators, and which to present in the EGSL Summary, are summarized in Table 3. With the exception of Habitat indicators (3), considerations and reflections are detailed in the respective sections of the document.

Based on the CSAS literature review, indicators and considerations for biogenic and physical structural habitat (excluding oceanographic habitat) were not identified for the offshore EGSL Summary at present, thus were not included. Existing longer term and large scale data required to provide reliable indicators were deemed inadequate. While data from RV surveys were used previously to identify areas of higher densities of structure-forming taxa such as corals and sponges (Murillo et al. 2016), catches are variable and result in variable indices (Chamberland et al. 2025). A number of marine refuges were put into place during the last decade to protect significant aggregations of corals and sponges. While there is some monitoring of these areas, results are too preliminary for inclusion in the Summary, although they are likely to be published in a different venue. We are also not aware of any long-term and large scale monitoring of physical, non-biogenic habitat in the EGSL.

Aquatic invasive species with known or projected impacts on fishery resources could justifiably be included in an Ecosystem Summary. The same is true for pathogens and contaminants. No known cases were identified for offshore stocks in the EGSL based on a review of available information. However, reporting on European green crab (*Carcinus maenas*) may be relevant for coastal ecosystems for the EGSL (DFO 2025c).

EGSL ECOSYSTEM SUMMARY INDICATORS

The following subsections provide the relevant background, some methodological details, and key results for the suite of indicators that will constitute the EGSL Ecosystem Summary.

A number of indicators presented below constitute standardized anomaly values from a long-term mean or baseline. Standardized anomalies are calculated as the annual value of the quantity of interest, minus the long-term or baseline-period average, divided by the standard deviation of values for the period in question. The resulting anomalies are dimensionless, and because they are calculated with respect to the standard deviation, their magnitude also indicates statistical significance, in a sense. Furthermore, annual anomalies for different quantities can be added together to produce composite indices, where this makes sense. The NL Climate Index (Cyr et al. 2025) and the shallow, intermediate and deep water climate indices for the EGSL (Galbraith et al. 2025a) are examples of composite indices. Anomaly-based indices described in the following sections are based on a long-term mean and standard deviation across all of the years in the index unless specified otherwise.

Anomalies are not used when presenting indicators for which the magnitude of the values is biologically-meaningful or is likely to be of interest to readers. For example, indicators for hypoxia and acidification presented below are expressed with respect to accepted threshold levels indicating severity, and this information is not otherwise reflected in anomalies. Similarly, for both the biomass of mid-trophic level prey and the abundance of apex predators, the magnitude of values are of similar importance to trends, for instance.

PHYSICAL ENVIRONMENT

Oceanographic conditions define the physical, chemical, and biological environment in which marine species live and interact. These conditions strongly influence the growth, reproduction, distribution, and survival of many commercially important species. As such, understanding environmental variability and how it shapes suitable habitat conditions for each stock is essential when evaluating population status and ecosystem dynamics.

Key environmental drivers frequently incorporated into stock assessments include temperature, dissolved oxygen, ocean acidification parameters, and zooplankton indices (Table 1). These factors are known to affect metabolic processes, habitat suitability, and food availability. However, they represent only part of a broader environmental mosaic. Additional drivers such as sea-ice cover and phytoplankton dynamics can also exert significant, sometimes cascading, effects across multiple trophic levels (e.g., Pendleton et al. 2012).

In this section, we highlight a few selected oceanographic indicators to illustrate ongoing trends within the EGSL. Consistent with long-standing practice in AZMP program reporting, several are summarized using general metrics, reported as anomalies from long-term averages, to provide a clear overview of the changing environmental context. For temperature and ice variables, the long-term mean (or normal conditions) is calculated for the World Meteorological Organization (WMO) standard 1991–2020 reference period for physical indices. For indices that do not have sufficient historical coverage, the longest available time series is used, with the reference period updated every five years until it spans the recommended 30-year interval.

Comprehensive and detailed assessments of oceanographic conditions in the EGSL are published annually by the members of the AZMP program (e.g., Blais et al. 2025; Galbraith et al. 2025a; Lizotte et al. 2026).

Temperature and ice

The summertime water column in the EGSL consists of three distinct layers: the surface layer, the cold intermediate layer (CIL), and the deeper layer. During fall and winter, the surface layer thickens and cools to form a winter surface mixed layer to an average depth of 75 m, encompassing up to 45% of all waters of the EGSL (Galbraith 2006). During spring, surface warming, sea ice melt waters, and continental runoff produce a lower-salinity and higher-temperature surface layer that typically reaches its maximum temperature in early August. Underneath this surface layer, cold waters from the previous winter are partly isolated from the atmosphere and form the summer CIL. This layer persists until the next winter, gradually warming up during summer and fall.

The May-November sea-surface temperature over the Gulf was at a record high in 2024, and all five years between 2021 and 2025 rank in the seven warmest since 1982 (Figure 2). The average April-November air temperature measured at weather stations surrounding the Gulf has been identified to be a good proxy for May-November sea-surface temperature over the Gulf (Galbraith et al. 2012, 2021, 2025a) and is shown before 1982 on Figure 2. An updated comparison finds high correlation between air and sea-surface temperatures (R^2 = 0.81, 1982-2025) and a warming trend of the sea-surface temperature proxy of 1.5 °C per century between 1893 and 2025.

Sea ice metrics of duration, maximum area and volume are highly correlated (R^2 = 0.80 to 0.86, 1969-2025) and therefore only seasonal sea ice maximum volume is retained for the Ecosystem Summary (Figure 2). In the 16-year span since 2010, 11 of the 16 lowest seasonal maximum ice volumes since 1969 have occurred (Figure 2). December-March air temperatures in the Gulf were found to be highly correlated with sea ice properties (R^2 = 0.75 to 0.86; 1969-2024, Galbraith et al. 2024). With the warming trend of 2.1 °C per century between 1893 and 2025 of December-March air temperatures in the Gulf, the seasonal sea ice cover is threatened over the long term.

Whereas the CIL is the remnant of the winter mixed layer, it is also driven by winter atmospheric conditions and is prone to warming. The spatial average of the CIL minimum temperature measured in August and September is retained for the Ecosystem Summary (Figure 2). Although there is interannual variability associated with occasional severe winters, there is an increasing trend of the CIL minimum temperature since 1985. The record high occurred in 2021 and all five years between 2021 and 2025 have been above normal (Figure 2). The CIL minimum temperature is well correlated (R^2 = 0.51) with September bottom temperatures deeper than 30 m in the sGSL (Magdalen Shallows) and other metrics for the CIL (Galbraith et al. 2025a), and is therefore presented in the Ecosystem Summary as the indicator for bottom temperature conditions in the sGSL and in the CIL more generally.

The deeper water layer below the CIL originates at the entrance of the Laurentian Channel at the continental shelf break and circulates towards the heads of the Laurentian, Anticosti, and Esquiman channels without much exchange with the upper layers. Decadal changes in temperature, salinity, and dissolved oxygen of the deep waters entering the Gulf are related to the varying proportion of the source, cold—fresh and oxygen-rich Labrador Current water and warm—salty and oxygen-poor slope water also known as North Atlantic Central Waters (McLellan 1957, Lauzier and Trites 1958, Gilbert et al. 2005, Jutras et al. 2020). The Gulf average temperature at 300 m increased a 100-year record in 2016 at 6.3 °C and set a record high of 7.1 °C in 2022 (Figure 2). The waters have since cooled, but the average temperature in 2025 remained above the record-breaking level of 2016. Water temperatures at depth layers below 150 m are highly correlated (R^2 = 0.58 between temperatures a 150 and 300 m and R^2 = 0.80 between temperatures a 200 and 300 m), even though they differ in absolute value (Galbraith et al. 2025a). The mean temperature at 300 m was chosen for the Ecosystem Summary as the indicator for interannual trends in water temperature at deeper depths, including bottom temperatures in deeper waters.

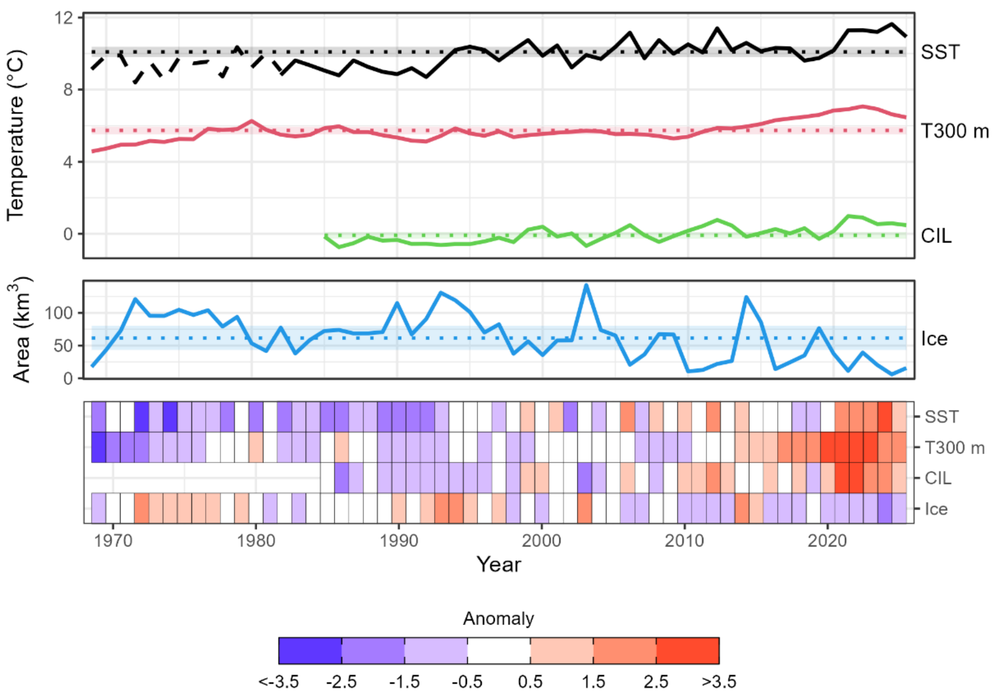

Figure 2. Water temperatures and sea ice volume in the EGSL. Top panel: Sea surface temperature (SST; solid black line), layer-averaged temperatures at 300 m (T300 m; solid red line), and cold intermediate layer (CIL; solid green line) minimum temperature. The solid portion of the SST line (1982-2025) was averaged over the Gulf excluding the Estuary (May–November). The dashed portion of the SST line (1969-1982) was established based on a proxy of April–November air temperatures. The CIL was based on August averages in the EGSL. Middle panel: Seasonal maximum ice volume (Ice; solid blue line) in the EGSL. For the top and middle panels, the dotted horizontal lines indicate the corresponding climatological means for 1991–2020, while the shaded areas indicate ± ½ SD around the climatological means. Bottom panel: Anomaly values, where the sign of the anomaly has been set to reflect warming conditions as positive anomaly values (i.e., an ice volume below the long-term average is associated with a positive anomaly value). Anomaly colours convey both the direction and magnitude of deviations: white indicates normal values within ± ½ SD of the climatological mean, red denotes warmer than normal anomalies, and blue reflects colder than normal anomalies.

Dissolved oxygen

In the marine environment, dissolved oxygen content is governed by water renewal and is often limited at depths below 100 m where ventilation is reduced. Deep-water oxygen saturation is therefore a key indicator of the stress imposed by low oxygen levels on benthic and demersal organisms. In the northwest (NW) Atlantic, hypoxia is generally defined as < 30% oxygen saturation (≈ 100 µmol L^{-1}; Plante et al. 1998). Here, we additionally consider waters with < 20% oxygen saturation to be severely hypoxic.

Driven by ocean warming, increased stratification, and circulation changes, the global ocean has lost about 2% of its oxygen over the past 50 years (Schmidtko et al. 2017), with deoxygenation in the EGSL exceeding the global average (Gilbert et al. 2010; Claret et al. 2018; Jutras et al. 2023). In the EGSL, rapid declines in deep-water oxygen saturation have occurred since 2016 (Blais et al. 2025), primarily due to reduced inflow of cold, oxygen-rich Labrador Current Water and increased intrusion of warm, oxygen-poor North Atlantic Central Water. Increased stratification and additional oxygen consumption linked to warmer temperatures, and eutrophication in the St. Lawrence Estuary has further intensified deep-water deoxygenation in recent years (Gilbert et al. 2005; Jutras et al. 2023; Blais et al. 2025).

Newly formed hypoxic zones (< 30% saturation) now occur in deep regions such as the central GSL and the Anticosti and Esquiman Channels, where such conditions were absent from historical records. Driven by the upward expansion of the hypoxic zone, waters at 200 m have also become hypoxic at multiple locations throughout the Estuary and the NW Gulf, whereas this was previously restricted to the head of the Laurentian Channel at this depth (Blais et al. 2025). In the Estuary, where deep waters have been hypoxic for decades, oxygen levels declined to near-lethal values for many commercially important species (11% in 2022; Blais et al. 2025), rendering these habitats unsuitable. Overall, this has resulted in an increasing extent of bottom area affected by hypoxic, and severely hypoxic, waters in both the Estuary and the Gulf since 2016. The maximum extent of the hypoxic zone occurred in 2020 in the Estuary, and in 2023 in the Gulf (Blais et al. 2025; Figure 3). In the Estuary, the area covered by severely hypoxic waters has risen from nearly 0% in the early 2010s to almost 60% in 2024 (Figure 3).

Declining oxygen levels alter habitat availability, ocean productivity, biodiversity, and biogeochemical cycles (Breitburg et al. 2018). Several species, including Atlantic Cod (*Gadus morhua*), Greenland Halibut (*Reinhardtius hippoglossoides*), Northern Shrimp (*Pandalus borealis*), and Atlantic Wolffish (*Anarhichas lupus*), show metabolic impairment as oxygen saturation declines below ~70% (Chabot and Dutil 1999; Chabot and Claireaux 2008; Dutil et al. 2014; Brennan et al. 2016). Only a few species, such as Northern Shrimp and Greenland Halibut, can survive severely hypoxic conditions below 20% saturation (Dupont-Prinet et al. 2013a, 2013b). A recent study indicates that Redfish (*Sebastes* spp.) may also experience physiological impairment under hypoxic conditions, particularly under warmer conditions (Guitard et al. 2025).

The indicators for hypoxia in the Ecosystem Summary were selected based on two considerations. First, because conditions differ substantially between the Estuary and the remainder of the Gulf, and because many stocks are distributed primarily in one area or the other, exposing them to different environmental conditions, indicators for each area are presented separately. Second, given there are biologically meaningful thresholds defining hypoxia and severe hypoxia, indicators describing conditions relative to these thresholds are probably the most relevant for informing stock assessment and management in an EAFM context. Accordingly, the state of hypoxia in the EGSL is presented as the percentage of bottom area deeper than 100 m that is covered by hypoxic and by severely hypoxic waters in each of the Estuary and GSL. This approach highlights changes in habitat availability for stocks overall, and for individual stocks when species-specific tolerances are known.

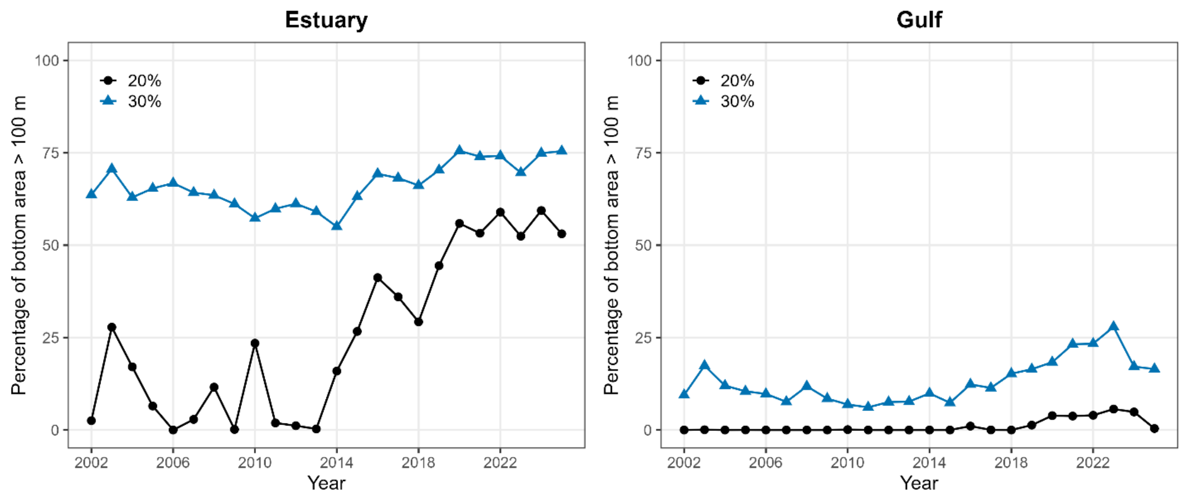

Figure 3. Trends and state of hypoxia in the EGSL: percentage of the bottom area where waters are deeper than 100 m covered by hypoxic waters (< 30% saturation; blue line) and severely hypoxic waters (< 20% saturation; black line) in the Estuary (left panel) and Gulf (right panel) of St. Lawrence.

CO_2-driven conditions including acidification and hypercapnia

As a sink for atmospheric carbon, the ocean takes up anthropogenic carbon dioxide (CO_2) that modifies inorganic carbon speciation and lowers pH, leading to ocean acidification (Caldeira and Wickett 2003; Feely et al. 2004, 2023). The global surface ocean pH has decreased from 8.18 in preindustrial times to 8.04 in 2024, corresponding to a ~40% increase in acidity (EEA 2024; NOAA 2024). Since the late 1980s, Atlantic Canadian subsurface waters (50 m and deeper) have exhibited rates of pH decrease (~0.03–0.04 per decade; Bernier et al. 2023) that are higher than global surface-water averages (~0.017–0.027 per decade; IPCC 2021). The subsurface carbonate chemistry signals in Atlantic Canadian waters are modulated by regional hydrographic conditions, watershed and groundwater inputs, as well as organic-matter cycling and carbonate buffering (Bernier et al. 2023; Gibb et al. 2023; Li et al. 2025; Barclay et al. 2026).

In the EGSL, carbonate chemistry is also largely influenced by the origin and movement of water masses, as well as ventilation and remineralization processes (Mucci et al. 2011; Gibb et al. 2023; Lizotte et al. 2026; Lavoie et al. In prep.[1]). Since 2020, the deep subsurface waters occupying the channels intersecting the EGSL have shown increasing partial pressures of CO_2 (pCO_2) and declining pH below the CIL, with the 200 m layer emerging as a hotspot of intensified acidification and hypercapnia, defined as $pCO_2 \geq 1000$ µatm (Lizotte et al. 2026). The lower Estuary represents the most impacted part of the EGSL, with low pH, aragonite and calcite undersaturation, and persistent hypercapnia from 200 m to near-bottom waters. The Magdalen Shallows remain the least affected in the EGSL, but near-bottom aragonite undersaturation does occur, and recent anomalies point to growing sensitivity in the area (Lizotte et al. 2026).

[1] Lavoie, D., S. Rousseau, M. Starr, P. Calosi, J. Chassé, D. Delisle, C. Carrier-Belleau, K. Azetsu-Scott, J. Dumas. In preparation. Seasonal variability of the carbonate system in the Gulf of St. Lawrence and its implications for marine invertebrates survival. Submitted to Progress in Oceanography.

Experiments and field studies point to a broad mix of organism-level responses to changing carbonate chemistry, spanning negative, neutral, and positive responses, which may vary across different life stages (Leung et al. 2022; Barclay et al. 2026). The greater negative impacts often stem from acid-base imbalance under high pCO_2 and low pH, which forces organisms to spend extra energy on ion transport to keep their internal chemistry steady (Pörtner 2008; Melzner et al. 2012; Doney et al. 2020; Liu 2021). In invertebrates, these energetic costs may coincide with greater dissolution pressure on calcified structures and higher metabolic demands for calcification, which can affect biomineralization, metabolism, growth, development, immunity, and survival (Doney et al. 2020; Shi and Li 2024; Barclay et al. 2026). In marine vertebrates, including fishes, altered acid-base balance can reduce the efficiency of blood oxygen binding and delivery, which constrains aerobic performance and elevates metabolic costs, particularly when combined with warming or hypoxia (Pörtner and Farrell 2008; Small et al. 2020; Huo et al. 2023; Jian et al. 2025). Beyond physiological impacts, high pCO_2 can interfere with an animal's ability to interpret cues and make decisions and, as a result, behaviors like foraging, predator avoidance, and habitat selection can be altered (Schunter et al. 2019; Liu 2021; Spicer and Morley 2022). Marine organisms in the EGSL, including scallops, clams, whelks, urchins, sea cucumbers, lobster, shrimp, crab, and several fish groups, may respond to changing carbonate chemistry in different ways, depending on their habitats and their tolerance to CO_2-driven stress. However, region-specific evidence in the EGSL remains limited, and many of these sensitivities are still not well understood (Barclay et al. 2026 and references therein).

As described above, increases in CO_2 lead to several inextricably-link processes associated with carbonate chemistry. Hypercapnia was chosen as an indicator of these processes for the Ecosystem summary given it is based on a biologically-relevant threshold. Although the data series is shorter (2014-2025), considerations for the choice of indicator for hypercapnia in the EGSL are similar to those for hypoxia presented above: notable differences between the Estuary and the remaining GSL, and the ability to present trends and status with respect to a biologically-relevant threshold. The selected indicator for hypercapnia is therefore the percentage of bottom water area, in locations deeper than 100 m in the Estuary and in the GSL, that is occupied by waters exceeding the hypercapnic threshold of 1000 µatm in pCO_2. The indicator clearly shows the increase in the area of hypercapnic bottom conditions in both the Estuary and Gulf, and the greater extent in the Estuary (Figure 4).

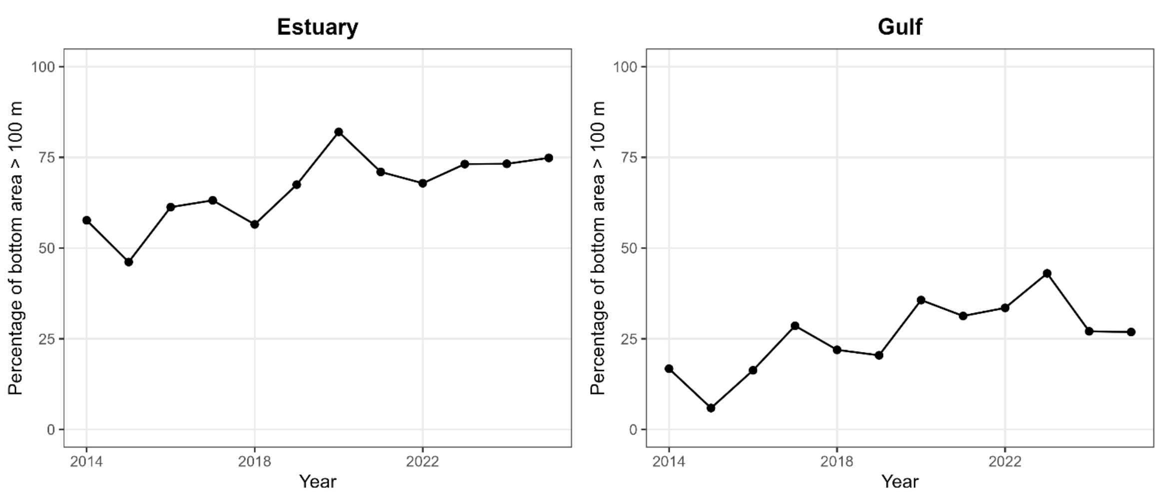

Figure 4. Trends and state of hypercapnia in the EGSL: percentage of the bottom area where waters deeper than 100 m are covered by hypercapnic waters (pCO_2 ≥ 1000 µatm) in the Estuary (left panel) and Gulf (right panel) of St. Lawrence.

FOOD WEB COMPONENTS

Mesozooplankton

Mesozooplankton are zooplankton ranging from 0.02 to 1 cm in size, and they are largely dominated by copepods in the EGSL. They drift with ocean currents and are sampled by the AZMP program using vertical net tows that typically span from near bottom to the surface. As primary consumers of phytoplankton, mesozooplankton form a critical energetic link between primary production and higher trophic levels. Smaller zooplankton species, including early developmental stages of larger copepod taxa, constitute the main prey for larval fish, while larger copepods support juvenile and adult fish (Peck et al. 2012), but also certain seabirds, and baleen whales (Barrett et al. 2007; Brennan et al. 2021). Larger, lipid-rich zooplankton provide more efficient energy transfer because they allow predators to acquire more calories with less foraging effort, supporting better growth and overall condition (Kattner et al. 2007).

Zooplankton abundance and community composition are key drivers of recruitment and body condition in several commercially important pelagic fish species, including Atlantic Herring (*Clupea harengus*), Atlantic Mackerel (*Scomber scombrus*), and Capelin (*Mallotus villosus*) (Brosset et al. 2019; Émond et al. 2024; Lehoux et al. 2022; Plourde et al. 2014). Zooplankton biomass distribution also directly influences the occurrence of North Atlantic right whales in their NA foraging areas (Brennan et al. 2021).

Several potential indicators for zooplankton were considered for the Ecosystem summary. Although the AZMP program publishes annual abundance indices for individual species and size-based groups (Blais et al. 2025), these metrics were considered too variable and detailed to summarize broad patterns affecting fishery resources. Annual average mesozooplankton biomass (dry weight), which reflects available energy within this trophic guild and correlates with community composition (Blais et al. 2025), was therefore chosen as a simple, robust index. Biomass is expressed as standardized anomalies rather than absolute values to address standardization issues arising from uneven seasonal sampling. This method also allows regional comparisons while enabling the calculation of a composite EGSL index from their standardized sum. Standardized anomalies were calculated using 2001-2025 as the reference period.

The decline in zooplankton biomass in the EGSL since 2001 (Figure 5) suggests a reduced ecosystem production potential compared to previous decades. Although the community shift from large lipid-rich copepods to smaller taxa appeared to stabilize in the late 2010s, the recent elevated abundance of small copepods and non-copepod taxa (Blais et al. 2025) may indicate reduced trophic transfer efficiency from primary producers to higher trophic levels. Similar trends have been observed across Canadian Atlantic waters (Galbraith et al. 2025b).

As per the approach for physical and chemical oceanographic variables, the period employed when calculating anomalies for microzooplankton will be updated every five years until the series spans the recommended 30-year interval.

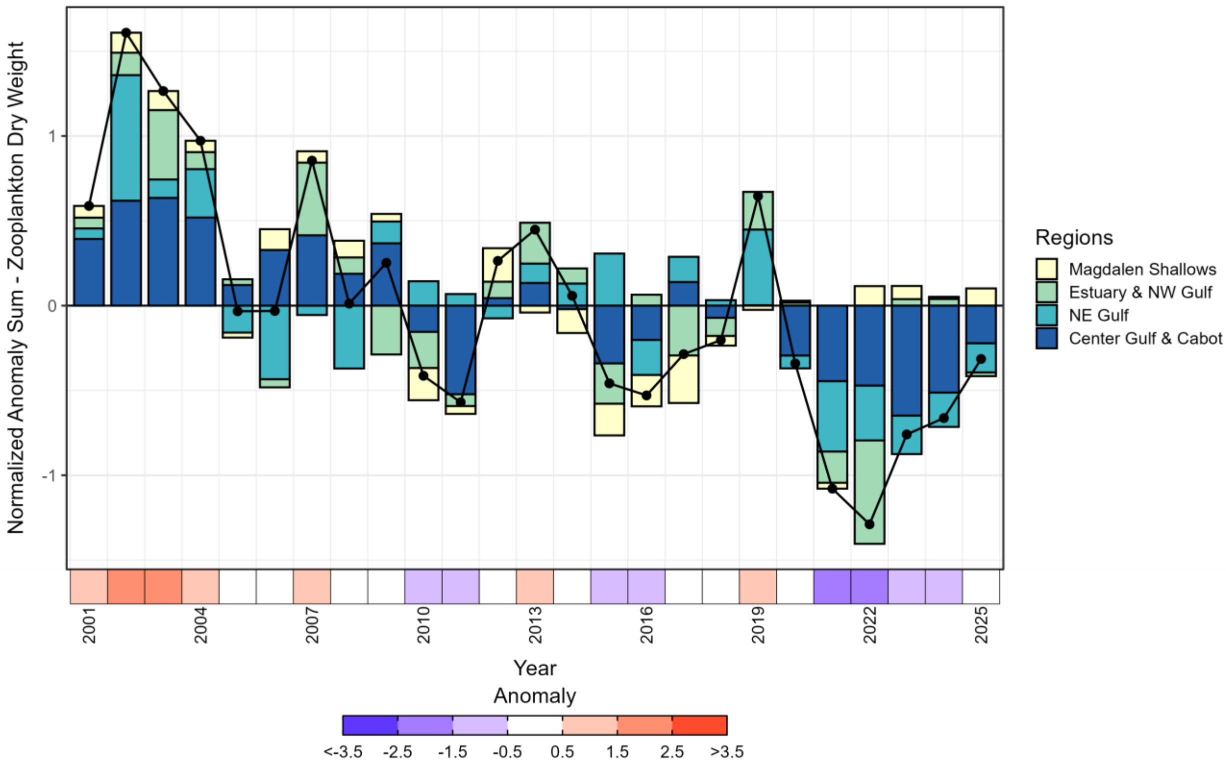

Figure 5. Composite dry weight zooplankton biomass index (black line and dots) for the EGSL derived by summing regional normalized anomalies (coloured boxes stacked above the abscissa are positive anomalies, and below are negative). Each bar represents the volume-weighted average of all Gulf ecosystem approach polygons (Duplisea et al. 2024). Time series at the bottom shows the composite zooplankton index that is renormalized again, using the 2001–2025 climatology. Colours convey both the direction and magnitude of deviations: white indicates near average values, red denotes above-average anomalies, and blue reflects below-average anomalies.

Forage species

Forage species play a central role in the EGSL food web by converting primary and secondary production into biomass that sustains a wide range of consumers including groundfish, pelagic fish, marine mammals and seabirds. In the EGSL, important forage species include Atlantic Mackerel, Atlantic Herring, Capelin, and Northern Shrimp, all of which support substantial predation pressure from year-round and seasonal predators and, in many cases have also supported commercial and bait fisheries by virtue of their abundance in the ecosystem. Although this list is not exhaustive, these taxa are among the most functionally important mid-trophic species in the ecosystem and are those for which scientific information on abundance, distribution, and ecological role is most developed. Other mid-trophic level taxa such as sand lance, euphausiids, mysids, other shrimp, and cephalopods are known to contribute to predator diets (Berkes 1973; Ouellette-Plante et al. 2020; Staudinger et al. 2020; Jac et al. 2025; Irani et al. 2026), and are included in the community composition indicators below. This includes emerging forage fish that are increasing in abundance in the EGSL, likely associated with distribution shifts, such as the Greater Argentine (*Argentina silus*).

For each of the key selected forage species, a brief overview is provided on its ecological role, major predators, and relevant considerations for interpreting trends. This is followed by a description of the indicator used to represent prey availability for the Ecosystem Summary.

Atlantic Mackerel

Atlantic Mackerel is a migratory pelagic schooling species, with the northern contingent of the NW Atlantic stock distributed throughout the EGSL and spawning predominately in the sGSL (Jac et al. 2025; Lehoux et al. 2025). Mackerel is a key forage fish supporting a broad suite of pelagic and demersal predators in the EGSL (Van Beveren et al. 2024). Its high energetic density contributes to its role as a dominant prey item for species such as Atlantic Bluefin Tuna (ABFT) (*Thunnus thynnus*; Turcotte et al. 2023; Burbank et al. 2024) and northern gannets (*Morus bassanus*; Guillemette et al. 2018; d'Entremont et al. 2021).

Mackerel abundance has declined substantially in recent decades, with the stock currently below its Limit Reference Point (LRP) and subject to a rebuilding plan (Lehoux et al. 2025). The ecosystem-level effects of decreased biomass of mackerel are largely unresolved, except in the case of northern gannets where this decrease was associated with declines in breeding success (Guillemette et al. 2018; d'Entremont et al. 2021). Reduced availability of Mackerel may also have increased predation pressure on alternative forage species (e.g., sand lance (*Ammodytes* spp.), Herring). In the Northeast United States shelf system, for example, fluctuations in forage fish biomass are linked to shifts in predator community structure, variability in recruitment of mid-level predators, and changes in spatial occupancy of forage assemblages (Suca et al. 2021). Mackerel spawn predominantly in the sGSL in June-July (Van Beveren et al. 2023). After spawning, they disperse more widely in eastern Canada waters for foraging. Because of the species' migratory nature, the amount of time the stock uses the EGSL in summer and fall may vary among years, influenced by temperature, prey availability, and broader environmental conditions. The time series for the northern contingent of Mackerel begins in 1969 and the stock is assessed at a 2-year frequency (Table 4).

Atlantic Herring

Atlantic Herring is among the most abundant pelagic forage species in the EGSL and supports multiple predator guilds (Benoît and Rail 2016). Canadian populations are composed of genetically distinct spring- and fall-spawning components, with unique spawning areas and temporal behaviours (Lamichhaney et al. 2017). Herring is a key prey item for numerous piscivorous fish and top predators (see below). Herring availability has also been associated with demographic responses in northern gannets, including breeding success (Guillemette et al. 2018), highlighting the species' central role.

Herring in the nGSL and fall spawning Herring in the sGSL are above their LRP, whereas spring spawning herring in the sGSL have been in the below their LRP and in the Critical Zone of the Precautionary Approach framework since 1999. Fall spawning herring in the sGSL experienced substantial declines from 2010 to 2020, however biomass has recently been increasing (Turcotte 2026; DFO 2026). Reduced biomass may have increased predation pressure on remaining components or shifted predator diets toward alternative forage species. Because of Herring's schooling behaviour and temporal predictability (e.g., spawning aggregations), predation can be spatially and temporally concentrated, generating substantial localized mortality. The time series for the nGSL Herring begins in 1966, whereas the sGSL Herring time series begins in 1978. The stocks are assessed at a 2-year frequency in opposite years for the nGSL and sGSL (Table 4).

Northern Shrimp

Northern Shrimp occupy an intermediate trophic position, functioning both as predators of zooplankton and as prey for numerous fish species and marine mammals. In the EGSL, Shrimp are consumed by Redfish, Atlantic Cod, hake, certain flatfishes, and other groundfish, as well as by some marine mammals (Savenkoff et al. 2006). Northern Shrimp are by far the most abundant shrimp species in multi-species surveys (Tamdrari et al. 2018). Northern Shrimp thus provide an important conduit linking lower trophic levels with commercially harvested piscivores.

EGSL Shrimp stocks have undergone pronounced changes over the past two decades, characterized by declines in biomass across multiple stock areas. These declines have been linked to warming waters, changes in habitat suitability, and increasing predation pressure (Boussens-Dumon et al. 2025). Three of the four EGSL Shrimp stocks are currently below their LRPs and are subject to rebuilding initiatives. Because Shrimp are broadly distributed in deep waters and available throughout much of the year, they have represented a relatively stable prey base for taxa capable of exploiting benthic and benthopelagic habitats. The time series for Northern Shrimp begins in 1990 for all but the stock in the Estuary which begins in 2008. Shrimp are also assessed at a 2-year frequency (Table 4).

Capelin

Capelin is a cold-water, energy-rich forage species that plays a foundational role in northern and sub-Arctic marine ecosystems, including parts of the EGSL. Capelin support a wide range of predators, including top predators (see below), and numerous demersal fishes. Although Capelin occur throughout the EGSL, indices describing their abundance and dynamics remain more uncertain compared to the forage species detailed above, therefore they will not be included in the indicator until comparable estimates are available.

Forage species indicator reporting

The indicator will consist of total biomass estimates for the forage species from their respective stock assessments, however these differ in duration and data availability depending on the assessment cycle (Figure 6). The indicator will begin in 1978 when the time series for sGSL Herring begins. Northern Shrimp biomass estimates are only available from 1990 onward for the majority of stock components, although biomass prior to that time was likely low (Tamdrari et al. 2018). The forage species indicator in the Ecosystem Summary will be updated to the most recent year in which data are available for all three species. Presently, these species are all assessed on a two-year cycle but are not aligned between regions and species.

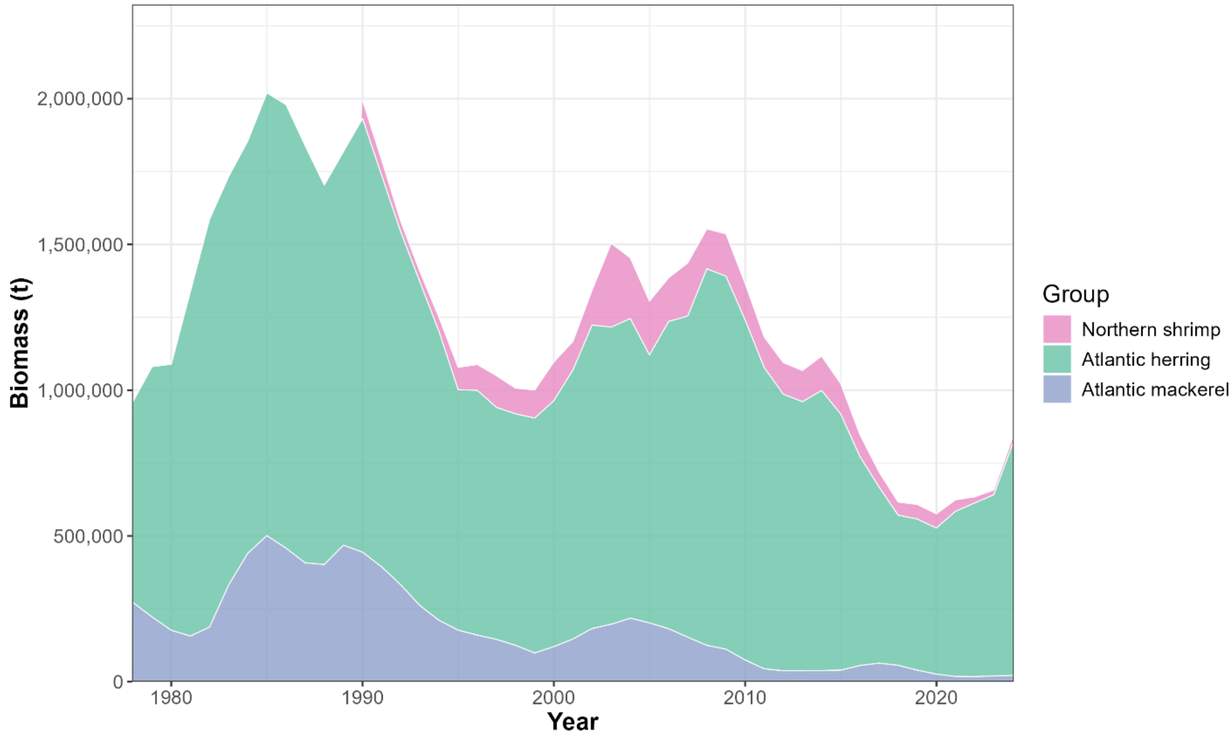

Figure 6. Biomass of key mid-trophic level forage species from their respective stock assessments. Note that the biomass contribution for northern shrimp begins in 1990.

Apex predators

The review of the most recent Science Advisory reports identified six principal apex predators affecting productivity of one or more commercially harvested offshore stocks in the EGSL: grey seal (*Halichoerus grypus*), harp seal (*Pagophilus groenlandicus*), northern gannets, ABFT, and piscivorous groundfish more generally. The list is not exhaustive, as it does not include other known predators of the EGSL for which data (e.g., diets, abundance) are insufficient to establish predation levels, such as odontocetes (toothed whales) and certain mysticetes, such as humpback (*Megaptera novaeangliae*) and minke whales (*Balaenoptera acutorostrata*). The list also excludes white shark (*Carcharodon carcharias*), for which there is evidence of increased presence since 2019-2021 in Canadian Atlantic waters, including the EGSL (Allegue et al. 2025), but no abundance nor diet composition estimates. Some of these predators may be included in future ecosystem summary reports as the information on their dynamics and possible impacts improves.

Among the taxa listed above, only grey seals, harp seals, northern gannets, and ABFT are included in the Ecosystem Summary in the section on Apex Predators. Other important groundfish predators, though not 'apex' are covered in by the trophic community index presented later in the community composition section of the Ecosystem Summary. For each apex predator, a brief summary of their role as predators and the associated indicator (source, frequency of update and relevant considerations) is presented in the following subsections. This is followed by a description and presentation of the figure intended to summarize trends in the abundance of those apex predators over the past decades. More accurate indicators of predation pressure, accounting for predator diets and prey consumption, could be developed for future Ecosystem Summaries.

Grey seals

Grey seals constitute a single population in the NW Atlantic, with year-round presence in the EGSL. While capable of exploiting a wide range of prey in response to spatiotemporal changes in their availability, grey seals tend to be generalists that predominantly rely on demersal fish species and sandlance (Bowen and Harrisson 2007; Hammill et al. 2014; Irani et al. 2026). Predation by grey seals has been linked to important increases in the natural mortality of different groundfish (e.g. Atlantic Cod, American Plaice (*Hippoglossoides platessoides*), White Hake (*Urophycis tenuis*), Yellowtail Flounder (*Myzopsetta ferruginea*)) and pelagic fish (e.g., Herring, Mackerel) stocks in the sGSL over the past few decades (Benoît et al. 2011; Swain and Benoît 2015; Rolland et al. 2022; Rossi et al. 2024; Van Beveren et al. 2024). Some of these stocks are at high risk of extirpation, as a result of the elevated predation-driven natural mortality resulting in part from low, post-collapse stock abundance (Neuenhoff et al. 2019; Swain et al. 2019a, b; Turcotte et al. 2025). While predation by grey seals has previously been suggested as a possible cause of high natural mortality of cod in the nGSL (Northwest Atlantic Fisheries Organization (NAFO) 3Pn4RS stock), a recent review of available evidence suggests the effect has likely been much less important than in sGSL (Ouellette-Plante et al. 2025).

In Canada, grey seals are assessed on a 5-year cycle, with the most recent abundance estimate of 366,400 seals in 2021 (Figure 7; Hammill et al. 2023). While the grey seal population experienced a rapid increase over the time series, the growth rate of the population has slowed in the more recent time period (to 1.5% annually between the last two assessments of 2016-2021) (Hammill et al. 2023). Under the Atlantic Seal Management Strategy (ASMS) framework (Lang et al. 2025), grey seals are situated above the Precautionary Reference Point (PRP) in the Healthy Zone (Hammill et al. 2023). The population is divided in two herds for management purposes, based on their breeding distribution: the GSL herd, and the Scotian Shelf herd (including Sable Island and coastal Nova Scotia). In addition, a portion of the population also breeds in US waters off Maine, Massachusetts, New Hampshire and New York, and is assessed by the U.S. NOAA (Wood et al. 2022). In Canada, the population assessment consists in pup production surveys conducted in early winter (December-January), which, along with other input data on removals and population vital rates, generates abundance estimates (Hammill et al. 2023). While the winter survey also provides distinct pup production estimates (and ultimately total abundance) for the two herds, this is limited to the winter distribution of breeding females and pups. However, grey seals are highly mobile and readily move between the EGSL, the Scotian Shelf and Gulf of Maine throughout the year (Breed et al. 2006; Cusson et al. 2025). Due to the redistribution of animals, the winter distribution of grey seal is not directly informative of the abundance (or proportion of the population) that is present in EGSL in other seasons, or in areas occupied by EGSL stocks seasonally such as the Sydney Bight (Hammill et al. 2014). Consequently, for the purpose of this Ecosystem Summary, total grey seal abundance in Canadian waters population is reported, knowing that only a proportion of those are present in the EGSL or feed on EGSL stocks. Based on new telemetry and survey data, spatiotemporal modelling of grey seal space use in the NW Atlantic is currently under development. This could provide seasonal regional abundance estimates in the future.

Harp seals

Harp seals constitute a single population in the NW Atlantic, with seasonal presence in the EGSL. They spend the summer in the eastern Canadian Arctic and west Greenland, migrating southward in the fall to the Newfoundland Shelf and the EGSL, where they feed, prior to whelping on the pack-ice in winter (Feb-Mar). The species then migrate back to the Arctic in early summer (Sergeant 1991, Stenson and Hammill 2014). Harp seals are generalist predators that predominantly feed on small pelagic fishes (mostly Capelin, also Atlantic Herring), invertebrates (e.g., shrimp and krill) and demersal fishes (e.g. Redfish and Atlantic Cod), while in the EGSL (Hammill and Stenson 2000). Predation by harp seals, particularly on younger fish has previously been considered for nGSL Cod (Chassot et al. 2009; Bousquet et al. 2014), although a recent cursory review of available evidence concluded important impacts seemed unlikely (Ouellette-Plante et al. 2025).

In the NW Atlantic, harp seals are assessed on a 5-year cycle, with the most recent abundance estimate of 4.4 million seals in 2024 (Van de Walle et al. 2025). While harp seal abundance increased rapidly from the 1970s through the 1990s, peaking at an estimated abundance of 7.5 million seals in 1998, the population then declined from 1998-2024 with the exception of a period of relative stability between 2009-2019 (Figure 7; Van de Walle et al. 2025). During the most recent assessment period of 2019-2024, harp seal abundance declined at a rate of 4.7% per year. Density-dependent mortality and the impacts of pup mortality caused by the loss of suitable sea ice are associated with this important decline (Van de Walle et al. 2025; Tinker et al. 2026). Under the Atlantic Seal Management Strategy framework (Lang et al. 2025), harp seals are situated below the PRP, in the Cautious Zone (Van de Walle et al. 2025). The population assessment consists in pup production surveys conducted in winter (Feb-Mar), which, along with other input data on removals and population vital rates, generates abundance estimates (Van de Walle et al. 2025). While distinct pup production estimates are produced for the main whelping areas located off the southeast coast of Labrador/northeast coast of Newfoundland, an area referred to as the “Front” (majority of births), and in the EGSL (including around the Magdalen Islands in sGSL and the Mecatina area in nGSL), the model produces a single abundance estimate of the entire NW Atlantic population. This is what is currently reported in this Ecosystem Summary, knowing that only a proportion of those animals are seasonally present in the EGSL. With the loss of seasonal ice (i.e., whelping habitat), a greater proportion of the population of births are occurring outside the Gulf (Stenson et al. 2020; Goulet et al. 2025), a trend that is projected to continue (Stenson and Hammill 2014; Stenson et al. 2022). While the potential predation impacts of harp seals in the EGSL are uncertain and likely to decline with ongoing and projected sea ice loss (Van de Walle et al. 2025; Tinker et al. 2026), harp seals are retained for the EGSL ecosystem summary for the time being given their importance as consumers in the area historically (Hammill and Stenson 2000), and their high abundance.

Northern gannets

Northern gannets are seasonal residents of the EGSL, where they feed on pelagic fishes from late spring to early fall. Predation on both Herring in the southern Gulf and Mackerel is non-negligible and increased from lower levels in the 1960s to a high and relatively stable level beginning in 2010 (Benoît and Rail 2016; Van Beveren at al. 2024). Mortalities caused by avian bird flu reduced the northern gannet breeding population by 40% during 2022 and 2023, although numbers have increased somewhat since then. Capelin are also taken by gannets, although predation impacts on Capelin have not been assessed. While northern gannets are included here as a top predator on pelagic fish resources, we note that reciprocally, breeding failures have been associated with difficulties finding prey, as noted in an earlier section (Guillemette et al. 2018). Consequently, gannet population dynamics indicate to some extent the relative status of pelagic resources (Rail 2021).

There are three northern gannet breeding colonies in the EGSL (by order of importance): Bonaventure Island, Bird Rocks (Magdalen Island archipelago) and Anticosti. The first two comprise over three-quarters of the total NW Atlantic population. Breeding pair surveys are undertaken by the Canadian Wildlife Service of Environment and Climate Change Canada (ECCC). Surveys occurred at least every five years between the 1960s and late 2000s, but have been annual since then. While Bonaventure Island and Bird Rocks colonies are regularly surveyed, the much less populous Anticosti population, representing < 1% of EGSL breeding pairs, is surveyed much less frequently. Monitoring of the colonies at least every five years is planned for the foreseeable future (J.-F. Rail ECCC, personal communication, 2026-01-05). The most recent survey estimate is from 2025.

The total number of breeding pairs in the Bonaventure Island and Bird Rocks colonies, for years in which both are surveyed, is retained as the indicator for northern gannet predation pressure in the EGSL.

Atlantic Bluefin Tuna

Atlantic Bluefin Tuna (ABFT) are highly migratory apex predators that occupy the EGSL from July to November (Block et al. 2019), where they support important commercial and recreational fisheries in the sGSL. Recent environmental DNA detections indicate that in the EGSL, ABFT now occur as far north as the Strait of Belle Isle (Leung et al. 2026). Consistent with these observations, climate change projections suggest that the most suitable environmental conditions for ABFT will shift poleward by the end of the century (Erauskin-Extramiana et al. 2026). ABFT are opportunistic predators that primarily feed on schooling teleost fishes. Atlantic Mackerel constitutes the dominant prey in the EGSL, followed by Atlantic Herring and sand lance (Turcotte et al. 2023; Burbank et al. 2024). Smaller ABFT feed predominantly on sand lance, while larger individuals target Atlantic Herring, particularly on their fall spawning grounds (Turcotte et al. 2021a), as well as Atlantic Mackerel. ABFT have high metabolic rates that require substantial prey consumption, and their predation has been associated with elevated natural mortality of Atlantic Herring in the sGSL (Turcotte et al. 2021b). Evidence from other NW ecosystems highlights the potential for prey switching in response to availability, including shifts from Herring to northern shortfin squid (*Illex illecebrosus*) during years of high squid abundance (Nadeau et al. 2025) and changes in dominant prey from Capelin and squid in the 1960s to Atlantic Cod in 2022–2023 in Newfoundland waters (Stewart et al. 2026). Collectively, these findings highlight that ABFT predation can be substantial, affect dynamic prey assemblages across space and time, and respond rapidly to shifting environmental conditions through changes in both diet and distribution, including within the EGSL.

The indicator used here relies on fishery-dependent data from the Canadian commercial ABFT fishery, which predominantly operates in the sGSL, at the eastern end of the Northumberland Strait, St. Georges Bay, and around both the western and eastern ends of Prince Edward Island. Spatiotemporal dynamics were modeled using the Vector Autoregressive Spatio-Temporal (VAST) framework (Akia and Hanke 2025). A Poisson-link delta model was applied, with set-level fishing success by size class as the response variable and trip duration as the effort metric, while incorporating temporal, spatial, catchability covariates (fleet, gear, Julian day, fishing effort), density covariates (SST, Herring biomass) and vessel effects. The indicator will be updated annually.

Apex predator indicator reporting

Abundance time series for the four selected apex predators are of variable duration, comprise different frequencies of estimates (annual estimates for all but northern gannet) and vary considerably in magnitude (scale). To accommodate these characteristics in a single figure, the abundance for harp seals is presented in hundreds of animals and abundance of grey seals in tens of animals (Figure 7).

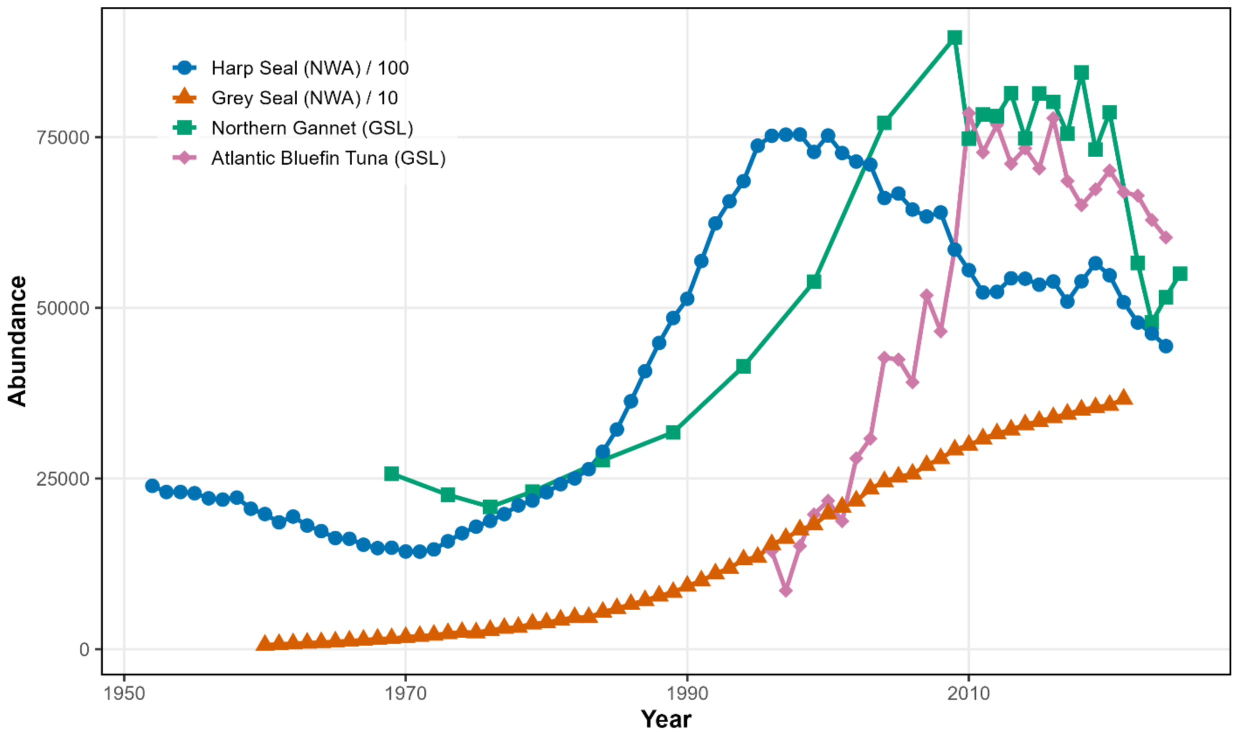

Figure 7. Time series of abundance for each of the four principal apex predators, noting that values for harp seals are in hundreds of animals and those for grey seals are in tens of animals. Note that abundance estimates for both seal species represent population-level (Northwest Atlantic, NWA) abundance that are not limited to EGSL, excluding animals breeding in U.S. waters for grey seal.

COMMUNITY COMPOSITION

Different community or composite indicators can provide information on changes in species composition and biological traits affecting ecosystem functioning and status and the delivery of ecosystem services, such as fisheries. Temporal changes in the biomass of trophic guilds, abundance distribution within and across size classes, and fish body condition are included as three community indicators relevant to fisheries productivity in the EGSL. The trophic guild indicator represents the changes in energy flux in the marine ecosystem. The size structure indicator summarizes changes in the extent and distribution of organisms by size class. Finally, the body condition indicator is a proxy for the general health of fish species in the ecosystem.

These indicators are based on data collected in the annual multispecies bottom trawl RV survey series (Chamberland et al. 2025, Benoît and Swain 2003). Since 2006, the nGSL RV survey occurs during August and provides a reliable time series on the occurrence, biomass and abundance of 101 fish and 175 invertebrate taxa (Isabel et al. 2025a). Catch data collected in the nGSL survey were standardized to account for differences in individual tow swept area and the stratified random sampling design (weighing by strata), as described in Chamberland et al. (2025). Meanwhile, the sGSL RV survey has been conducted annually in September since 1971 and provides a time series on the abundance, size composition, and spatial distribution of more than 120 species of marine and diadromous fish and over 100 marine invertebrate taxa. Three inshore strata were incorporated into the survey design in 1984, and consistent fish length measurements have been available for all species since 1985, forming the basis for community composition indicators. To ensure temporal comparability, survey catch rates were adjusted to account for changes in vessels and fishing gear that occurred over the time series (Benoît and

Swain 2003; Benoît 2006; Benoît and Yin 2023; Benoît et al. 2024). Because the nGSL RV survey overlaps with the sGSL RV survey in the Laurentian Channel (strata 415, 425, and 439), and because the sGSL is largely a shallow-shelf survey in contrast with the nGSL survey which covers mainly deeper channels, these strata were excluded from the sGSL dataset. Consequently, community composition indicators derived from the sGSL RV survey include all strata except those in the Laurentian Channel, and are reported for the period 1985 to present.

Community indicators rely on robust and consistent taxonomic identification and data collection over time. For the nGSL, the selection of taxa for inclusion in the development of composite indicators is described in Isabel et al. (2025a, 2025b). Methodological details on the calculation of community indicators can be found in Isabel et al. (2025b). The same taxa and methodology was applied to the sGSL.

Trophic guild

Trophic guilds group species that rely on similar food resources, feeding strategies, and associated ecosystem functions. Based on Isabel et al. (2025b), eight trophic guilds were defined for fish and invertebrate taxa sampled in the EGSL RV surveys:

1. benthivorous fishes,
2. benthivorous invertebrates,
3. demersal micronekton,
4. filter-feeding invertebrates,
5. limivorous and detritivorous fishes and invertebrates,
6. mesopelagic micronekton,
7. piscivorous fishes and invertebrates, and
8. planktivorous fishes.

Some taxa and life history stages of taxa were ascribed to more than one guild based on their ecology (Chevenet et al. 1994; Isabel 2025b). In the sGSL RV survey, anemone, decapods, and tunicates were not consistently identified to finer taxonomic resolution. Consequently, they were retained at these broader taxonomic levels and assigned to the trophic guild that best represented their primary ecological function (Appendix B).

Changes in the relative importance of trophic guilds reflect variation in energy flows, transfers within and among trophic levels, and overall food web productivity (Tam et al. 2017; van Denderen et al. 2021). The trophic guilds indicator measures the relative importance of each trophic guild as the annual average weight per tow (standardized catch rates) in the surveys.

In the nGSL, temporal trends in the relative importance of the different trophic guilds show an increase and dominance of the planktivorous and piscivorous guilds since 2016 (Figure 8). This increase is driven by an important increase in the biomass of Redfish, which are assigned to both planktivorous (0.4) and piscivorous guilds (0.6). The importance of Redfish in diving guild dynamics is clear when they are removed from the analysis (Figure 8). The increase in planktivorous and piscivorous guilds is associated with a decrease in the relative importance of the demersal micronekton guild dominated by Northern Shrimp.

The sGSL shows a strong decrease in the benthivorous fishes and the piscivorous invertebrates and fishes trophic guilds since 1984, associated with the collapse of groundfish (Figure 8). Contrarily, benthivorous invertebrates and limivorous and detritivorous fishes and invertebrates have increased over the time series, until recent declines, primarily due to increases in

American Lobster (*Homarus americanus*) in the survey. Planktivorous fish have varied through the time series but have remained at lower levels since 2018. The demersal micronekton guild (i.e., decapods) in the sGSL also increased to relatively high levels from 2003 to 2018, before decreasing to low levels.

The trophic guilds indicator suggests a persistent imbalance and restructuring among trophic levels in the nGSL and sGSL food webs.

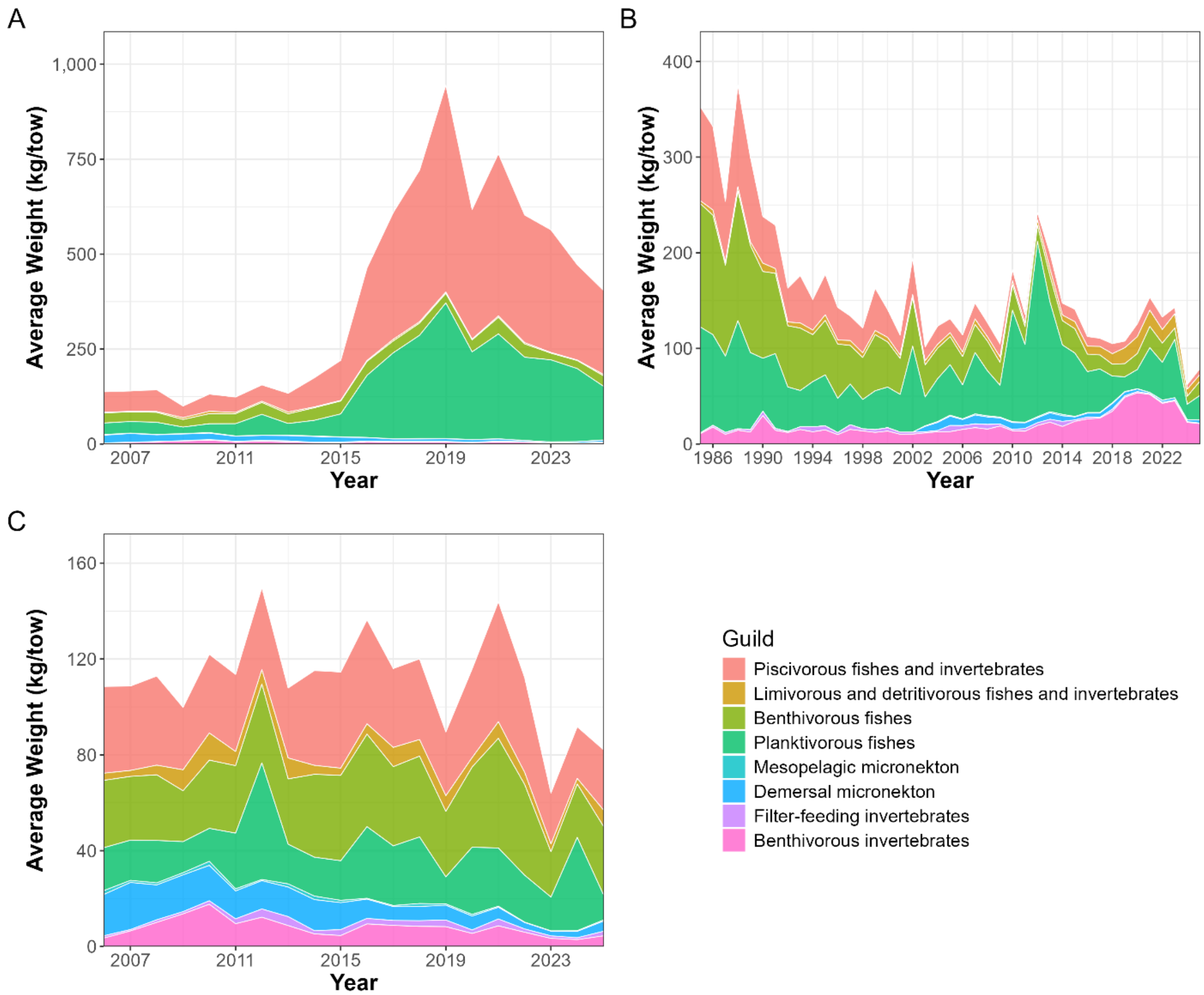

Figure 8. Standardized catch rates (average weight in kg per tow) for each trophic guild for (A) nGSL, (B) sGSL, and (C) nGSL without Redfish. Note the different x-axis range for panels (A) and (C), compared to panel (B).

Size structure

Community size structure is the distribution of organisms by body size, which is a fundamental trait influencing the occurrence and intensity of interspecific interactions, as well as ecosystem productivity and resilience (Birkeland and Dayton 2005; Barneche et al. 2018). Changes in the distribution of abundance across size classes can result from multiple factors including altered interspecific relationships, environmental conditions, or fishing pressure (Rogers et al. 2011; Martins et al. 2023; Blanchard et al. 2005).

The size structure of the community of organisms sampled in the survey is calculated as the standardized mean number of individuals within 10 cm size classes ranging from ≥ 5 to < 85 cm, and a final length class of 85 cm to 100 cm. These are then transformed to standardized anomalies for each size class, using the time series mean and standard deviation for each class. In the nGSL, the size structure analysis is based on length data for 39 fish taxa, 13 shrimp taxa, and the northern shortfin squid. The sGSL size structure is based on 119 fish taxa consistently measured throughout the time series and does not include length information for invertebrates.

In the nGSL, the size structure of the community was marked by the arrival of large cohorts of Redfish causing successive, positive anomalies in the 5-15 cm size class (in 2013-2014), 15-25 cm size class (in 2016-2019) and 25-35 cm size class (in 2019-2025) (Figure 9). Concurrently, there has been an increase in negative anomalies for small (5-15 cm) organisms (mainly shrimp taxa) since 2017. Strong negative anomalies for size classes between 35 and 55 cm are observed in the last three or four years. Species contributing the most to these strong anomalies are groundfish including American Plaice, Atlantic Cod, White Hake, and Greenland Halibut. In the sGSL, the size structure of the community shows a large scale decrease in size classes ≥ 35 cm from 2000 to present, largely due to the collapse of groundfish. The 25-35 cm size class has also decreased from 2016 to present, driven by the decrease in pelagic fishes. From 2010 to present, the small size classes (5-25 cm) have increased likely due to Redfish, as described in the nGSL.

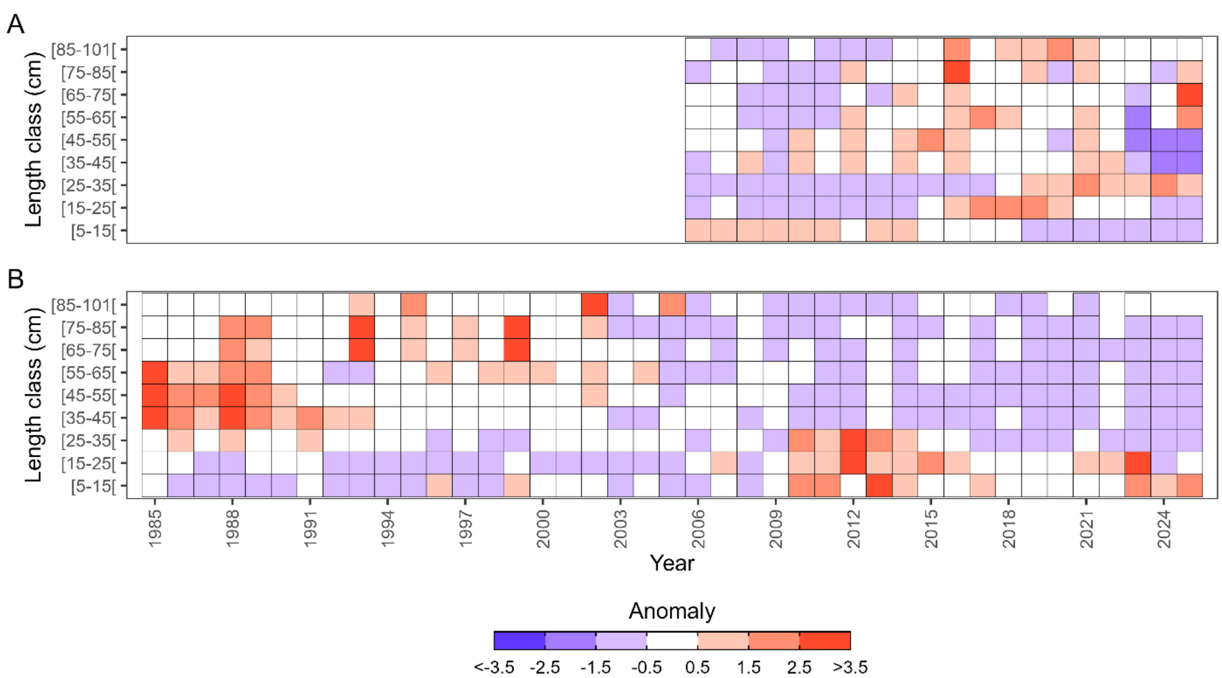

Figure 9. Annual anomalies in standardized abundance (number of individuals per tow) by 10 cm size classes for (A) nGSL and (B) sGSL. Colours convey both the direction and magnitude of deviations: white indicates near average values (0 and ± 0.5), red denotes above-average anomalies, and blue reflects below-average anomalies.

Fish condition

Body condition is an indicator of fish nutritional status, energy reserves, and general health (Harmelin-Vivien et al. 2012; Schloesser and Fabrizio 2017; Brosset et al. 2023). High condition positively affects growth, survival, and reproductive investment at the population level (Perretti et al. 2017). Changes in fish body condition reflect physiological stress or shifting productivity resulting from changes in food resource availability, environmental conditions, and/or the intensity of intraspecific and interspecific interactions (Latour et al. 2017; Haberle et al. 2023; Gernez et al. 2025).

Fish body condition is estimated using Le Cren's relative condition factor (Kn; Le Cren 1951) and calculated only for fish taxa captured in at least 10 RV tows per year between 2006 to 2025, which resulted in 25 fish species in the nGSL. For the sGSL, Kn was calculated for 14 fish taxa that were captured in at least 10 tows per year between 2006 to 2025, matching the criterion for the nGSL, and which were not missing from more than three consecutive survey years between 1985 to 2005. The length-weight relationship used for each taxon in the nGSL are included in Isabel et al. 2025b, while those for sGSL are in Appendix C of this document. Taxa were assigned to one of four habitat guilds modified from Fishbase (Frose and Pauly 2025) by DFO experts:

1. benthic,
2. demersal,
3. benthopelagic, or
4. pelagic (Appendix D).

The mean value across taxa in each habitat guild was used as the index.

In the nGSL, the overall pattern of body condition of fish species shows a decline after 2011 (Figure 10). The body condition of demersal fish species exhibit negative anomalies in recent years. These include Greenland Halibut, White Hake, and Longfin Hake (*Phycis chesteri*) which have shown multiple negative anomalies in recent years (Isabel et al. 2025b).

In the sGSL, patterns in body condition of fish appear fairly consistent across habitat guilds. The early time period is generally characterized by stronger positive anomalies, with the exception of a period of poor body condition across habitat guilds in the mid-1990s. Since 2005, body condition has been poorer overall in all habitat guilds with a slight improvement in pelagic fish in the last year. A similar improvement for pelagic fish in 2025 was observed for the nGSL.

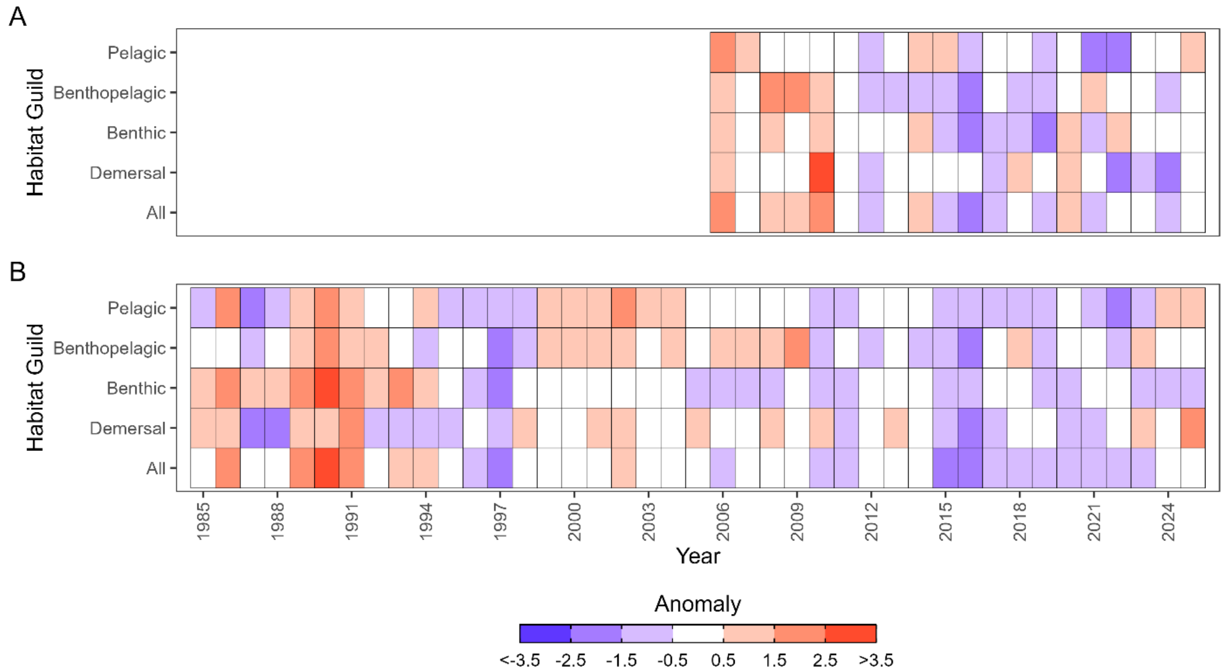

Figure 10. Annual anomalies in fish body condition for each habitat guild and combined (all) in nGSL (upper panel) and sGSL (bottom panel). Colours convey both the direction and magnitude of deviations: white indicates near average values (0 and ± 0.5), red denotes above-average anomalies, and blue reflects below-average anomalies.

Community composition indicator reporting

The combined community composition indicators consist of the temporal changes in the trophic guilds, size structure, and fish condition and the last two are presented as annual anomalies. Annual anomalies are calculated relative to the series means, which cover different periods of years for the nGSL (2006-2025) and sGSL surveys (1985-2025). The trophic guilds indicator is presented for all eight trophic guilds. The size structure indicator consists of the nine length classes from 5 cm to 100 cm. The fish condition indicator is presented for each habitat guild individually and combined.

The community composition indicators in the Ecosystem Summary will be updated following the annual RV surveys.

STATUS OF HARVESTED STOCKS AND FISHERY PRODUCTION

Two metrics are proposed to summarize the status and yield of fishery resources in the EGSL. The first summarizes individual stock status with respect to their reference points, which collectively across stocks, provides a summary of the health of the EGSL stocks. The second, summarizes fishery landings according to major species groups, groundfish, pelagic fish and crustaceans, thereby providing an indicator of a key goods (fishery yield) provided by the EGSL ecosystem. Although landings are an imperfect representation of surplus production, as they are influenced by management constraints and market demand, greater allowable taxa-specific catches would likely have been permitted and taken if stocks were assessed to sustainably support them. One notable exception is Redfish, for which economic constraints of various forms, and bycatch management measures, have resulted in landings well below the large allowable catches in 2024 and 2025 (60,000 tonnes (t) annually; DFO 2025e). In addition, while managed under the ASMS framework (Lang et al. 2025), which has been used to provide sustainable harvest levels for Atlantic seals and other marine mammal stocks in Canada, harp and grey seals are not included in this section, as catches are not reflective of surplus production for various reasons. Importantly, landings should not be interpreted as an indicator of fishing pressure, because, taken alone, they do not account for the biomass or productivity of the harvested stocks.

Other indicators relevant to this theme include ecosystem-level fisheries production and exploitation (e.g., Koen-Alonso et al. 2019), however these are not developed for the EGSL. For instance, an annual ecosystem-level exploitation rate, calculated as the sum of annual landings divided by the sum of macrofauna (fish and invertebrates) biomass from surveys, requires adjustments for size and species specific catchabilities to be accurate. Such catchability values are not available for the EGSL community.

Status of commercially harvested stocks

Draft national guidelines for the production of Ecosystem Summaries recommend including a summary of the status of commercially harvested stocks. Stock status is typically evaluated relative to established reference points. A commonly used approach is the Kobe plot, which plots stock status over time along two axes:

1. the state variable (abundance or biomass) relative to a biological reference point, and
2. exploitation rate (or fishing mortality) relative to its reference point.

Together, these axes define stocks as being overfished or underfished (state) and being subjected to overfishing or underfishing (rate). Status across numerous stocks can be summarized according to these four categories. Within the offshore EGSL, most commercial stocks have an adopted LRP, while few have other state (e.g., upper stock reference) or rate (fishing limit) reference points. This is largely because the LRP is set by DFO Science, whereas the other reference points generally result from longer consultative processes with stakeholders and rightsholders, and are established by DFO Fisheries and Harbour Management sector (DFO 2009b, 2023). Two offshore EGSL stock groups lacked LRPs at the time the present document was written, snow crab (*Chionoecetes opilio*) stocks in the Estuary and nGSL and Capelin, for which LRPs are expected in later in 2026 and sometime in before the end of 2028, respectively. These stocks will be included in the summary once LRPs are available.

In Canada’s Precautionary Approach framework, the LRP defines the boundary between the Critical and Cautious Zones and helps operationalize the objective of avoiding serious harm to fish stocks (DFO 2009b). Stocks at or below their LRPs are considered to be at an unacceptable risk of impaired productivity or reproductive capacity (Shelton and Rice 2002). Such serious harm may arise from changes in biological processes such as recruitment, growth, maturation, and survival, potentially reducing resilience and the capacity of stocks to rebuild (DFO 2023a). Reporting status exclusively with respect to LRPs makes sense for EGSL stocks given the high proportion that are near or below their LRP. Notably, rebuilding plans have been developed, or are currently being developed for numerous stocks below their LRP and therefore in the Critical Zone of DFO’s Precautionary Approach framework: Atlantic Cod (NAFO 4TVn and 3Pn4RS stocks), NAFO 4T White Hake, NAFO 4T American Plaice, NAFO 4T Winter Flounder, NAFO 4TVn spring spawning Atlantic Herring, Atlantic Mackerel, and three of the four Northern Shrimp stocks.

Stock state metrics and LRPs are derived from assessment models for both Cod stocks, NAFO 4T White Hake, NAFO 4T Yellowtail Flounder, NAFO 4T Winter Flounder (*Pseudopleuronectes americanus*), NAFO 4T American Plaice, NAFO 4RST Witch Flounder

(*Glyptocephalus cynoglossus*), NAFO 4RST Atlantic Halibut (*Hippoglossus hippoglossus*), the four Herring stocks, Atlantic Mackerel, and Northern Shrimp stocks. Survey-derived values are used for the remaining stocks: NAFO 4RST Greenland Halibut, and Redfish species (Table 4). NAFO 3Pn4RS Atlantic Cod are assessed on a four-year cycle, with interim year updates based on a survey derived proxy of spawning stock biomass (SSB) available for 1992 onwards. To ensure consistency in the metric being reported, model-derived values will be used for the first portion of the time series (1973-1991) and the proxy will be reported the years subsequent. NAFO 4TVn Cod are also assessed on a four-year cycle, with an interim year update at the halfway point. NAFO 4T White Hake, Plaice and the three flounder stocks are assessed on five-year cycles with an interim update for all five stocks at approximately the halfway point. The interim updates are based on the RV survey index relative to a rescaled LRP, the model-derived SSB values and the interim indicator will be updated for the stock status. In contrast, Mackerel and Herring stocks are assessed on a two-year cycle with no interim year updates. Stock status indicators for each stock will be updated to the most recent assessment or update value available for the Ecosystem Summary. A summary of the frequency of assessment updates, the nature of the stock state variable and the current years in the time series for the stocks included in the summary is presented in Table 4.

The stock status indicator for the Ecosystem Summary is the ratio of each stock's state variable to the associated LRP. A value of 1 indicates a stock at their LRP, while values < 1 indicate a stock in the Critical Zone. Under the provisional default reference points in DFO's Precautionary Approach framework (DFO 2009b), values > 2 may indicate a stock in the Healthy Zone, although this should not be overinterpreted in the absence of a formally adopted upper stock reference point. Time series for the ratio of each stock state relative to the LRP is presented using colour coding and for their respective duration (Figure 11).

Collectively, the results show that approximately half of assessed offshore stocks in the EGSL are in the Critical Zone (Figure 11). Many of these stocks are subject to rebuilding plans, all of which, except that for Mackerel (DFO 2024a), have concluded that rebuilding will not occur unless there are important improvements in productivity, including reduction in natural mortality (Benoît and Ouellette-Plante 2023; Turcotte and McDermid 2024; Turcotte et al. 2024, 2025). Among groundfish, stocks found in the deeper channels of NAFO 4RST generally have more favorable status, although Greenland Halibut have recently fallen below their LRP. In contrast, groundfish from the sGSL (NAFO 4T) and nGSL cod have been below their LRP for some time. Three Herring stocks are either at or increasing towards levels considered to be healthy, while Mackerel and spring spawning NAFO 4T Herring have been in the Critical Zone for over a decade. Elevated rates of natural mortality have been identified as a principal cause of a lack of rebuilding in sGSL groundfish, Herring and nGSL Cod (Swain and Benoît 2015; Turcotte et al. 2021b, 2025; Benoît and Ouellette-Plante 2023).

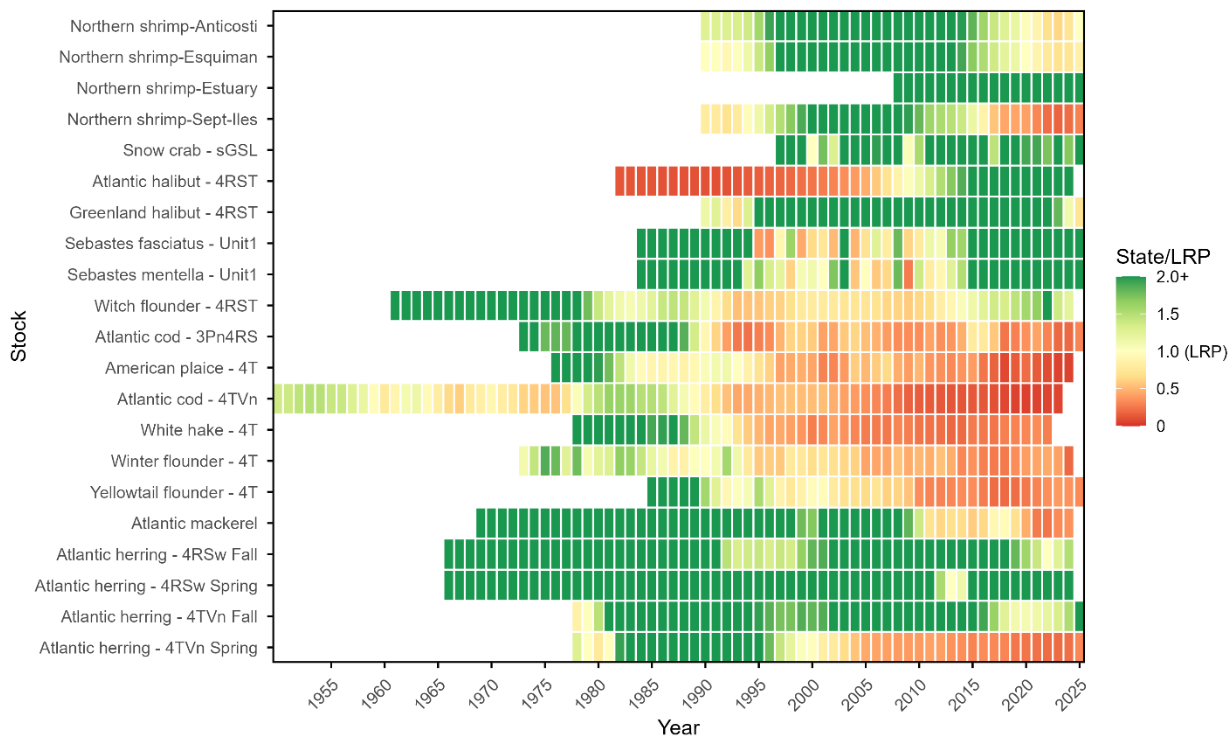

Figure 11. Stock state relative to the limit reference point (LRP) for mid and offshore stocks in the EGSL. Values below 1 (orange to red) indicate stocks below their LRP and in the critical zone of the Precautionary approach, while values greater than 1 (light to dark green) indicate stocks above their LRP. Note that stocks differ with respect to starting year for their time series and the most recent year available.

Fishery yield

Three major species groups comprise commercial fishery landings for mid and offshore species of the EGSL. While there are landings of shortfin squid in a number of years, these are very small compared to landings of other groups; there are no other fisheries targeting mollusks in mid and offshore waters in the EGSL. Atlantic Mackerel is retained for the summary because a majority of the exploited biomass occurs in the EGSL during the summer, and an important portion of removals have historically been taken there.

The data for landings were extracted from DFO’s Zonal Interchange File Format (ZIFF) database or from specific assessments (Herring, Capelin, Cod, Redfish in Unit 1 and Mackerel stocks). In addition to landings of traditional commercially-harvested species, the ZIFF database includes landings for non-traditional species for which landings may not be captured in the longer spanning NAFO database, thereby providing more complete accounting. For the two cod stocks, Unit 1 Redfish and sGSL herring, fisheries occur or have occurred on overwintering grounds just outside the EGSL, and this yield largely reflects production from in the EGSL. For sGSL herring, about 15% of landings were made on overwintering grounds in NAFO 4Vn in the early 1980s, dropping to zero since 1999 (Rolland et al. 2022). For nGSL cod, an average of 21.5% of landings have been on overwintering grounds in 3Pn since 1985 (Ouellette-Plante et al. 2025), while for sGSL cod the average (in NAFO 4Vn) was around 35% in the early 1970s, dropping to between 1 and 10% since 1994 (Swain et al. 2019b). To ensure proper accounting of these seasonal landings, values were taken from the respective assessments rather than ZIFF. More generally, in the case of the pelagic fishes, there were discrepancies between the total landings in the database and those from the assessments in earlier years, and consequently the latter were used.

A disadvantage of basing reporting on data from ZIFF is that data are only available as of 1985. This limits the historical period over which trends in landings are provided and could result in a so-called shifted baseline (sensu Pauly 1995) in our perception of fishery yields for the EGSL if longer term values are not considered in analyses of EGSL landings. Although the series could be extend back further if it were limited to main commercial species, landings data for 4TVn Herring, which comprise an important portion of pelagic fish landings, are only available as of 1978 because of uncertainties in stock composition in a large winter purse seine fishery in NAFO 4Vn in the early portion of the 1970s. For the purposes of supporting single-stock focused ecosystem approaches to fishery management, reporting landings since 1985 is likely sufficient. Future versions of the ecosystem summary, aiming to support broader ecosystem-based fishery management, may consider providing both a more complete 1985+ summary and a longer-spanning series for the main commercial species.

Landings summarized in Figure 12 reflect the well document collapse of groundfish in the early 1990s, and declines since the mid-2000s. Landings of pelagics, but more importantly of crustaceans, largely increased between 1985 and the late 1990s. Declines since around 2010 in crustacean and pelagic fish landings reflect, respectively, declines in Northern Shrimp, and declines in 4TVn (spring and fall) and 4RSw (fall) Herring, and Mackerel. Overall, there has been an order of magnitude decline in landings of EGSL stocks since the mid-1980s.

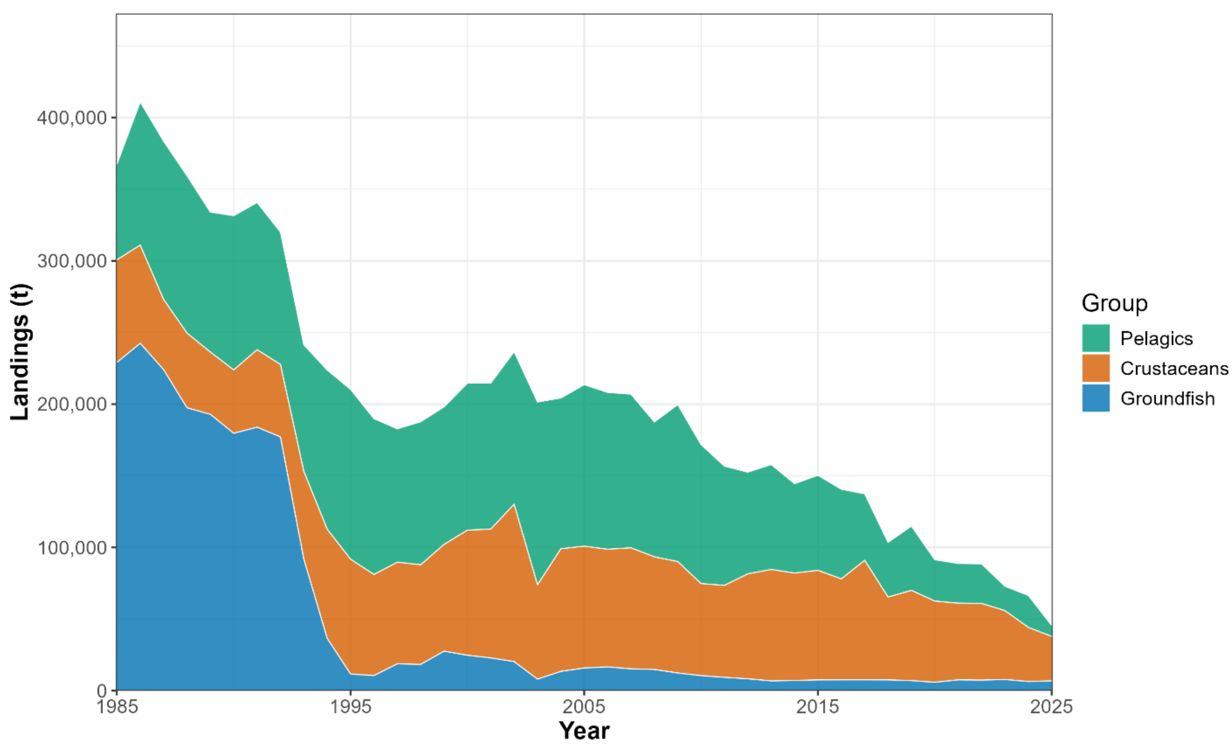

Figure 12. Total landings by major fishery resource group for mid and offshore commercial fisheries on EGSL stocks, 1985-2025. Note that values for 2023-2025 should be considered preliminary and are subject to change in subsequent updates to the landings data.

CLIMATE CHANGE AND OTHER CONSIDERATIONS

Previous state of the ocean reports and projections from regional climate models indicate that the recent oceanographic trends described in this document are expected to persist into the future (Long et al. 2016; Lavoie et al. 2019; 2020; Mei et al. 2024; Han et al. 2025). As air temperatures continue to rise and large-scale circulation patterns shift, the EGSL is projected to warm throughout the entire water column, with the strongest trends occurring in the deep waters of the northeastern EGSL (NEGSL; Figure 13). In combination with surface freshening, this warming will further strengthen stratification, influencing estuarine circulation, reducing deepwater ventilation and accelerating ongoing deoxygenation and acidification (Figure 14).

Rising air temperatures, especially in winter will reduce winter heat loss and sea ice cover, allowing heat to accumulate within the water column during the year. As a result, the CIL is projected to warm (Figure 13). Projections show that surface waters in the EGSL will not warm up uniformly but that the sGSL will warm up at a faster rate than the nGSL. In addition to atmospheric forcing, changes in the properties of water masses entering the Laurentian Channel through Cabot Strait and are expected to contribute to continued warming at depth (**Error! Reference source not found.**). Warmer conditions are projected to lengthen the stratified season and increase the frequency and duration of anomalously warm events.

Enhanced stratification will add to the broader decline in oxygen and pH driven by increasing atmospheric pCO_2 and circulation changes that favour a greater contribution of Gulf Stream Water (smaller oxygen concentrations) relative to Labrador Sea Water in the deep inflow to the Laurentian Channel (Lavoie et al. 2019, 2020). Changes in the properties of these source waters themselves will also reinforce these trends. In parallel, the EGSL is expected to experience a decline in its major nutrient inputs, both from upwelling at the head of the Laurentian Channel and from exchanges through the Cabot Strait and Strait of Belle Isle (Mei et al. 2024). The riverine nutrient input is projected to increase due to the increase in runoff (Mei et al. 2024) but will not counteract the loss mentioned above. This reduction in nutrient supply is projected to lead to lower primary and secondary production, with cascading impacts throughout the food web.

The Gulf of St. Lawrence numerical model results (Lavoie et al. 2020, Mei et al. 2024) have been used to assess future changes in harmful algae blooms (Boivin-Rioux et al. 2022), copepod biomasses (Lehoux et al. 2024), habitat of the Northern Shrimp (Shink et al. In prep.[2]), Eastern Oyster (*Crassostrea virginica*) settlement (Cunningham et al. In press.), and impact of ocean acidification on the survival of the American Lobster stage V and Blue Mussel (*Mytilus edulis*; Lavoie et al. In prep.[1]). Lehoux et al. (2024) combined a Species Distribution Models (SDMs) and regional climate ocean simulations based on the Representative Concentration Pathway 8.5 scenario (Lavoie et al. 2020) to project interdecadal abundance and individual body weight of *Calanus* species in the EGSL. Warming temperatures are detrimental to *C. hyperboreus*, that display a 40% decrease in biomass between the 2000-2009 and 2080-2089 periods. On the other hand, the environmental conditions become more favorable for the smaller *C. finmarchicus*, which displays an increase in biomass. The end result is a 25% decrease in total *Calanus* biomass over the same period. Using the same projections (Lavoie et al. 2020, Mei et al. 2024), Shink et al. (In prep.[2]) showed a substantial decrease in the favorable habitat of the northern shrimp in the EGSL, particularly in the Lower St. Lawrence Estuary and the NW GSL region where deoxygenation and acidification are more important than

[2] Shink, R., Lavoie, D., Bourdages, H., Roux, M. and Isabel, L. In preparation. Prediction of the Suitable Habitat of the Northern Shrimp, *Pandalus borealis*, in the Estuary and Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc.

in the NEGSL, and with warming leads to a cumulative stress that leads to the upward displacement of the shrimp habitat. The survival of the stage V of the American Lobster will also be threatened with the continued acidification of the EGSL water (Lavoie et al. In prep.[1]). Ocean acidification does not threaten the Blue Mussel at the moment but conditions will deteriorate by 2080 in some areas of the EGSL (Lavoie et al. In prep.[1]).

Overall, the continued decline in dissolved oxygen will lead to habitat loss, especially in the deep Lower St. Lawrence Estuary and NW GSL, while the continued acidification will become detrimental for some species, depending on the spatial and horizontal location of their habitat (which can also vary with life stages). The biomass of large bodied zooplankton (generally associated with cold water) will also decline, while species associated with warmer water will increase. However, the regional model also predict a general decline in primary production and phenological changes that will cascade down the food chain.

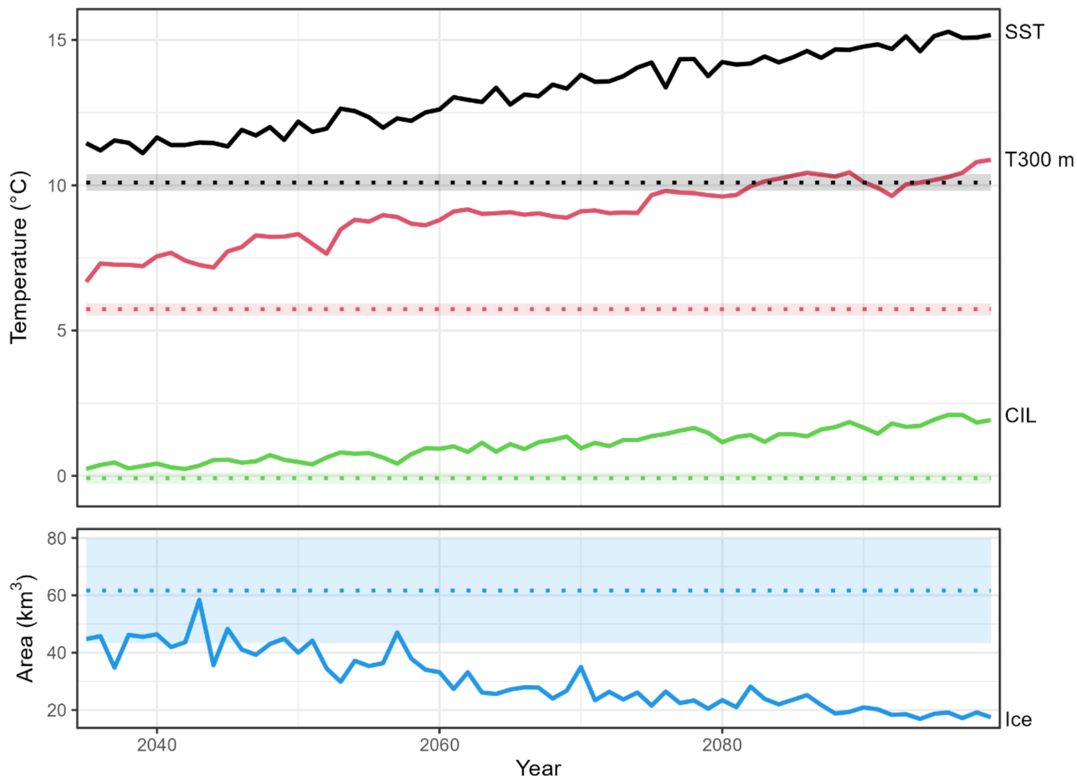

Figure 13. Projected changes in physical environment (water temperatures and sea ice volume) in the EGSL for 2035 to 2100 rescaled to the empirical climatological means of 1991–2020 (see Figure 2). Top panel: Sea surface temperature (SST; solid black line), layer-averaged temperatures at 300 m (T300 m; solid red line), and cold intermediate layer (CIL; solid green line) minimum temperature. The SST was averaged over the Gulf excluding the Estuary (May–November). The CIL index was based on August averages in the EGSL. Bottom panel: Seasonal maximum ice volume (Ice; solid blue line) in the EGSL. For both panels, the dotted horizontal lines indicate the corresponding climatological means for 1991–2020, while the shaded areas indicate ± ½ SD around the climatological means. All projections were derived from an ensemble of four downscaled (CCSM4, MPI-ESM-MR and CanESM2) climate simulations under the RCP 8.5 scenario.

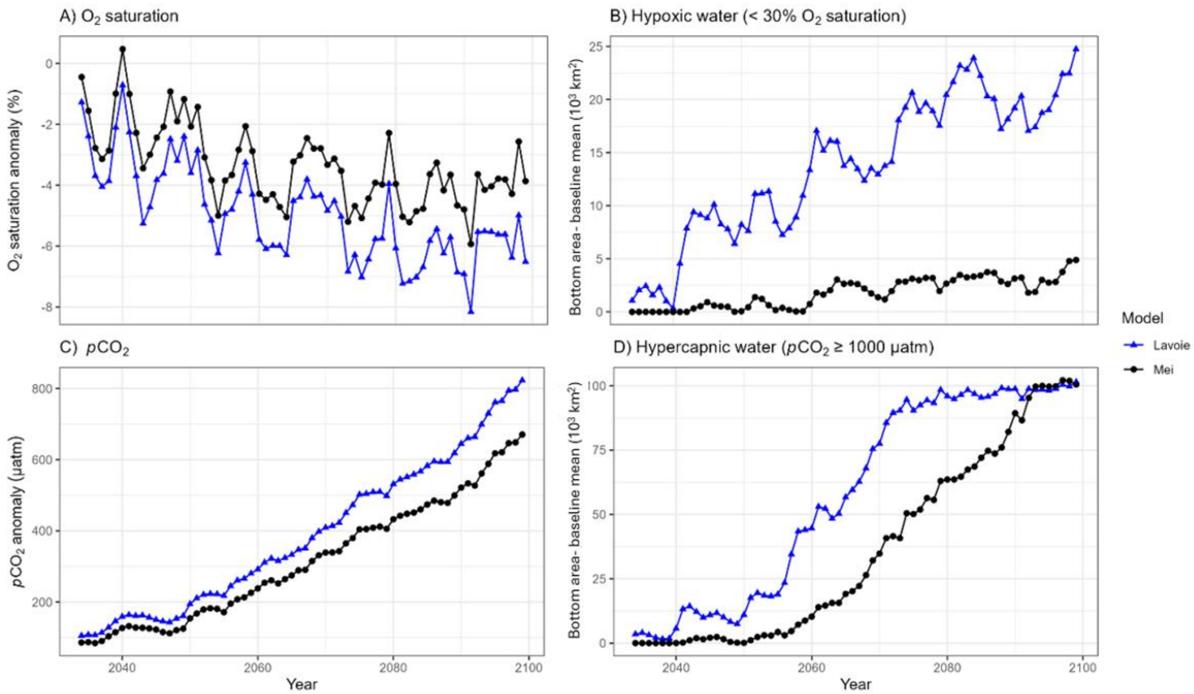

Figure 14. Difference between mean oxygen saturations (A) and mean partial pressure of CO_2 (pCO_2, C) in the Estuary and Gulf of St. Lawrence below 200 m in future years (2035 to 2100) and the 2005 to 2025 climatology simulated with the regional climate model of the EGSL using downscaled forcing from MPI-EMS-LR using the RCP 8.5 scenario for two different simulations (Lavoie et al. 2020 and Mei et al. 2024). The right panels represent the difference between the climatological and future area of hypoxic water (< 30% oxygen saturation); B) and for hypercapnic water (pCO_2 ≥ 1000 µatm); D) for EGSL regions deeper than 100 m.

Community temperature index

Climate change is an emerging pressure causing increased variability and directional changes in oceanographic conditions affecting the structure and functions of marine communities. The community temperature index (CTI) is a measure of the average thermal preference of species within a community (Devictor et al. 2008). The indicator is used to monitor temporal shifts in community structure in response to temperature changes in ecosystems (Devictor et al. 2012; Burrows et al. 2020; Chust et al. 2024). An increase in the CTI corresponds to an increase in the prevalence of taxa associated with warmer water condition in the surveyed community, while a decrease in CTI reflects an increase in taxa associated with colder conditions.

The CTI indicator is based on data collected during the annual RV surveys as described in the Community Composition section. A CTI was derived using catch biomass and bottom water temperature data collected at each trawl station within core strata (all strata in sGSL) over the survey series. Core strata in the nGSL were used to ensure consistency in the sampling of different thermal habitats by the survey over time. The CTI was calculated as the sum product of the median temperature value associated with 50% of cumulative catches of each taxon in the survey series (nGLS: 2006-2025 and sGSL: 1985-2025), and its annual contribution to total survey biomass (Isabel et al. 2025b). The nGSL CTI encompassed a total of 48 fish and 88 invertebrate taxa, whereas the sGSL CTI consisted of 60 fish and 105 invertebrate taxa.

The CTI showed a progressive, positive trend over time in both the nGSL and sGSL, indicating an increase in the relative importance of taxa associated with warmer water conditions in the surveyed community (Figure 15). The nGSL CTI was relatively stable at or above 4.8 °C since 2016, and peaked at 5.0 °C in 2024. The sGSL CTI was relatively stable from 1987 through 2001, with a mean of 7.5 °C, then increased to a mean of 8.8 °C from 2015 through 2025. The sGSL CTI peaked at 9.8 °C in 2023, and leveled at 8.6 °C for 2024 and 2025. The sGSL is warmer and more variable than the nGSL because it is dominated by shallow waters (the Magdalen Shallows) that respond rapidly to atmospheric forcing, while the nGSL is dominated by deeper basins and channels that buffer temperature change. As a result, the sGSL shows stronger interannual variability, whereas the nGSL exhibits cooler and more stable conditions.

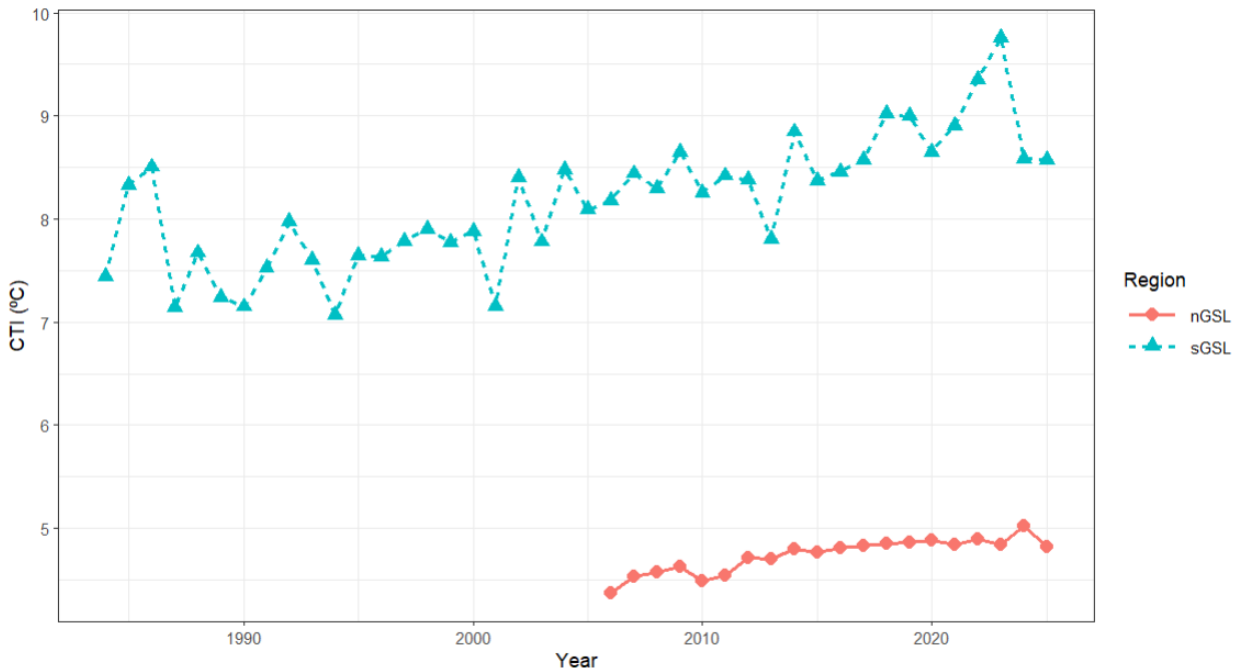

Figure 15. Community temperature index (CTI), based on thermal preference and the annual relative biomass contribution of taxa sampled in the nGSL survey (circles and solid line) and sGSL survey (triangles and dashed line).

CONCLUSION

This research document presents the careful thought process and considerations applied in selecting a parsimonious, yet comprehensive suite of indicators for an Ecosystem Summary designed to support the further application of EAFM in the EGSL both leading up to and during the March 30, 2026 CSAS peer-revies. The selected indicators collectively capture key physical, biological, and fishery-related ecosystem attributes, and are presented in a manner intended to facilitate interpretation and use by assessment biologists, managers, and other users.

An important outcome of this work is the development of a framework, using Ecosystem Summary for EAFM table of contents, that can be implemented on an annual basis with minimal additional demands on existing resources. The use of existing indicators and the high degree of automation incorporated into the production of the Ecosystem Summary promotes consistency across years and enhances transparency and repeatability, supporting long-term utility as a core EAFM product.

While efforts were deployed to select an optimal suite of indicators, it is acknowledged that the Ecosystem Summary for the EGSL will evolve over time. Improvements in monitoring programs, advances in ecosystem research, and emerging environmental, ecological, or anthropogenic pressures are all expected to motivate refinement of existing indicators and consideration of additional ones. Input from key users including assessment scientists, fishery managers, stakeholders, and rightsholders will also continue to motivate inclusion of additional content. At the same time recognizing that the more detailed and spatially explicit information needed for specific EGSL stocks will remain available through complementary products such as the *gslea* package and AZMP annual reports. Development of ecosystem indicators, or a stand-alone Ecosystem Summary, for the EGSL coastal zone remains a priority.

Several potential refinements to current indicators suite are anticipated in the near-future and were mentioned in the text. These include improved characterization of apex predators in the EGSL through spatial-seasonal modelling of grey seal distribution, and the use of pupping distributions for harp seals which will help refine estimates of the presence in the EGSL of these two wider ranging apex predators. This will help better specify potential predation risks. In addition, there are ongoing efforts to develop a reliable indicator for Capelin abundance, facilitating its inclusion in the forage species indicator, as well as efforts to develop LRPs for the stocks not presently included in the stock status plot: Capelin and nGSL snow crab.

Justifications for the exclusion of specific indicators or indicator classes were presented in this document. These included habitat indicators and a broader suite of fishery indicators. In addition to these, we note in the following paragraphs three indicator classes that might be notable by their omission, acknowledging that this list is not exhaustive.

First, are indicators associated with primary production. The AZMP program monitors aspects of phytoplankton dynamics such as chlorophyll biomass and community composition (Blais et al. 2025). Recent analysis of remotely-sensed chlorophyll biomass has revealed important spatial patterns and a strong positive temporal trend for the EGSL (Laliberté and Larouche 2023). Key to linking these results with EGSL fishery resources as part of EAFM is accounting for production and grazing to better understand primary production and not just chlorophyll biomass.

Second, aspects of plankton phenology and community composition have been linked to model-estimated recruitment for certain EGSL pelagic fish stocks (Brosset et al. 2019; Turcotte 2022; Burbank et al. 2023). While these relationships may remain important for specific stocks, they have not yet been consistently synthesized across stocks into a unified set of drivers that would support the inclusion in a general Ecosystem Summary. In addition, inferred environmental-recruitment relationships can be sensitive to model choices, which may complicate cross-stock comparisons and the identification of robust and common patterns (Brooks and Deroba 2015; Robertson and Regular 2026).

Third, changes in life-history of well monitored species, notably size-at-age and maturation, are known to reflect plastic, and sometimes genetic, responses to environmental, ecological, and anthropogenic drivers (e.g., Jørgensen et al. 2007; Crozier and Hutchings 2014). However, ascribing potential drivers is not straightforward and requires detailed analysis (e.g., for the EGSL: Swain et al. 2007; Swain 2010; Beaudry-Sylvestre et al. 2024). The benefits of including life-history indicators, for which drivers may differ between species, are questionable and should remain outside the Ecosystem Summary for EAFM.

Overall, this document provides a robust and transparent foundation for an EGSL Ecosystem Summary that is fit for purpose within an EAFM context. The framework is intended to support integrated assessment and decision-making while remaining flexible to incorporate future scientific advances and management needs.

ACKNOWLEDGEMENTS

The authors thank the various stock assessment leads for taking the time to validate Table 1 of this document and for providing inputs to the stock status indicator. We also thank Jean-François Rail for providing the abundance data for northern gannets and wish him a happy retirement. Finally, we thank Jon Fisher, Karen Cogliati, and Hannah Munro for their review of this work. Olivier Riche contributed key elements leading to the production of the figures on projected changes in dissolved oxygen and hypercapnia.

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TABLES

Table 1. Summary of relevant ecosystem variables incorporated or mentioned in the latest CSAS advisory reports for fish, invertebrate and marine mammal stocks in the Estuary and Gulf of St. Lawrence (EGSL). The information in the table is based on Science Advisory Reports and Science Responses since 2021 (to 2025-10-10). Note that coastal invertebrates are presented separately from invertebrate stocks in the mid- and offshore.

Species	Stock(s)	Latest advisory report; key references for EVs*	Relevant EVs (and their purported effect)
Pelagic fish			
Atlantic Herring	4TVn (spring)	DFO 2024b; Benoît and Rail, 2016; Burbank et al. 2023; Turcotte 2022; Turcotte and McDermid 2024.	Zooplankton abundance, composition and phenology, SST (recruitment) Predator abundance – various (natural mortality) Temperature (size-at-age, fecundity, availability to the fall acoustic survey)
	4TVn (fall)	DFO 2024c; Benoît and Rail 2016; Burbank et al. 2023	Zooplankton abundance, composition and phenology (recruitment) Predator abundance – various (natural mortality) Temperature (size-at-age, fecundity, availability to the fall acoustic survey)
	4RSw (spring and fall)	DFO 2024d; DFO 2022b	Zooplankton abundance, composition and phenology (condition)
	4S	DFO 2025d	Temperature Zooplankton dynamics (recruitment, condition; impact on productivity uncertain)

Species	Stock(s)	Latest advisory report; key references for EVs*	Relevant EVs (and their purported effect)
Atlantic Mackerel	Northern contingent	DFO 2025e Plourde et al. 2015; Brosset et al. 2020; Van Beveren et al. 2024	Predation – various predators (natural mortality) Match/mismatch - larvae and zooplankton prey (recruitment)
Capelin	4RST	DFO 2024e	Temperature (habitat availability; impacts on productivity uncertain)
Diadromous fish			
Alewife and Blueback Herring	Gulf region	DFO 2022c; Breau and Gibson 2024	River water level (effect on catch-per-unit-effort) River water temperature (effect on catch)
Atlantic Salmon	SGSL	DFO 2025f	Marine productivity in the Atlantic (smolt survival) Air and river water temperature (survival; productivity) Predation in river – small mouth bass
Striped Bass	SGSL	DFO 2025g; Chaput and Douglas 2022	Temperature (availability of overwintering habitat)
Atlantic Silverside	SGSL	DFO 2024f	NIL
Groundfish			
Atlantic Cod	4TVn	DFO 2024g; DFO 2019 Swain et al. 2015; Turcotte et al. 2024	Predation – grey seals (elevated natural mortality, distribution shift; size-at-age)

Species	Stock(s)	Latest advisory report; key references for EVs*	Relevant EVs (and their purported effect)
	3Pn4RS	DFO 2025h; DFO 2023b	Prey availability – capelin and shrimp (condition → mortality). Bottom-water temperature; hypoxia (distribution and productivity) Predation - seals (uncertain)
White Hake	4T	DFO 2024h; Benoît et al. 2011; Swain et al. 2015; Turcotte et al. 2025	Predation – grey seals (elevated natural mortality, distribution shift; size-at-age)
Atlantic Halibut	4RST	DFO 2025i	Bottom-water temperature (warming expected to be beneficial)
Greenland Halibut	4RST	DFO 2025j; Dupont-Prinet et al. 2013b; Ghinter et al. 2021	Bottom-water temperature; hypoxia Prey availability – capelin and shrimp (growth, mortality)
Witch Flounder	4RST	DFO 2022d	NIL
Redfish	Units 1&2	DFO 2025k; Guitard et al. 2025	Bottom-water temperature; hypoxia Prey availability (growth, development; anticipated: mortality, recruitment)
American Plaice Yellowtail Flounder Winter Flounder	4T	DFO 2025l; Swain and Benoît 2015	Predation – grey seals (natural mortality)

Species	Stock(s)	Latest advisory report; key references for EVs*	Relevant EVs (and their purported effect)
Decapods			
Snow crab	SGSL	DFO 2025m	Bottom water temperature; extent of the CIL [temperatures between -1 and 3°C] (distribution, population dynamics)
	ENGSL	DFO 2025n; Burmeister and Sainte-Marie 2010; Émond et al. 2020; Mullowney and Baker 2021	Bottom water temperature; thickness and temperature of the CIL; winter ice cover (distribution, productivity, growth and size-at-terminal moult) SST in summer/spring (larval development and survival rates)
Northern Shrimp	EGSL	DFO 2025o; Dupont-Prinet et al. 2013a; Guscelli et al. 2023	Predation – redfish (mortality) Bottom-water temperature; hypoxia (mortality; overall productivity)
Coastal invertebrates			
American lobster	SGSL	DFO 2023c	Prey availability – rock crab, lobster, cunner Predator abundance – various Bottom temperature (habitat index)
	QC North shore	DFO 2024i	Prey availability – rock crab Temperature
	Gaspé	DFO 2024j	Prey availability – rock crab Temperature

Species	Stock(s)	Latest advisory report; key references for EVs*	Relevant EVs (and their purported effect)
	IDM	DFO 2024k	Prey availability – rock crab Temperature
Atlantic rock crab	SGSL	DFO 2025p	Predator abundance – lobster (predation mortality) Bottom-water temperature (impacts uncertain)
Sea scallop	QC coastal	DFO 2023d	Water temperature Acidification Predation and parasites – barnacle and shell-boring worms (impacts uncertain)
	IDM	DFO 2025q	Temperature ~ 30 m depth Acidification (impacts uncertain)
	SGSL (4T)	DFO 2024l; Dickie 1958	Vulnerable to temperatures exceeding 21 °C (mortality) Predation by rock crab Acidification (impacts uncertain)
Sea cucumber	QC inshore	DFO 2025r	Predation – various predators Acidification Water temperature (reduced spawning) (overall, impacts on stock uncertain)

Species	Stock(s)	Latest advisory report; key references for EVs*	Relevant EVs (and their purported effect)
Whelks	QC coastal	DFO 2025s	Bottom water temperature Acidification Predator abundance - lobster, rock crab and sea stars (poorly known, possible effects on growth, development and distribution)
Green sea urchin	ENGSL	DFO 2025t	Bottom water temperature Predation - lobster and rock crab (impacts poorly known; EVs not quantified at correct scale) Macroalgae abundance and distribution affected by ocean warming and acidification (impacts on larval and juvenile growth and survival)
Softshell clam	QC coastal	DFO 2023e	Shoreline erosion; storms; acidification Predation – rock crab and sea stars (impacts poorly understood)
Arctic surfclam	QC coastal	DFO 2024m	Temperature Acidification (effect of ecosystem changes poorly understood)
Atlantic surfclam	IDM	DFO 2024n	Warming expected to be beneficial, but not quantified (extension of range, increased stock productivity)
Marine mammals			

Species	Stock(s)	Latest advisory report; key references for EVs*	Relevant EVs (and their purported effect)
Harp seal	NW Atlantic	DFO 2025u; Tinker et al. 2023.	Sea ice anomalies (pup survival; pupping and whelping habitat) Newfoundland and Labrador climate index (Cyr and Galbraith 2021) (negative relationship with pregnancy rates and pup survival)
Harbour seal	NW Atlantic	DFO 2024o	Competition – grey seals Predation – sharks, other predators (effects poorly understood)
Grey seal	NW Atlantic	DFO 2022e	Sea ice (pup survival in EGSL)
Beluga	St. Lawrence Estuary	DFO 2023f	Water temperature (calf mortality)

Notes: Acronyms: CIL- Cold intermediate layer; SST – sea surface temperature; ENGSL – Estuary and Northern Gulf of St. Lawrence; SGSL – Southern Gulf of St. Lawrence; IDM- Îles-de-la-Madeleine.
*Key references are those that specifically support the advice with respect to the effect of EVs, not an exhaustive list of references on the ecology/biology of the stock or of possible impacts of EVs.
Note on relevant EVs: NIL indicates EVs not mentioned; unknown indicates assessment reported lack of knowledge.

Table 2. Details for environmental variables identified in Table 1 as affecting one or more stocks in the EGSL. The comments column includes considerations for the choice of indicator to be reported.

Environmental variable	**Location**	**Properties / details**	**Affected stocks**	**Availability**	**Comment**
Ocean temperature	Sea surface, EGSL	-	Snow crab recruits Herring (4TVn, 4RsW, 4S)	AZMP annual reporting	SST with air proxy; May to November. Alternatively, or additionally, use EGSL shallow anomalies[1].
	Cold-intermediate layer (CIL), EGSL	Extent, temperature, thickness	Snow crab Capelin	AZMP annual reporting	CIL temperature index, CIL volume and CIL area are highly correlated. A single metric could be reported. Alternatively use EGSL intermediate depth anomalies[1].
	Bottom – specific coastal areas	-	Various coastal invertebrates; American lobster	AZMP annual reporting	Site specific and thus unsuitable for an overview document.
	Bottom – below CIL, EGSL	-	3Pn4RS Atlantic Cod 4RST Greenland Halibut Atlantic Halibut Redfish Northern Shrimp	AZMP annual reporting	Temperatures at 150, 200 and 300 m highly correlated, Values at a single depth could be reported. Alternatively use EGSL deep anomalies[1].
	Bottom – estuaries	-	Striped Bass	Variable	Likely site specific and thus unsuitable for an overview document.

Environmental variable	Location	Properties / details	Affected stocks	Availability	Comment
Sea ice	-	Duration, volume	Snow crab (ENGSL) Harp seal Grey seal Capelin	AZMP annual reporting	Ice duration, first and last occurrence, volume and area are highly correlated. Report just one. While the EGSL intermediate depth anomalies[1] index includes ice volume, it is likely appropriate to report a specific ice indicator given the specific ice association for some species.
Climate Index (NL)	NL Shelf and neighboring areas	-	Harp seal	AZMP NL region annual reporting	This index is reported by DFO elsewhere and is possibly more/most relevant for harp seals on the Newfoundland and Labrador shelves. It would not be included in the EGSL ecosystem summary.

Environmental variable	Location	Properties / details	Affected stocks	Availability	Comment
Hypoxia	EGSL	-	3Pn4RS Atlantic Cod 4RST Greenland Halibut Redfish Northern Shrimp	AZMP annual reporting	Reporting options include oxygen saturation at a given depth, either as an area average and/or for the Estuary only as indicator for ‘extreme’ conditions. Alternatively the % area or volume considered hypoxic could provide a more direct and interpretable indicator.
Acidification	EGSL	-	Indicated in advice for various coastal invertebrates, although likely also relevant for non-coastal invertebrates and other taxa.	AZMP regional and zonal annual reporting	pCO_2 is likely to be the most relevant metric to report, notably because it can be linked to key thresholds related to organismal biology. Reporting with respect to a known biological threshold could provide a more direct and interpretable indicator.

Environmental variable	Location	Properties / details	Affected stocks	Availability	Comment
Phytoplankton	EGSL	Bloom phenology	Various coastal bivalves Capelin	-	Although phytoplankton dynamics were linked in general terms to stock biology for some taxa, specific links in the EGSL have not been proposed. In their absence, an indicator for phytoplankton will not be presented in the Ecosystem summary at this time.
Zooplankton	EGSL	Abundance, composition, phenology	Herring (4TVn, 4RSw, 4S) Mackerel	-	Possible indicators include those for warm vs. cold copepods, and large vs. small calanoids, and possibly phenology-related indicators. However, these may not be straightforward to interpret. Total biomass would be a good indicator of overall changes in secondary production.
River water level, river temperature	Various in EGSL hydrographic basin	-	Alewife, Blueback Herring Atlantic Salmon	River-specific monitoring	Site and freshwater specific; beyond the scope of the EGSL ecosystem summary.

Environmental variable	Location	Properties / details	Affected stocks	Availability	Comment
Prey	EGSL	Capelin	3Pn4RS Atlantic Cod 4RST Greenland Halibut Redfish Harp seal	Stock assessment	Capelin abundance indices are presently not sufficiently reliable to serve as an indicator of prey availability for these predators.
	EGSL	Shrimp	3Pn4RS Atlantic Cod 4RST Greenland Halibut Redfish	Stock assessment	The total assessed biomass of the 4 EGSL shrimp stocks from their assessments can be presented as an indicator of prey abundance for these predators.
	GSL	Herring and Mackerel	Numerous groundfish species in the sGSL and top predators (e.g., Atlantic Bluefin Tuna, Grey seal)	Stock assessment	Although these two prey species were not explicitly mentioned in Science advisory reports for their predators in the past 5 years, they are known to be important prey for many predators and should be included in reporting.

Environmental variable	Location	Properties / details	Affected stocks	Availability	Comment
	EGSL – specific coastal areas	Rock crab, cunner, other lobster	Lobster	Northumberland Strait survey, bio-collector surveys.	Some prey indices are available for some coastal areas (e.g., Northumberland Strait). Nonetheless, prey indicators for coastal species would be presented in an eventual ecosystem summary for coastal areas, not the current summary.
Predators (with available time series)[2]	EGSL	Grey seal	Atlantic Cod (4TVn, 3Pn4RS) White Hake American Plaice Yellowtail Flounder Winter Flounder Mackerel Herring (4TVn)	Stock assessment, ideally/eventually with adjustment for proportion in EGSL	-
	EGSL	Harp seal	Possible: Cod (3Pn4RS)	Stock assessment, ideally with adjustment for proportion breeding in EGSL	-
	EGSL	Atlantic Bluefin Tuna	Mackerel Herring (4TVn)	Stock assessment and Akia et al. 2025[3]	-
	GSL colonies	Northern gannets	Mackerel Herring (4TVn)	ECCC (Canadian Wildlife Service)	-

Environmental variable	Location	Properties / details	Affected stocks	Availability	Comment
	EGSL	Piscivorous groundfish (general)	Mackerel Herring (4TVn)	RV survey reporting	-
	EGSL (Unit 1)	Redfish	Shrimp	Stock assessment	Too specific to shrimp for the Ecosystem summary.
	EGSL, specific coastal areas	Lobster	Rock crab, urchins, whelks, soft-shelled clams, surfclams	Stock assessment	Would be presented in an eventual ecosystem summary for coastal areas.
	EGSL, specific coastal areas	Rock crab	Scallops (4T), urchins, whelks, soft-shelled clams, surfclams	-	Would be presented in an eventual ecosystem summary for coastal areas, not the current summary.

[1]Composite climate indices from Galbraith et al. 2022.
[2]Other predators identified in Table 1 but without time series or only local series: sea stars (predation on whelks, soft-shelled clams).
[3]Akia, A.V., Hanke, A., and Duplisea, D. 2025. Size-specific abundance dynamics of Atlantic Bluefin Tuna in Canadian waters. Fish. Res. 291: 107567.

*Table 3. Other key indicators of ecosystem state and trends relevant to fish stocks and fisheries identified in draft national EAFM guidelines, with reflections for the EGSL that guided indicator selection. **NOTE**: the indicators should be easily explainable/interpretable with little explanation to fit with the short/succinct format of the Ecosystem Summary.*

Class	Detailed considerations	Preliminary reflections
Food web components; trophic state indicators	Forage species indicators	-Abundance indices for key prey identified in Tables 1 and 2 could be presented. -Forage species index based on RV survey is likely to be too variable. -Options include present standardized individual indices or a single index based on anomalies for well monitored forage species: Shrimp, Herring (4TVn and 4RSw) and Mackerel.
	Food consumption, predation mortality, time series of diets	-Diet and consumption time series are available for few species, and may be too variable to constitute useful indicators. -Indices of fish condition (e.g., Isabel et al. 2025), presented as stacked anomalies, would provide an indicator of nutritional/physiological stress.
Biodiversity indicators	Composite/biodiversity indicators of response to fishing or other pressure/stressor driver	-Survey catch rates by trophic guild (Isabel et al. 2025); easily explained and interpreted. -Survey catch rate anomalies by size class (Isabel et al. 2025); more easily explained and interpreted than size spectrum slope, for example.
Habitat indicators and considerations	Biogenic habitat (coral/sponge communities; eel grass beds)	-Existing data are not presently adequate to produce indicators that accurately represent state and trends for these habitat.

Class	Detailed considerations	Preliminary reflections
	Physical habitat, other than oceanographic	-Same consideration as above for biogenic habitat.
Aggregated fisheries metrics	Examples include Kobe plot of composite stock statuses, and total landings to biomass ratio	-Few EGSL stocks have a the full suite of reference points and/or model required for a Kobe plot; also Kobe plot biomass axes are generally with respect to BMSY, whereas for many EGSL stocks status with respect to the LRP is more relevant. A plot summarizing biomass/LRP across stocks is a good option. -Reporting of landings with respect to PA zones and for stocks without PA could be considered for the future. While a (growing) number of stocks have an LRP, very few have other accepted reference points, making consistent reporting more laborious. -Reporting landings trends by groups (e.g., pelagic, demersal and benthic (split crustacean and mollusk) would provide an indicator of ecological goods. -The team questioned the relevance of the total landings to biomass ratio given that biomass is not accurately estimated due to species/size differences in catchability.
Perspectives on climate change impacts	Projections; risk index; anticipated changes in species distribution, life history, etc.	-Community thermal index (Isabel et al. 2025) provides an integrated indicator of community response to ocean temperature change. -Perspectives on possible future climate impacts will be provided by summarizing projections of various oceanographic parameters under climate change scenarios.

Class	Detailed considerations	Preliminary reflections
Other considerations	Aquatic invasive species (AIS) with projected impact on fishery resources	-The group is not aware of such a case for the mid- and offshore. Green crab in the nearshore might be relevant and could be reported in an eventually coastal ecosystem summary.
Emerging issues	-	-Include a brief section, if relevant, on emerging issues not covered by the other considerations.

Table 4. Stock-specific details for the status indicator reported for individual stocks.

Stock	Frequency of update	Stock state variable	Area	Time series
Pelagic fish				
Atlantic Mackerel	2 years	Model SSB	GSL	1969-2024
Atlantic Herring - 4RSw Fall	2 years	Model SSB	nGSL	1966-2024
Atlantic Herring - 4RSw Spring	2 years	Model SSB	nGSL	1966-2024
Atlantic Herring - 4TVn Fall	2 years	Model SSB	sGSL	1978-2025
Atlantic Herring - 4TVn Spring	2 years	Model SSB	sGSL	1978-2025
Groundfish				
Sebastes fasciatus - Unit1	Annual	Survey SSB	GSL	1984-2025
Sebastes mentella - Unit1	Annual	Survey SSB	GSL	1984-2025
Atlantic Cod - 3Pn4RS	Annual	Model SSB and proxy	nGSL	1973-2025
Atlantic Cod - 4TVn	2 years	Model SSB and proxy	sGSL	1950-2023
White Hake – 4T	3 years	Model SSB and proxy	sGSL	1978-2022
Atlantic Halibut – 4RST	2 years	Model SSB	GSL	1982-2024
American Plaice - 4T	3 years	Biomass 30+ and proxy	sGSL	1976-2015
Greenland Halibut – 4RST	Annual	Biomass 40+	GSL	1990-2025
Winter Flounder - 4T	3 years	Biomass 25+ and proxy	sGSL	1973-2022
Witch Flounder - 4RST	3 years	Model SSB and proxy	GSL	1961-2021
Yellowtail Flounder – 4T	3 years	Model Biomass and proxy	sGSL	1985-2025
Decapods				
Northern Shrimp-Anticosti	Annual	B/B_{MSY}	nGSL	1990-2025
Northern Shrimp-Esquiman	Annual	B/B_{MSY}	nGSL	1990-2025
Northern Shrimp-Estuary	Annual	B/B_{MSY}	nGSL	2008-2025
Northern Shrimp-Sept-Iles	Annual	B/B_{MSY}	nGSL	1990-2025
Snow crab – sGSL	Annual	Residual Biomass	sGSL	1997-2025

APPENDIX A: ECOSYSTEM SUMMARY FOR ECOSYSTEM APPROACH TO FISHERIES MANAGENT FOR OFFSHORE WATERS OF THE ESTUARY AND GULF OF ST. LAWRENCE TO 2025

SUMMARY OF KEY SIGNALS

Over the past decade and more, parts of the Estuary and Gulf of St. Lawrence (EGSL) have experienced marked warming, acidification and increased hypercapnia and hypoxia, notably in deeper waters in the channels of the EGSL. Despite conditions improving slightly over the EGSL in 2024–2025, the Estuary continues to exhibit persistent low-oxygen and high-CO_2 in deep waters.

Total zooplankton biomass has followed a declining trend since at least the early 2000s reaching a low in 2022, in large part due to a shift from large lipid-rich copepods to smaller taxa. This trend may indicate reduced trophic transfer from primary producers to higher trophic levels.

The biomass of mid-trophic level forage species, including pelagic fishes and Northern Shrimp, decreased by approximately two-thirds between 1985 and 2020. Subsequent increases have resulted from increasing biomass in northern Gulf spring spawning Herring and to a lesser extent southern Gulf fall spawning Herring.

The abundance of apex predators is currently above historical low levels; although harp seals have been declining since the mid 1990s.

Indicators for the fish and macroinvertebrate communities in the EGSL show trophic restructuring over the past decade, characterized by increases in small-bodied and pelagic components, alongside declines in benthivores and large groundfish. Biomass in the northern Gulf increased to high levels since 2015, largely driven by Redfish, while biomass in the southern Gulf has declined since the early 1990s. Size structure and fish body condition indicators show reductions in larger-bodied species and poorer condition across most habitat guilds, with recent improvements limited to smaller species and pelagic groups.

Approximately half of assessed mid and offshore stocks in the EGSL are in the Critical Zone of their Precautionary Approach Framework, with uncertain prospects for rebuilding. Among groundfish, stocks found in the channels of the EGSL generally have more favorable status.

Commercial fishery landings have declined by about an order of magnitude since 1985, as a result of the collapse of many groundfish stocks in the late 1980s and 1990s, declines in pelagic fish landings since around 2000 and more recent declines in shrimp landings.

Downscaled climate projections to the end of the century indicate intensifying warming waters, stronger stratification, and ongoing increases in hypoxia and hypercapnia across the EGSL, particularly in deep waters. These changes are expected to reduce primary and secondary production and cause shifts species relative abundance and distribution, favouring warm-adapted and acidification-tolerant species.

The purpose of this Ecosystem Summary is to provide an integrative suite of ecosystem indicators relevant to fish stocks and fisheries in the offshore waters of the EGSL to support implementation by Fisheries and Oceans Canada (DFO) of an Ecosystem Approach for Fisheries Management (EAFM). The Ecosystem Summary provides information needed by DFO Science, Fisheries Management, other decision-makers, and external stakeholders to meet management objectives.

Details on the selection of indicators, methodology and sources for additional and more detailed indicators for this ecosystem can be found in Benoît et al. (2026). Detailed reporting of physical, biological and chemical oceanographic conditions, and results of multispecies research vessels surveys are produced annually. For the most recent such reports, see Blais et al. (2025), Galbraith et al. (2025) and Chamberland et al. (2025).

BACKGROUND

The EGSL is a semi-enclosed inland sea (Figure A1). The southern Gulf is dominated by the Magdalen Shallows and the northern Gulf by deep channels. The Estuary is an important transition zone between the St. Lawrence River, with a drainage basin of over 1.6 million km^2, including the five Laurentian Great Lakes, and the marine environment. The waters of the EGSL are largely subpolar with a large freshwater input from the St. Lawrence River and warm Atlantic water found in the deep channels. Historically, the EGSL was covered with sea ice during winter. Seasonal changes in ice, near-surface temperatures and freshwater run-off are important drivers in this ecosystem (DFO 2009), since they are important in determining freshwater input and the timing of phytoplankton blooms.

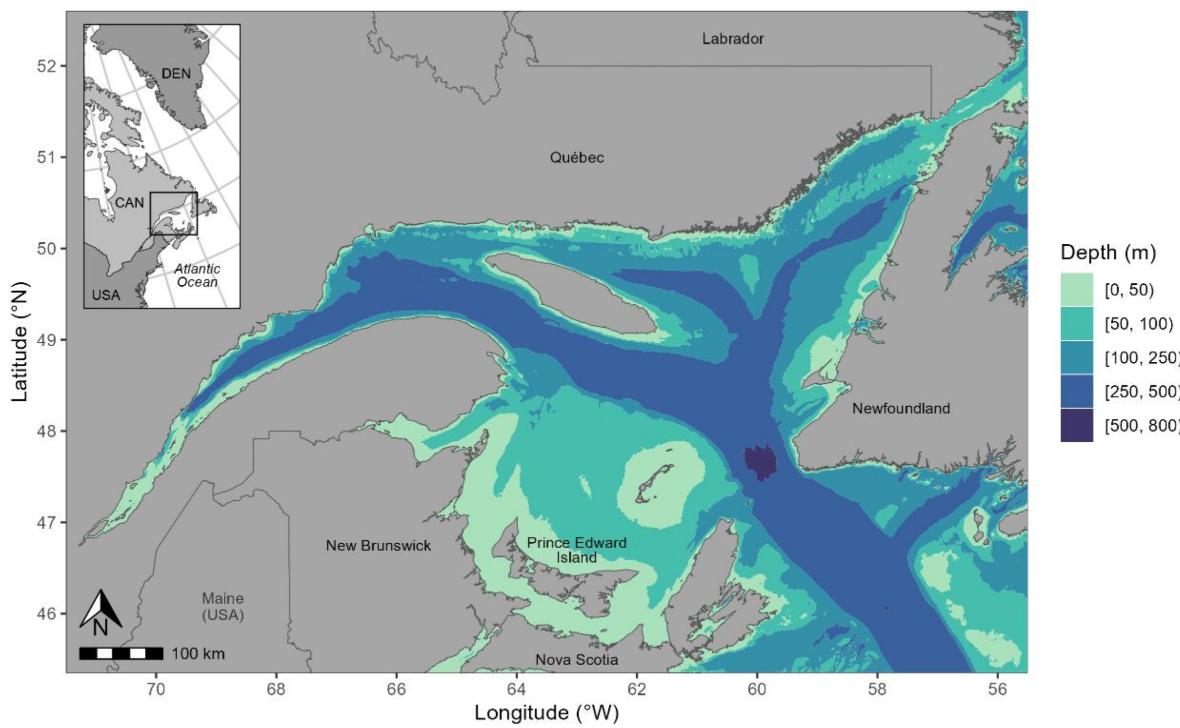

Figure A1. Map of the Estuary and Gulf of St. Lawrence (EGSL), including bathymetric contours. Note that the area south of Newfoundland and east of Nova Scotia (Cape Breton) is not part of the EGSL

There has been commercial fishing in the EGSL for centuries (Lear 1998). Industrialization of fishing beginning in the 1950s led to the collapse of Atlantic Herring stocks during the 1970s, and several groundfish species starting in the late 1980s. Important fisheries targeting crustaceans, principally Snow Crab and Northern Shrimp developed during the 1980s and 1990s. A distinguishing characteristic of the EGSL ecosystem, and the southern Gulf of St. Lawrence (sGSL) in particular, is the large number of stocks for which the rate of natural mortality is particularly high, contributing to ongoing depleted status (Swain and Benoît 2015; Turcotte et al. 2021).

As a whole, the state of knowledge for this ecosystem is generally rich; However, important gaps remain notably for nearshore and coastal environments where coverage by surveys is less comprehensive but improving.

A number of indicators presented in this Ecosystem Summary constitute standardized anomaly values calculated as the annual value of the quantity of interest, minus its long-term mean (or baseline), divided by the standard deviation of values for the period in question. The resulting quantities are dimensionless, and because they are calculated with respect to the standard deviation, their magnitude also indicates statistical significance. Annual anomalies for different quantities are added together to produce composite indices, where this makes sense.

PHYSICAL ENVIRONMENT

Temperature and ice

The summertime water column in the EGSL consists of three distinct layers: the surface layer, the cold intermediate layer (CIL), and the deeper layer. During fall and winter, the surface layer thickens and cools to form a winter surface mixed layer to an average depth of 75 m. During spring, surface warming, sea ice melt waters, and continental runoff produce a lower-salinity and higher-temperature surface layer that typically reaches its maximum temperature in early August. Underneath this surface layer, cold waters from the previous winter are partly isolated from the atmosphere and form the summer CIL. This layer will persist until the next winter, gradually warming up during summer and fall. There are four indicators used to describe temperature and ice conditions: May-November sea-surface temperature, maximum sea ice volume, CIL minimum temperature, and average temperature at 300 m.

The May-November **sea-surface temperature** over the EGSL was at a record high in 2024 and all five years between 2021 and 2025 rank in the seven warmest since 1982 (Figure A2). Using April-November air temperature as a reliable proxy for May-November sea-surface temperature, there has been a warming trend of 1.5 °C per century between 1893 and 2025.

In the 16-year span since 2010, 11 of the 16 lowest seasonal **maximum sea ice volumes** since 1969 have occurred (Figure A2). December-March air temperatures in the EGSL are highly correlated with sea ice properties (Galbraith et al. 2024); with a warming trend of 2.1 °C per century of December-March air temperatures between 1893 and 2025, seasonal sea ice cover in the EGSL is threatened long term.

Despite interannual variability associated with occasional severe winters, there is an increasing trend in **CIL minimum temperature** since 1985 (Figure A2). The record high occurred in 2021 and all five years between 2021 and 2025 have been above normal. The CIL minimum temperature is well correlated with bottom temperatures in the sGSL (Magdalen Shallows) and is representative more broadly of bottom conditions where the CIL touches the ocean floor.

The **average temperature at 300 m**, which is highly correlated with temperatures at other depths below 150 m, increased to a 100-year record of 7.1 °C in 2022 (Figure A2). These waters have since cooled but remain well above the long-term mean. The deeper water layer below the CIL originates at the entrance of the Laurentian Channel and circulates towards the heads of the channels in the EGSL without much exchange with the upper layers. Decadal changes in temperature, salinity, and dissolved oxygen of these deep waters are related to the variation in the proportion of the source, cold, fresh and oxygen-rich Labrador Current water and warm, salty and oxygen-poor slope water also known as North Atlantic Central Waters (McLellan 1957, Lauzier and Trites 1958).

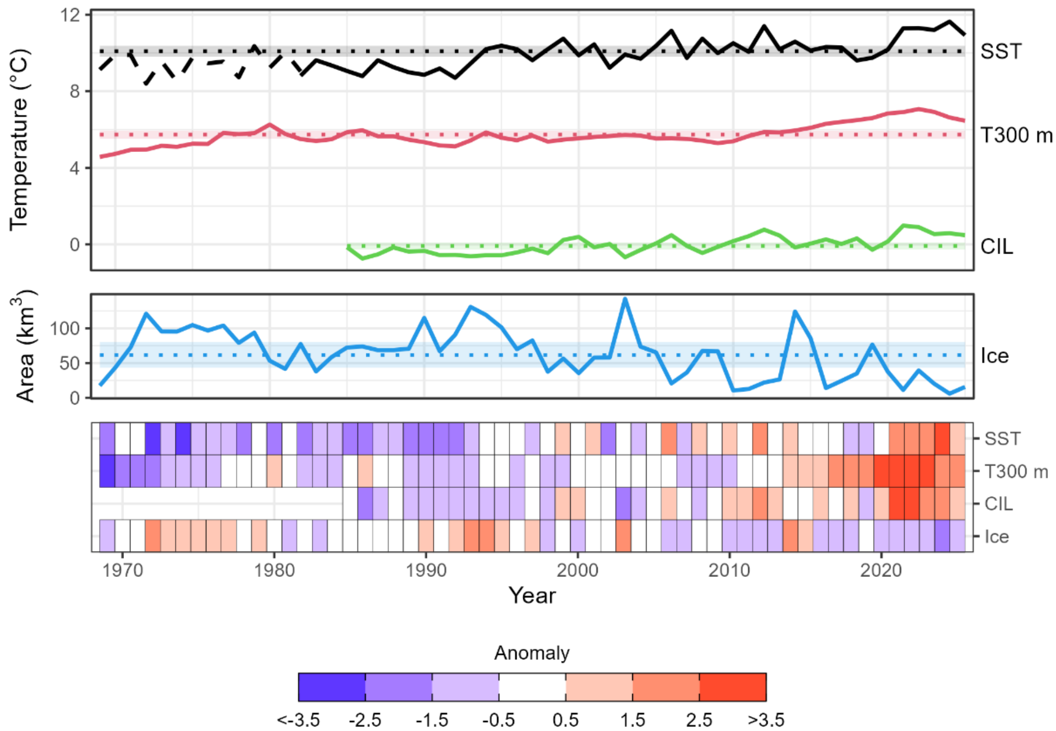

Figure A2. Water temperatures and sea ice volume in the EGSL. Top panel: Sea surface temperature (SST; solid black line), layer-averaged temperatures at 300 m (T300 m; solid red line), and cold intermediate layer (CIL; solid green line) minimum temperature. The solid portion of the SST line (1982-2025) was averaged over the Gulf excluding the Estuary (May–November). The dashed portion of the SST line (1969-1982) was established based on a proxy of April–November air temperatures. The CIL was based on August averages in the EGSL. Middle panel: Seasonal maximum ice volume (Ice; solid blue line) in the EGSL. For the top and middle panels, the dotted horizontal lines indicate the corresponding climatological means for 1991–2020, while the shaded areas indicate ± ½ SD around the climatological means. Bottom panel: Anomaly values, where the sign of the anomaly has been set to reflect warming conditions as positive anomaly values (i.e., an ice volume below the long-term average is associated with a positive anomaly value). Anomaly colours convey both the direction and magnitude of deviations: white indicates normal values within ± ½ SD of the climatological mean, red denotes warmer than normal anomalies, and blue reflects colder than normal anomalies.

Dissolved oxygen

Driven by ocean warming, increased stratification, and circulation changes, the global ocean has lost about 2% of its oxygen over the past 50 years (Schmidtko et al. 2017), with deoxygenation in northwest Atlantic (NWA) nearshore waters exceeding the global average (Gilbert et al. 2010). In the EGSL, the surface area of deeper waters considered hypoxic (< 30% saturation; ≈ 100 μmol L^{-1}) or severely hypoxic (< 20% saturation) began increasing rapidly after 2016. While conditions improved in the Gulf in 2024 and 2025, no comparable improvement of conditions occurred in the Estuary (Figure A3). These conditions reflect changes in the relative contributions of cold, oxygen-rich Labrador Current water and warm, oxygen-poor North Atlantic Central water, which take longer to reach the Estuary. Additional respiration linked to warmer temperatures and eutrophication in the St. Lawrence Estuary has further intensified deep-water deoxygenation in recent years (Jutras et al. 2023; Blais et al. 2025).

Newly hypoxic zones have formed in deep regions such as the central GSL and Anticosti and Esquiman Channels (Blais et al. 2025). Waters at 200 m have also become hypoxic at multiple locations, whereas this was previously restricted to the head of the Laurentian Channel at this depth. In the Estuary, where deep waters have been hypoxic for decades, oxygen levels declined to near-lethal values (11% in 2022) for many commercially important species. More generally, metabolic impairment is expected for a number of EGSL species when oxygen saturation declines below ~70%, including Atlantic Cod, Greenland Halibut and Northern Shrimp. Only a few species, such as Northern Shrimp and Greenland Halibut, can tolerate severely hypoxic conditions (< 20% saturation).

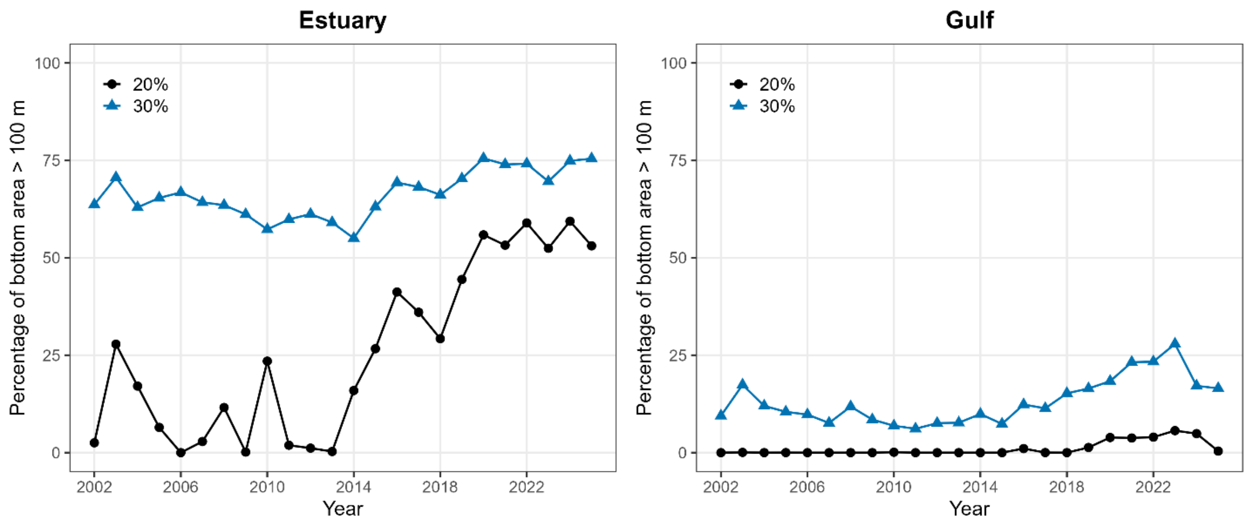

Figure A3. Trends and state of hypoxia in the EGSL: percentage of the bottom area where waters are deeper than 100 m covered by hypoxic waters (< 30% saturation; blue line) and severely hypoxic waters (< 20% saturation; black line) in the Estuary (left panel) and Gulf (right panel) of St. Lawrence.

CO_2-driven conditions including acidification and hypercapnia

As a sink for atmospheric carbon, the ocean takes up anthropogenic carbon dioxide (CO_2), modifying inorganic carbon speciation and lowering pH, leading to ocean acidification. Since the late 1980s, Atlantic Canadian subsurface waters (< 50 m) have exhibited rates of pH decrease (~0.03–0.04 per decade; Bernier et al. 2023) that are higher than global surface-water averages (~0.017–0.027 per decade; IPCC 2021). Associated with acidification are the phenomena of hypercapnia, excessive CO_2 in seawater leading to elevated CO_2 in marine organism tissues, and aragonite and calcite undersaturation, a lack of carbonate ions required to maintain solid calcium carbonate, notably causing unprotected shells and skeletons of marine organisms to dissolve.

Organismal responses to changing carbonate chemistry span negative to positive varying across species and life stages (Leung et al. 2022; Barclay et al. 2026). Among the greater anticipated negative impacts are those related to organisms expending additional energy on ion transport to keep their internal chemistry steady. In invertebrates, these energetic costs may coincide with greater dissolution pressure on calcified structures and higher metabolic demands for calcification.

Since larger scale standardized monitoring began in 2014, the percentage of the surface area of waters deeper than 100 m considered hypercapnic (defined as partial pressures of CO_2 ≥ 1000 µatm) increased from around 50% to 75% in 2025 in the Estuary, and from around 15%

to 40% in 2023, dropping to around 25% in 2024-2025 in the Gulf (Figure A4). The lower Estuary is the most impacted part of the EGSL, with low pH, aragonite and calcite undersaturation, and persistent hypercapnia from 200 m to near-bottom waters. The Magdalen Shallows remain the least affected in the EGSL, but near-bottom aragonite undersaturation has been occurring more frequently (Lizotte et al. 2026).

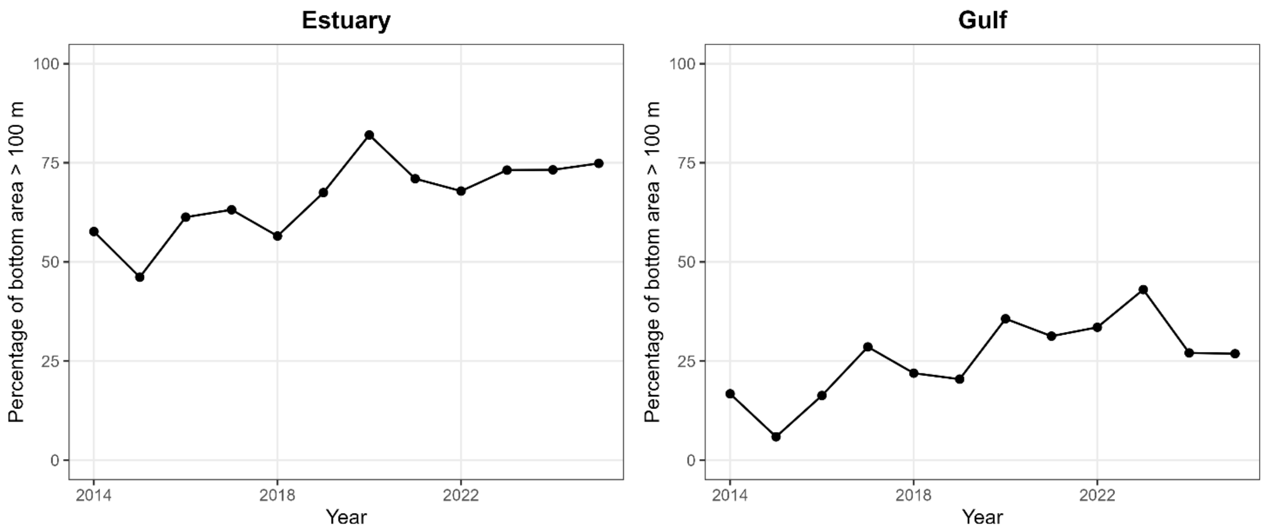

Figure A4. Trends and state of hypercapnia in the EGSL: percentage of the bottom area where waters are deeper than 100 m covered by hypercapnic waters (pCO_2 ≥ 1000 µatm) in the Estuary (left panel) and Gulf (right panel) of St. Lawrence.

FOOD WEB COMPONENTS

Zooplankton

As primary consumers of phytoplankton, mesozooplankton form a critical energetic link between primary production and higher trophic levels. Their biomass therefore provides a general indicator of the annual energy available to predators.

Total zooplankton biomass in the EGSL has followed a declining trend since 2001, reaching a low in 2022 (Figure A5). This decline is generally associated with reduced abundance of large zooplankton species (Blais et al. 2025). The decline, along with recent elevated abundance of small copepods and non-copepod taxa, may indicate both reduced net trophic transfer and reduced trophic transfer efficiency from primary producers to higher trophic levels.

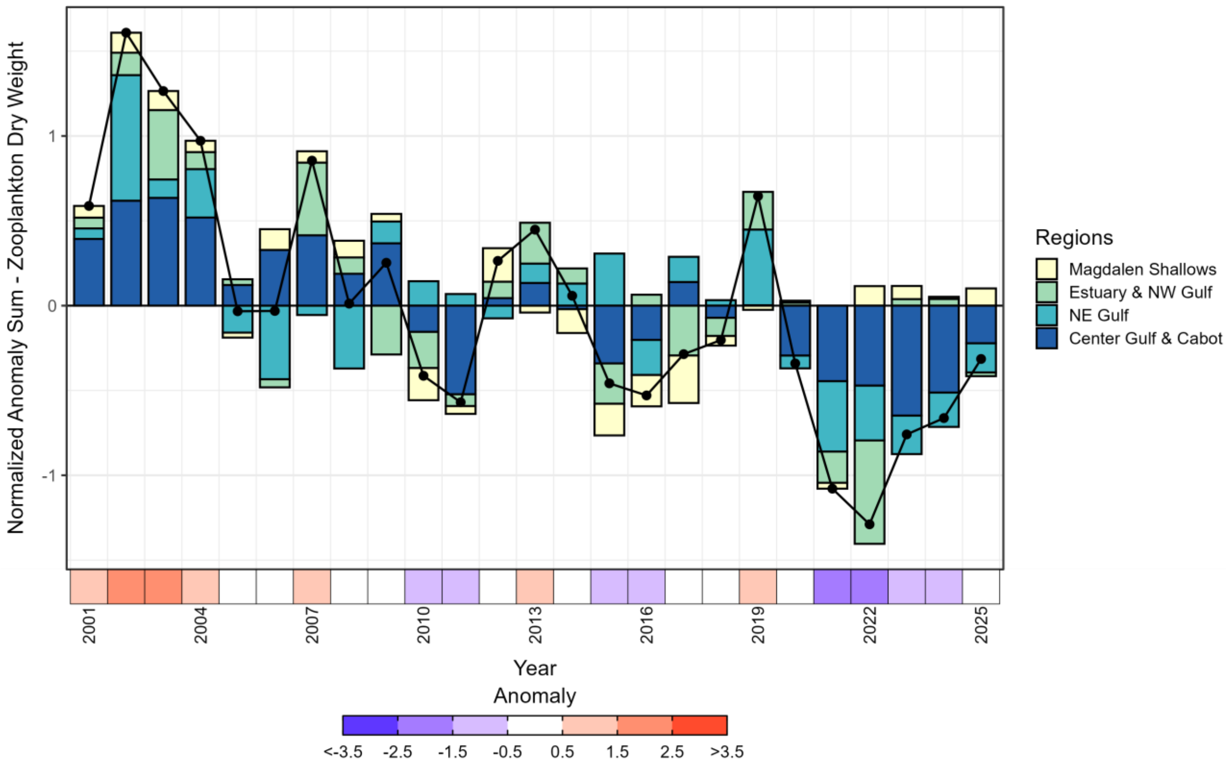

Figure A5. Composite dry weight zooplankton biomass index (black line and dots) for the EGSL derived by summing regional normalized anomalies (coloured boxes stacked above the abscissa are positive anomalies, and below are negative). Each bar represents the volume-weighted average of all Gulf ecosystem approach polygons (Duplisea et al. 2024). Time series at the bottom shows the composite zooplankton index that is renormalized again, using the 2001–2025 climatology. Colours convey both the direction and magnitude of deviations: white indicates near average values, red denotes above-average anomalies, and blue reflects below-average anomalies.

Forage species

In the EGSL, key mid-trophic level forage species include Atlantic Mackerel (*Scomber scombrus*), Atlantic Herring (*Clupea harengus*), Capelin (*Mallotus villosus*), and Northern Shrimp (*Pandalus borealis*), all of which support substantial predation pressure from resident and migratory predators (fish, birds, and mammals) and also support or have supported fisheries. These species play a key role in the transfer of secondary production to higher tropic levels. Reliable estimates of biomass from assessments are presently available for all of these species, except Capelin.

The biomass of forage species in the EGSL decreased by about two-thirds between 1985 and 2020, principally due to declines in Mackerel and Herring during the 1990s, and declines in all species since 2010 (Figure A6). Recent increases in Herring biomass since 2020 mainly reflect increases in spring spawning northern Gulf of St. Lawrence (nGSL) Herring (NAFO 4RSw) and, to a lesser extent, fall spawning sGSL Herring (NAFO 4T).

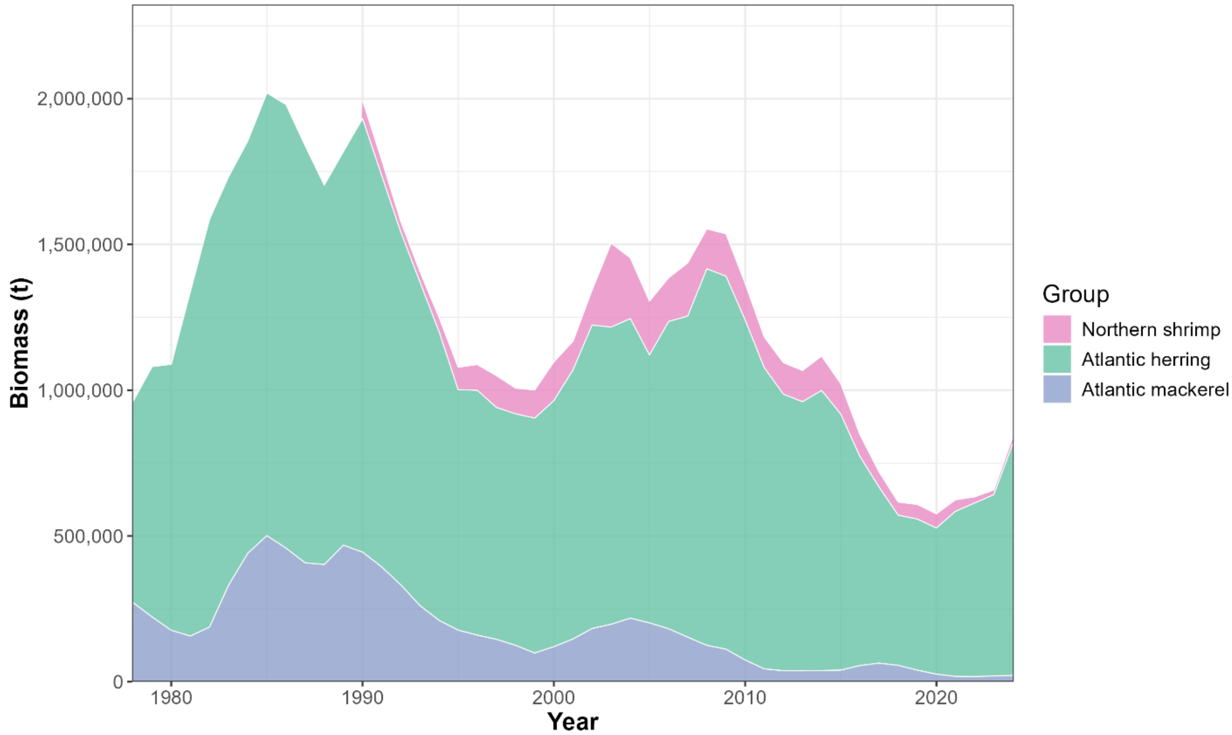

Figure A6. Biomass of key mid-trophic level forage species from their respective stock assessments. Note that the series for Northern shrimp begins in 1990.

Apex predators

Four main apex predator species with sufficient information on abundance and trophic role were identified for the EGSL: harp seals (*Pagophilus groenlandicus*), grey seals (*Halichoerus grypus*), Atlantic Bluefin Tuna (ABFT; *Thunnus thynnus*) and northern gannets (*Morus bassanus*). All are important predators of small pelagic fishes, while the seals, grey seals in particular, are notably important predators of groundfish as well. While other top predators are known to occur in the EGSL, such as toothed whales and sharks, limited data on abundance, distribution and diet presently hinder estimation of their impacts.

The apex predator species recovered from historical lows in the 1960s-1970s, or in the case of ABFT, in the mid-1990s (Figure A7) . Recent population estimates for grey seals and ABFT are at or near post-recovery highs. Meanwhile harp seal abundance has been declining since the mid 1990s, and northern gannet abundance dropped in 2021 as a result of mortality from bird flu; both are presently at median long-term population levels. While abundance estimates for northern gannets and ABFT are specific to numbers foraging in the EGSL, estimates for the two seal species are for their entire NW Atlantic populations, only a portion of which forage in the EGSL. Evidence indicates that the proportion of the harp seal population using the EGSL seasonally is likely declining, as loss of sea ice whelping habitat has shifted to outside the EGSL (Goulet et al. 2025), a trend projected to continue (Stenson and Hammill 2014).

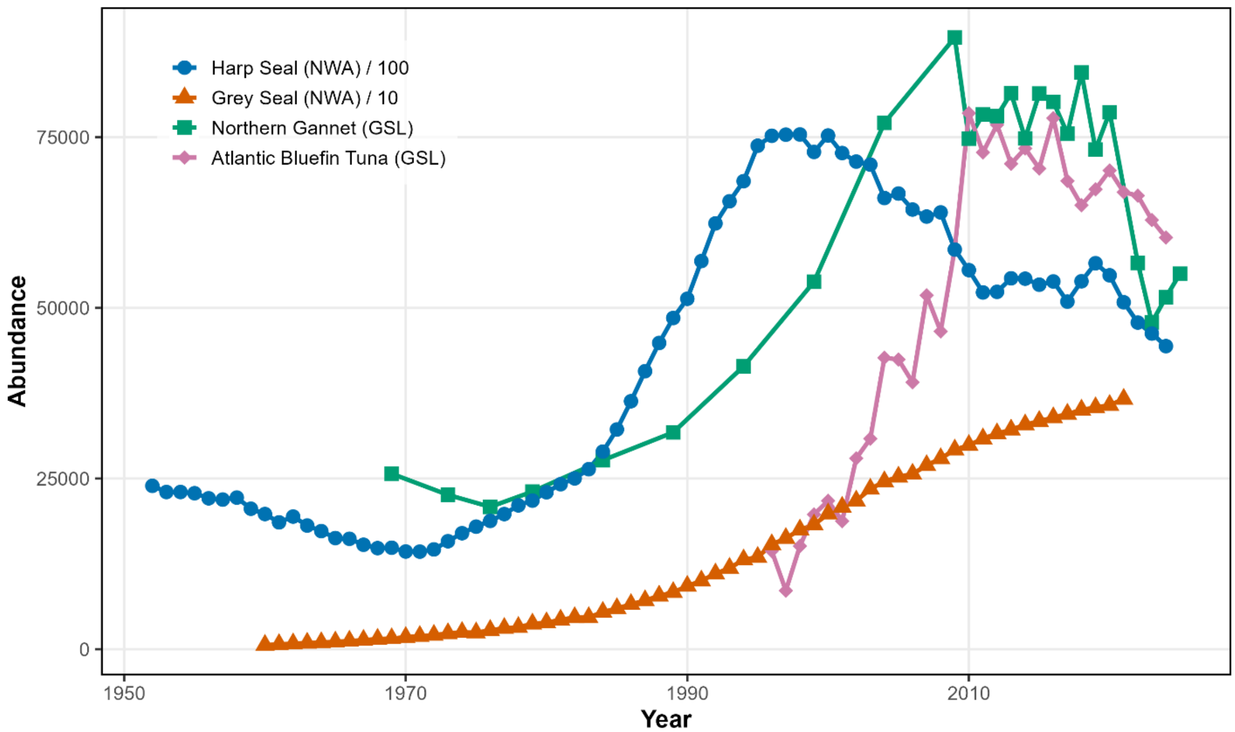

Figure A7. Time series of abundance for each of the four principal apex predators, noting that values for harp seals are in hundreds of individuals and those for grey seals are in tens of individuals. Note that abundance estimates for both seal species represent population-level (Northwest Atlantic, NWA) abundance that are not limited to EGSL, excluding animals breeding in U.S. waters for grey seal.

ECOLOGICAL AND ENVIRONMENTAL INTERACTIONS

Community composition

Community composition indicators track how species and biological trait composition changes over time, informing ecosystem functioning and fish productivity (Isabel et al. 2025). These indicators use long-term multispecies bottom-trawl research vessel (RV) surveys in the nGSL and sGSL (Chamberland et al. 2025, Benoît and Swain 2003).

Trophic guilds

Trophic guilds group species with similar feeding and associated ecosystem functions. Eight guilds were defined in the EGSL RV surveys (Figure A8). Fish and invertebrates caught on the RV surveys were assigned to one or multiple trophic guilds based on their role in the ecosystem. In the nGSL, planktivorous and piscivorous guilds have dominated since 2016 due to the surge in the biomass of Redfish, which belong to both guilds. Meanwhile in the sGSL, benthivorous fishes and piscivorous fishes/invertebrates have declined heavily associated with the groundfish collapse. Shrimp-dominated demersal micronekton have declined across the EGSL in recent years. The sGSL also saw an increase in benthic invertebrates that peaked in the early 2020s primarily due to American Lobster. Together, these patterns signal long-standing trophic imbalances and restructuring in both regions.

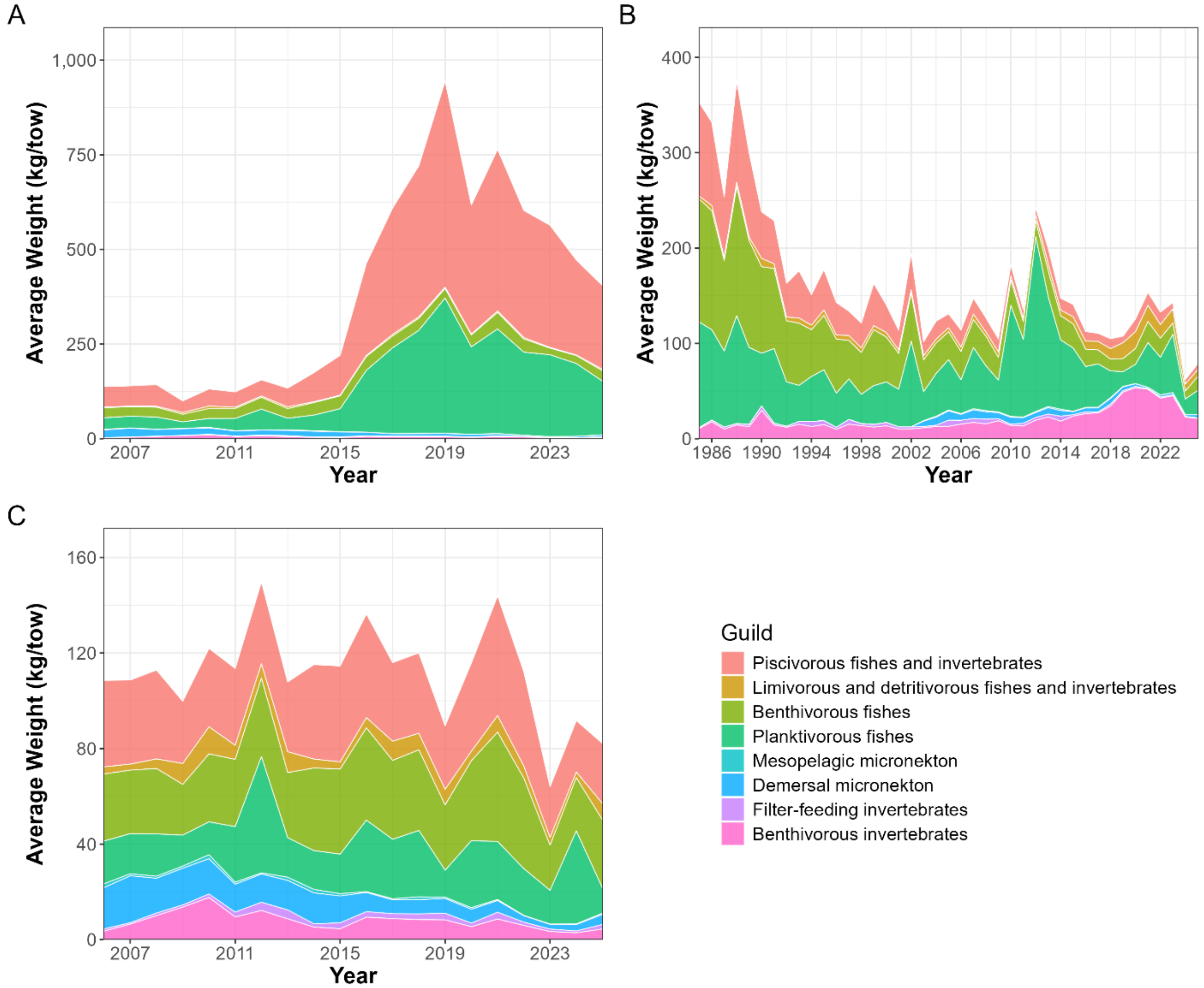

Figure A8. Standardized catch rates (average weight in kg per tow) for each trophic guild for (A) nGSL, (B) sGSL, and (C) nGSL without Redfish.

Size structure

Community size structure reflects how individuals are distributed across body-size classes, a trait linked to productivity, resilience, and species interactions. In the nGSL, size structure has been strongly influenced by Redfish recruitment pulses, producing successive positive anomalies moving from small to intermediate size classes from 2013 to 2025 (Figure A9). At the same time, small organisms (mainly shrimp) have declined since 2017, and larger size classes (35–55 cm) have shown pronounced negative anomalies in recent years, driven by declining groundfish. In the sGSL, size classes ≥ 35 cm have steadily decreased since 2000, reflecting groundfish collapse and lack of recovery. Pelagic fish-dominated size classes (25–35 cm) have also declined since 2016, while small size classes (5–25 cm) have increased since 2010, largely associated with Redfish.

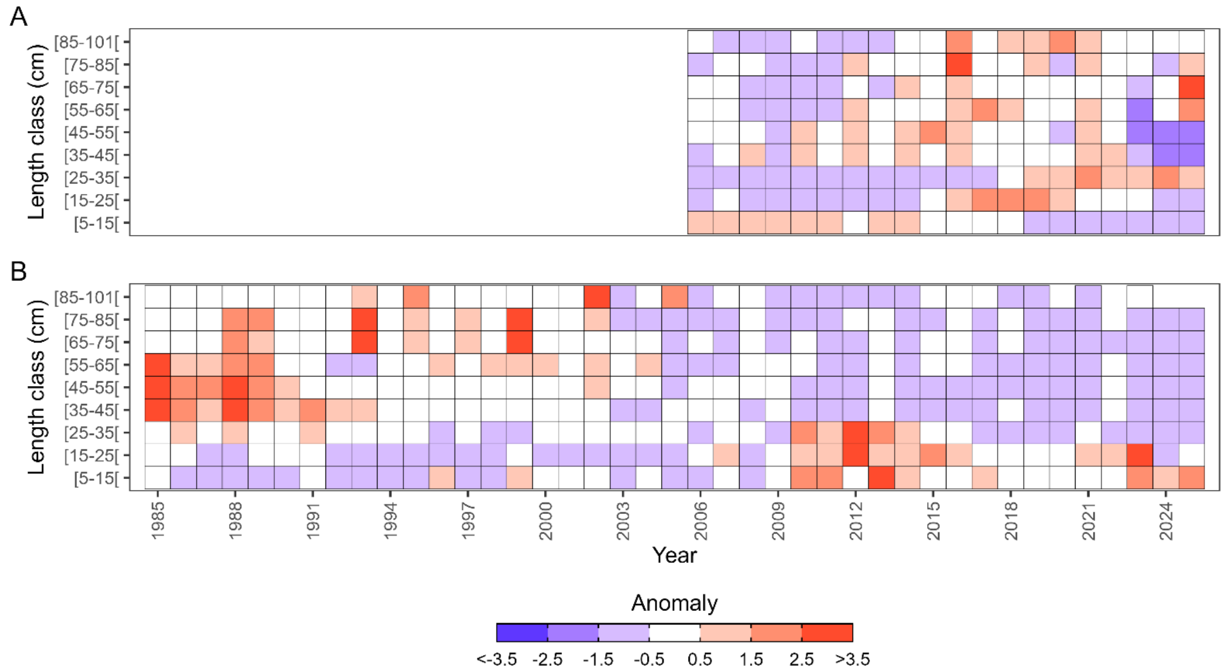

Figure A9. Annual anomalies in standardized abundance (number of individuals per tow) by 10 cm size classes for (A) nGSL and (B) sGSL. White indicates near average values (0 and ± 0.5), red denotes above-average anomalies, and blue reflects below-average anomalies.

Fish condition

Fish body condition reflects nutritional status, energy reserves, and overall health. Condition was estimated for commonly caught fish species, and then summarized by habitat guild (benthic, demersal, benthopelagic, pelagic) or for the community as a whole.

In the nGSL, fish condition generally declined after 2010 (Figure A10). Demersal species show negative anomalies recently, including larger bodied species like Greenland Halibut, White Hake, Longfin Hake, and Redfish. In the sGSL, habitat guilds show similar trends of generally strong condition early in the time series, a system-wide dip in the mid-1990s, and poorer overall condition since 2005, with slight improvement in pelagic and demersal species in the last year.

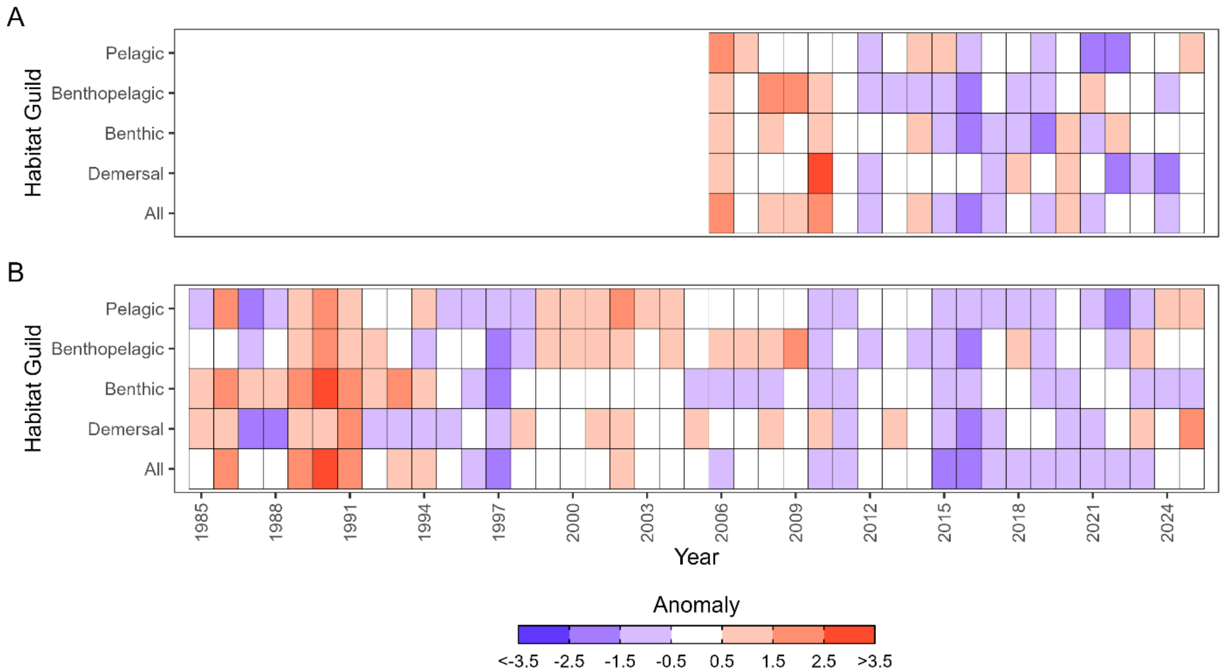

Figure A10. Annual anomalies in fish body condition for each habitat guild and combined (all) in nGSL (upper panel) and sGSL (bottom panel). Colours convey both the direction and magnitude of deviations: white indicates near average values (0 and ± 0.5), red denotes above-average anomalies, and blue reflects below-average anomalies.

STATUS OF HARVESTED STOCKS AND FISHERY PRODUCTION

The status of mid and offshore EGSL stocks is expressed as the ratio of the state quantity, typically adult biomass or its proxy, and the limit reference point (LRP). All offshore EGSL stocks have an LRP, except EGSL Capelin and northern GSL Snow Crab, for which an LRP is expected in the coming years.

Approximately half of the EGSL stocks are in the Critical Zone of their Precautionary Approach (Figure A11). Rebuilding plans have been developed, or are currently being developed for many of these stocks: Atlantic Cod (NAFO 4Tvn and 3Pn4RS stocks), NAFO 4T White Hake, NAFO 4T American Plaice, NAFO 4T Winter Flounder, NAFO 4TVn spring spawning Atlantic Herring, Atlantic Mackerel, and three of the four EGSL Northern Shrimp stocks. With the exception of Atlantic Mackerel for which fishing is most likely preventing recovery, all other rebuilding plans conclude that rebuilding is unlikely unless stock productivity improves. Elevated rates of natural mortality have been identified as a principal cause of a lack of rebuilding in sGSL groundfish, Herring and nGSL Cod (Swain and Benoît 2015; Turcotte et al. 2021, 2025; Benoît and Ouellette-Plante 2023). Among groundfish, stocks found in the deeper channels of the EGSL generally have more favourable status.

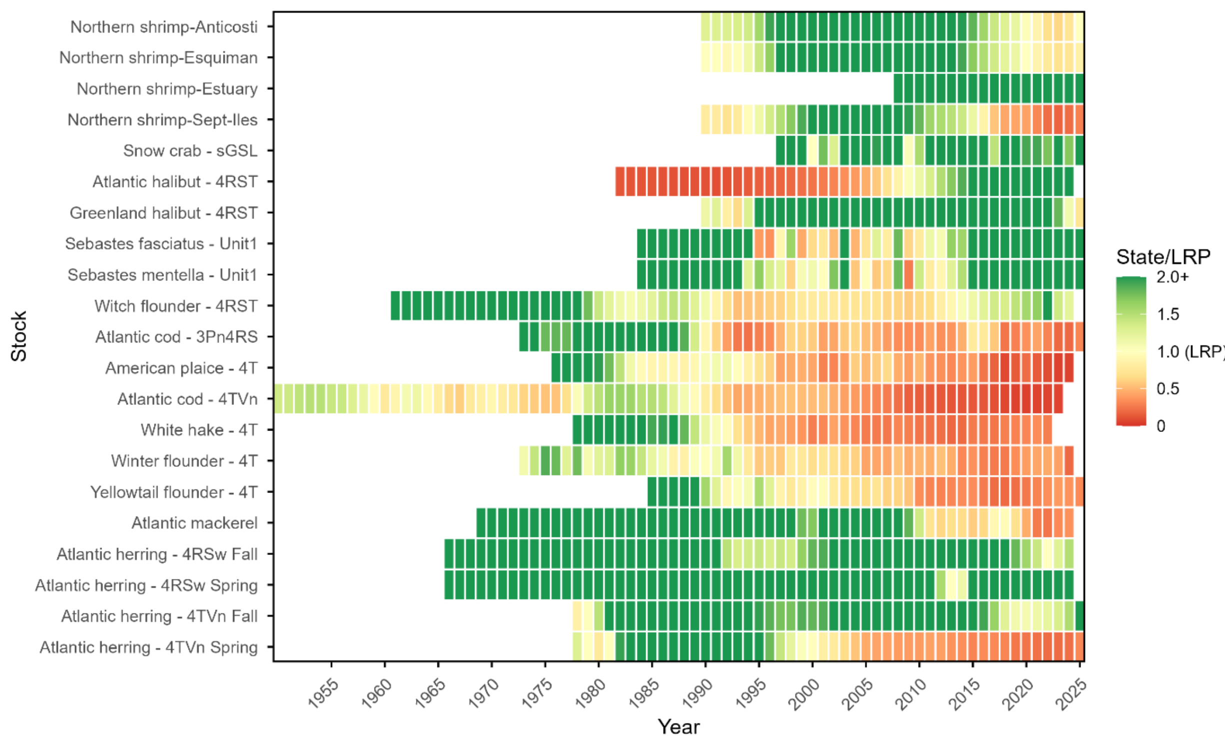

Figure A11. Stock status relative to the limit reference point (LRP) for mid and offshore stocks in the EGSL. Values below 1 (orange to red) indicate stocks below their LRP and in the critical zone of the Precautionary approach, while values greater than 1 (light to dark green) indicate stocks above their LRP. Note that stocks differ with respect to starting year for their time series and the most recent year available.

Commercial fisheries in the mid and offshore EGSL almost exclusively target three species groups: pelagic fish, groundfish and crustaceans. Total landings have declined by an order of magnitude since the mid-1980s, principally as a result of the collapse of many groundfish stocks up to 1995, ongoing declines in pelagic fish landings since the early 2000s, and recent declines in Northern Shrimp landings (Figure A12). Since 2024, DFO has set a total allowable catch of 60,000 tonnes annually for Redfish (*Sebastes* spp.), of which only a small fraction has been taken due to various economic and technical constraints. Even considering this additional potential fishery yield, there has been a large decrease in fishery resource production in the EGSL over at least four decades.

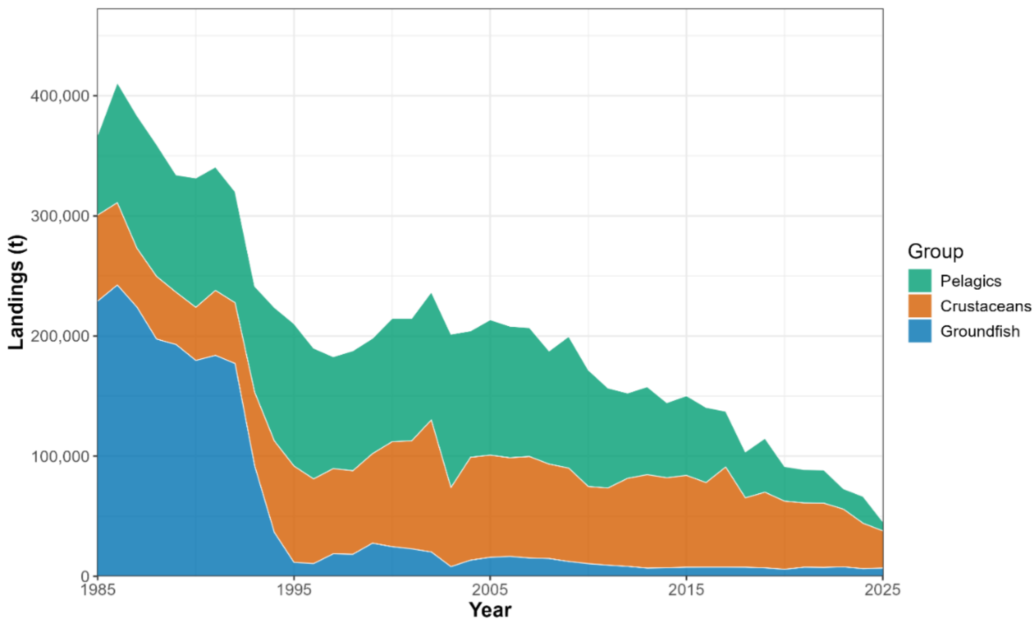

Figure A12. Total landings by major fishery resource group for mid and offshore commercial fisheries on EGSL stocks, 1985-2025. Note that values for 2023-2025 should be considered preliminary and are subject to change in subsequent updates to the landings data.

CLIMATE CHANGE AND OTHER CONSIDERATIONS

Climate models and assessments indicate that the environmental changes occurring in the EGSL of continued warming, freshening, stronger stratification, and declining oxygen and pH are expected to intensify through the coming century (Figures A13 and A14). Deep waters, particularly in the northeastern Gulf, are projected to warm the most, while reduced mixing and altered circulation will further limit deep-water ventilation. These physical changes are already being linked to projected shifts in biological communities, including declining biomass of cold-adapted *Calanus* marine species, including shrinking suitable habitat for Northern Shrimp, and increasing vulnerability of crustacean species sensitive to acidification. Overall, these trends point to substantial habitat loss in deep regions like the Lower St. Lawrence Estuary and the Northwestern GSL, along with shifts from large, cold-water zooplankton toward smaller, warm-water associated species.

Future warming will also reduce winter heat loss, diminish sea ice cover, and extend the duration of strongly stratified conditions, leading to further warming of the CIL and deep layers of the EGSL. Surface warming will be uneven, with faster rates during summer and in the sGSL, and changes in water masses entering through Cabot Strait and the Laurentian Channel will accelerate deep-water warming. At the same time, reduced nutrient inputs from oceanic exchanges and upwelling are expected to outweigh projected increases in riverine nutrients, resulting in lower primary and secondary production. Together, strengthened stratification, nutrient declines, and continued deoxygenation and acidification are expected to drive ecosystem-level productivity losses and propagate cascading effects throughout the food web.

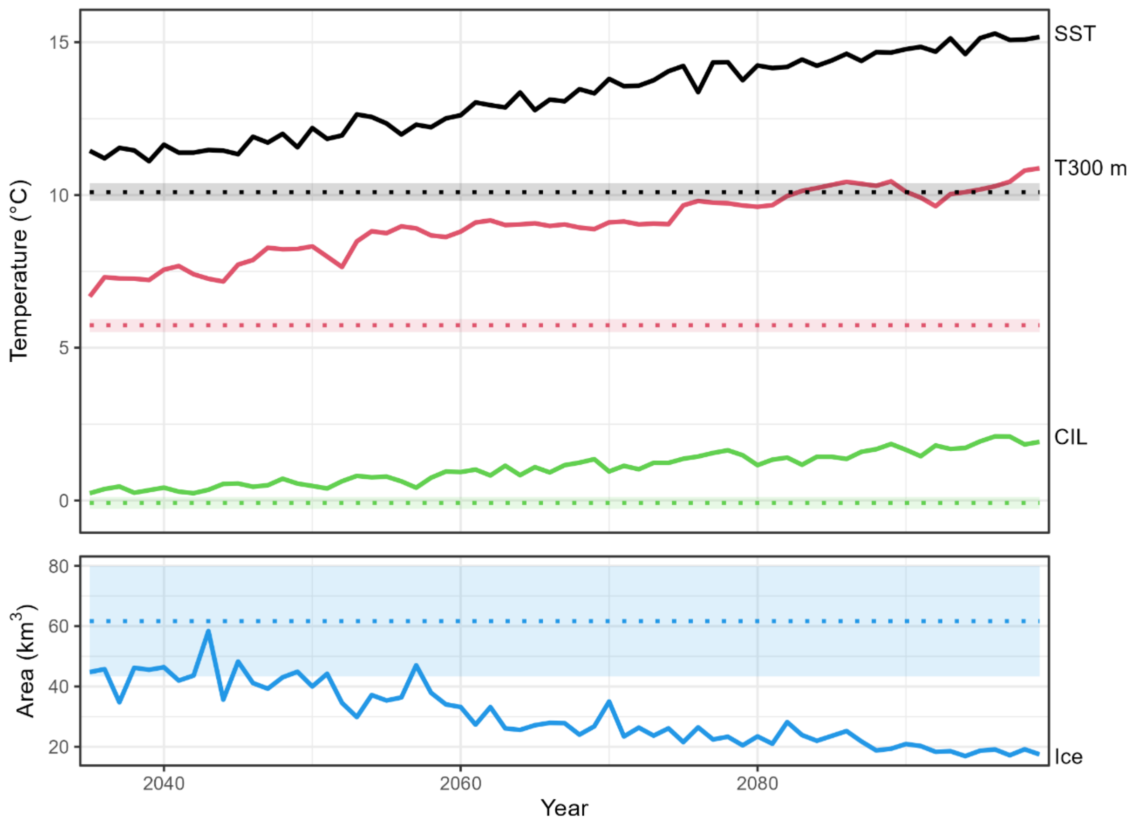

Figure A13. Projected changes in physical environment (water temperatures and sea ice volume) in the EGSL for 2035 to 2100 rescaled to the empirical climatological means of 1991–2020. Top panel: Sea surface temperature (SST; solid black line), layer-averaged temperatures at 300 m (T300 m; solid red line), and cold intermediate layer (CIL; solid green line) minimum temperature. The SST was averaged over the Gulf excluding the Estuary (May–November). The CIL was based on August averages in the EGSL. Bottom panel: Seasonal maximum ice volume (Ice; solid blue line) in the EGSL. For both panels, the dotted horizontal lines indicate the corresponding climatological means for 1991–2020, while the shaded areas indicate ± ½ SD around the climatological means. All projections were derived from an ensemble of four downscaled (CCSM4, MPI-ESM-MR and CanESM2) climate simulations under the RCP 8.5 scenario.

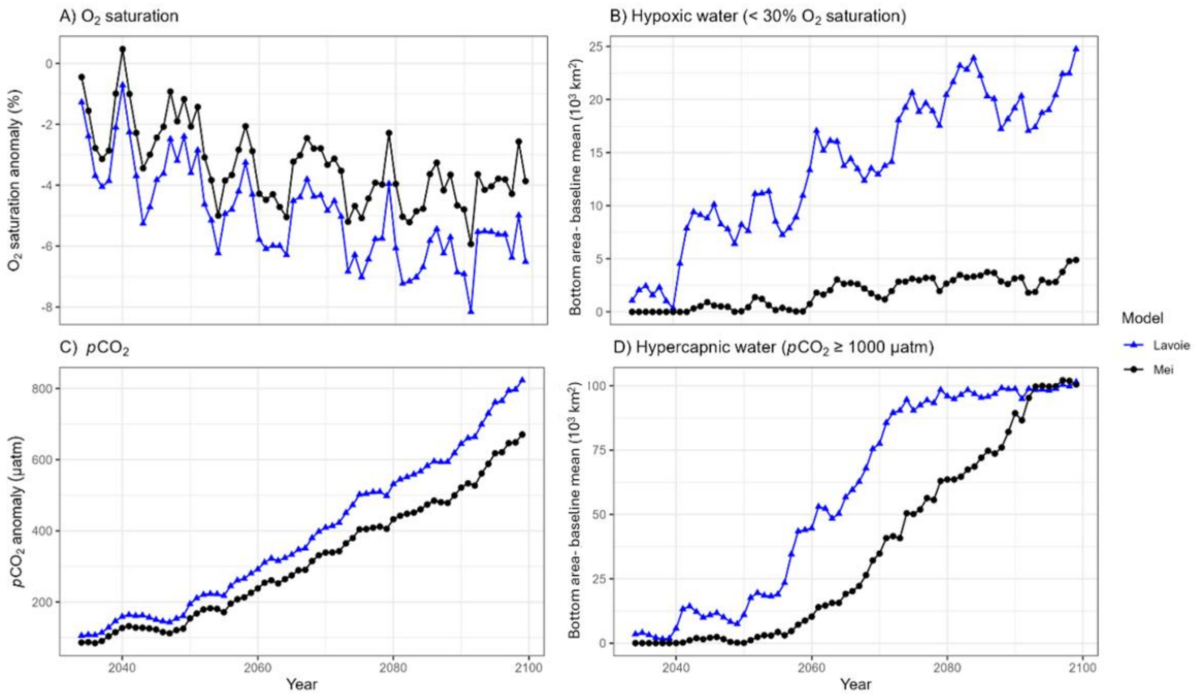

Figure A14. Difference between mean oxygen saturations (A) and mean partial pressure of CO_2 (pCO_2, C) in the Estuary and Gulf of St. Lawrence below 200 m in future years (2035 to 2100) and the 2005 to 2025 climatology simulated with the regional climate model of the EGSL using downscaled forcing from MPI-EMS-LR using the RCP 8.5 scenario for two different simulations (Lavoie et al. 2020 and Mei et al. 2024). The right panels represent the difference between the climatological and future area of hypoxic water (< 30% oxygen saturation); B) and for hypercapnic water (pCO_2 ≥ 1000 µatm); D) for EGSL regions deeper than 100 m.

Community temperature index

The community temperature index (CTI) is a measure of the average thermal preference of species within a community (Devictor et al. 2008), and is used to monitor temporal shifts in community structure in response to temperature changes in ecosystems (Devictor et al. 2012; Burrows et al. 2020; Chust et al. 2024; Isabel et al. 2025). The nGSL and sGSL CTI increased over time, indicating an increase in the relative importance of taxa associated with warmer water conditions in the surveyed community (Figure A15). The nGSL CTI was relatively stable at or above 4.8 °C since 2016, and peaked at 5.0 °C in 2024. The sGSL CTI was relatively stable from 1987 through 2001, with a mean of 7.5 °C, then increased to a mean of 8.8 °C from 2015 through 2025.

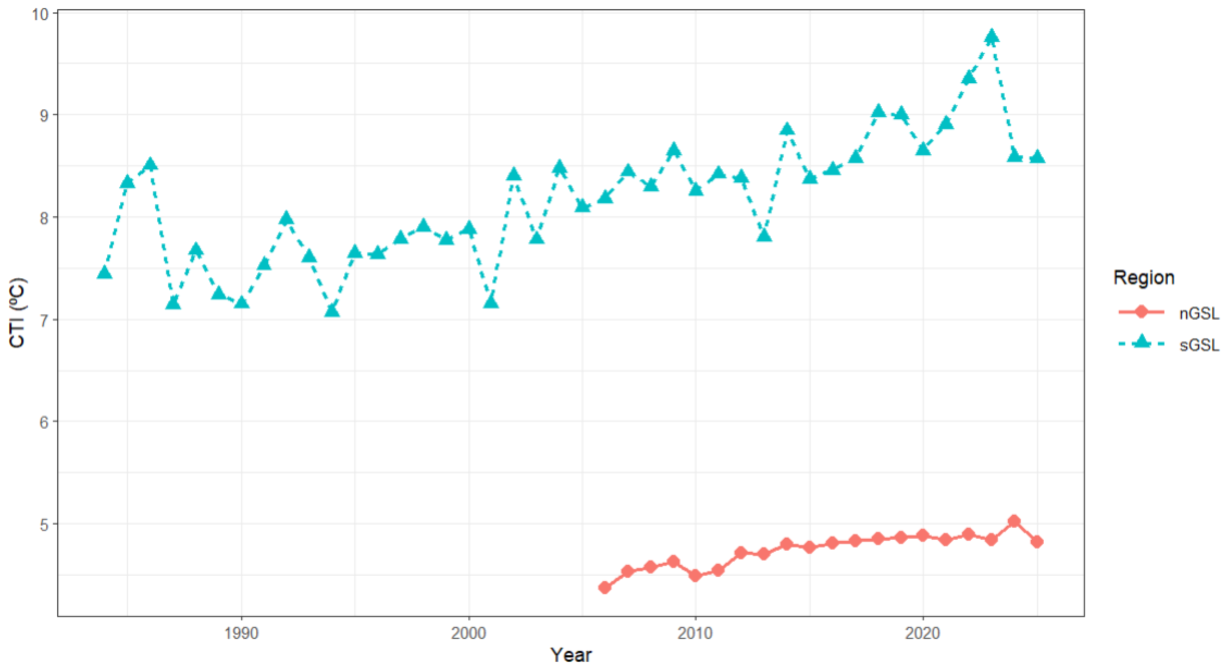

Figure A15. Community temperature index (CTI), based on thermal preference and the annual relative biomass contribution of taxa sampled in the nGSL survey (circles and solid line) and sGSL survey (triangles and dashed line).

CONCLUSION

The EGSL is currently undergoing important ecological change driven by persistent environmental stressors and shifting trophic dynamics. Over the last decade, the system has faced intensifying warming, acidification, and hypoxia, particularly within its deeper channels. While 2024 and 2025 offered a slight reprieve in the Gulf, conditions in the Estuary remain at levels likely to cause physiological stress for many organisms. This physical shift is mirrored by a decline in total zooplankton biomass and a transition toward smaller-bodied , lipid-poor taxa, signaling a potential bottleneck in energy transfer from primary producers to higher trophic levels. There have been important long-term declines in mid-trophic forage species and commercial landings, with the ecosystem now characterized by a restructured community where small-bodied and pelagic species are increasingly dominant over traditional groundfish and benthivores.

Looking ahead, the recovery of EGSL fish and macroinvertebrate community remains highly uncertain, with approximately half of the assessed mid- and offshore stocks currently in the Precautionary Approach’s Critical Zone. Although certain groundfish in deep-water channels and specific populations like Redfish show more favourable biomass status, the overall community reflects reduced size structures and poorer body condition. Climate projections through the end of the century suggest that these pressures—intensified warming, hypoxia, hypercapnia and acidification – along with increase stratification and nutrient depletion will likely persist. These conditions are expected to further constrain primary and secondary productivity, ultimately favouring warm-adapted and acidification-tolerant species, while permanently altering the distribution and abundance of the region's historical marine resources.

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APPENDIX B: TROPHIC GUILDS CLASSIFICATION FOR THE SOUTHERN GULF OF ST. LAWRENCE MULTI-SPECIES RESEARCH VESSEL SURVEY

Table B1. Trophic guilds for each taxon (taxonomic classification and species latin name) with the corresponding survey code from the southern Gulf of St. Lawrence multi-species research vessel survey. The tropic guilds consist of piscivorous fishes and invertebrates (PFI), limivorous and detritivorous fishes and invertebrates (LDFI), benthivorous fishes (PF), planktivorous fishes (PF), mesopelagic micronekton (MM) demersal micronekton (DM), filter-feeding invertebrates (FI), and benthivorous invertebrates (BI) and are adapted from Isabel et al. (2025a).

Taxonomy	Code	PFI	LDFI	BF	PF	MM	DM	FI	BI	Note
Gadus morhua	10	0.33	0	0.33	0.34	0	0	0	0	.
Melanogrammus aeglefinus	11	0.33	0	0.33	0.34	0	0	0	0	.
Urophycis tenuis	12[1]	0.6	0	0.4	0	0	0	0	0	.
Merluccius bilinearis	14	0.42	0	0.29	0.29	0	0	0	0	.
Pollachius virens	16	0.5	0	0	0.5	0	0	0	0	.
Microgadus tomcod	17	0.16	0	0.66	0.18	0	0	0	0	.
Sebastes norvegicus	20	0.6	0	0	0.4	0	0	0	0	.
Sebastes sp.	23[1]	0.6	0	0	0.4	0	0	0	0	.
Hippoglossus hippoglossus	30	0.8	0	0.2	0	0	0	0	0	.
Reinhardtius hippoglossoides	31	0.7	0	0.2	0.1	0	0	0	0	.
Hippoglossoides platessoides	40	0.2	0	0.8	0	0	0	0	0	.
Glyptocephalus cynoglossus	41	0.2	0	0.8	0	0	0	0	0	.
Limanda ferruginea	42	0.2	0	0.8	0	0	0	0	0	.
Pseudopleuronectes americanus	43	0.2	0	0.8	0	0	0	0	0	.
Anarhichas lupus	50	0.33	0	0.67	0	0	0	0	0	.
Anarhichas minor	51	0.5	0	0.5	0	0	0	0	0	.
Anarhichas denticulatus	52	0.33	0	0.34	0.33	0	0	0	0	.
Clupea harengus	60	0	0	0	1	0	0	0	0	.
Alosa sapidissima	61	0	0	0	1	0	0	0	0	.
Alosa pseudoharengus/Alosa aestivalis	62	0	0	0	1	0	0	0	0	.
Osmerus mordax	63	0	0	0	1	0	0	0	0	.
Mallotus villosus	64	0	0	0	1	0	0	0	0	.
Scomber scombrus	70	0	0	0	1	0	0	0	0	.
Boreogadus saida	110	0	0	0	1	0	0	0	0	.
Phycis chesteri	112	0	0	0.5	0.5	0	0	0	0	.
Enchelyopus cimbrius	114	0	0	1	0	0	0	0	0	.
Gaidropsarus ensis	115	0	0	1	0	0	0	0	0	.
Micromesistius poutassou	117	0	0	0	1	0	0	0	0	.
Gadus ogac	118	0.5	0	0.5	0	0	0	0	0	.
Helicolenus dactylopterus	123	0.33	0	0.67	0	0	0	0	0	.
Cyclothone microdon	154	0	0	0	1	0	0	0	0	.
Stomias boa boa	159	0.5	0	0	0.5	0	0	0	0	.
Argentina silus	160	0	0	0	1	0	0	0	0	.
Chauliodus sloani	169	1	0	0	0	0	0	0	0	.

Taxonomy	Code	PFI	LDFI	BF	PF	MM	DM	FI	BI	Note
Bathylagus euryops	176	0	0	0	1	0	0	0	0	.
Malacosteus niger	177	0.5	0	0.5	0	0	0	0	0	.
Amblyraja radiata	201	0.33	0	0.5	0.17	0	0	0	0	.
Malacoraja senta	202	0.17	0	0.5	0.33	0	0	0	0	.
Leucoraja ocellata	204[1]	0.5	0	0.5	0	0	0	0	0	.
Bathyraja spinicauda	205	0.8	0	0.2	0	0	0	0	0	.
Rajella fyllae	207	0.33	0	0.67	0	0	0	0	0	.
Squalus acanthias	220	0.67	0	0.33	0	0	0	0	0	.
Centroscyllium fabricii	221	0.33	0	0.67	0	0	0	0	0	.
Myxine limosa	241	0.2	0.6	0.2	0	0	0	0	0	.
Myoxocephalus octodecemspinosus	300	0.25	0	0.75	0	0	0	0	0	.
Myoxocephalus scorpius	301	0.25	0	0.75	0	0	0	0	0	.
Gymnocanthus tricuspis	302	0	0	1	0	0	0	0	0	.
Myoxocephalus aenaeus	303	0.25	0	0.75	0	0	0	0	0	.
Triglops murrayi	304	0	0	1	0	0	0	0	0	.
Cottunculus microps	307[1]	0	0	1	0	0	0	0	0	.
Icelus bicornis	313[1]	0	0	1	0	0	0	0	0	.
Icelus spatula	314	0	0	1	0	0	0	0	0	.
Hemitripterus americanus	320	0.33	0	0.67	0	0	0	0	0	.
Artediellus sp.	323, 306, 880[1]	0	0	1	0	0	0	0	0	.
Aspidophoroides monopterygius	340	0	0	1	0	0	0	0	0	.
Aspidophoroides olrikii	341	0	0	1	0	0	0	0	0	.
Leptagonus decagonus	350	0	0	0.5	0.5	0	0	0	0	.
Gasterosteus aculeatus	361	0	0	0.25	0.75	0	0	0	0	.
Polymetme thaeocoryla	389	0	0	0	1	0	0	0	0	.
Lophius americanus	400	0.8	0	0.2	0	0	0	0	0	.
Ceratias holboelli	401	0.95	0	0	0.05	0	0	0	0	.
Cryptopsaras couesii	402	0.95	0	0	0.05	0	0	0	0	.
Nezumia bairdii	410	0	0	0.75	0.25	0	0	0	0	.
Cyclopterus lumpus	501	0.2	0	0.2	0.6	0	0	0	0	.
Careproctus reinhardti	520	0	0	0.75	0.25	0	0	0	0	.
Synaphobranchus kaupii	602	0.43	0.14	0.43	0	0	0	0	0	.
Lycenchelys verrillii	603	0	0	1	0	0	0	0	0	.
Nemichthys scolopaceus	604	0	0	0	1	0	0	0	0	.
Ammodytes sp.	611	0	0	0	1	0	0	0	0	.
Serrivomer beanii	613	0.5	0	0	0.5	0	0	0	0	.
Gymnelus viridis	616	0	0	1	0	0	0	0	0	.
Lycenchelys paxillus	617	0	0	1	0	0	0	0	0	.
Pholis gunnellus	621[1]	0	0	0.75	0.25	0	0	0	0	.
Lumpenus lampretaeformis	622	0	0	0.67	0.33	0	0	0	0	.
Leptoclinus maculatus	623[1]	0	0	1	0	0	0	0	0	.

Taxonomy	Code	PFI	LDFI	BF	PF	MM	DM	FI	BI	Note
Stichaeus punctatus	624	0	0	0.78	0.22	0	0	0	0	.
Ulvaria subbifurcata	625	0	0	0.75	0.25	0	0	0	0	.
Eumesogrammus praecisus	626	0.2	0	0.6	0.2	0	0	0	0	.
Cryptacanthodes maculatus	630	0	0	1	0	0	0	0	0	.
Anisarchus medius	632	0	0	1	0	0	0	0	0	.
Zoarces americanus	640	0	0	1	0	0	0	0	0	.
Melanostigma atlanticum	646	0	0	0	1	0	0	0	0	.
Peprilus triacanthus	701	0	0	0	1	0	0	0	0	.
Borostomias antarcticus	716	0.5	0	0	0.5	0	0	0	0	.
Scomberesox saurus	720	0	0	0	1	0	0	0	0	.
Xenodermichthys copei	725	0	0	0	1	0	0	0	0	.
Sternoptychidae	705	0.2	0	0	0.8	0	0	0	0	.
Myctophiformes	811	0.19	0	0	0.81	0	0	0	0	.
Paraliparis calidus	868	0	0	0.25	0.75	0	0	0	0	.
Epigonus sp.	878	0	0	0.33	0.67	0	0	0	0	.
Hoplostethus mediterraneus mediterraneus	10527	0.5	0	0	0.5	0	0	0	0	.
Seasnail/snailfish unspecified[1]	500	0	0	0	1	0	0	0	0	a
Liparis fabricii	505	0	0	0	1	0	0	0	0	.
Liparis bathyarcticus	7701	0	0	0.75	0.25	0	0	0	0	b
Paraliparis copei	511	0	0	0	1	0	0	0	0	.
Liparis atlanticus	503	0	0	0	1	0	0	0	0	a
Liparis liparis	504	0	0	0	1	0	0	0	0	a
Liparis tunicatus	506	0	0	0	1	0	0	0	0	a
Liparis gibbus	512	0	0	0	1	0	0	0	0	a
Liparis coheni	513	0	0	0	1	0	0	0	0	a
Lycodes unspecified[1]	642	0	0	1	0	0	0	0	0	a
Lycodes terraenovae	619	0	0	1	0	0	0	0	0	.
Lycodes lavalaei	620	0	0	1	0	0	0	0	0	.
Lycodes pallidus	627	0	0	1	0	0	0	0	0	a
Lycodes polaris	628	0	0	1	0	0	0	0	0	.
Lycodes reticulatus	641	0	0	1	0	0	0	0	0	a
Lycodes esmarkii	643	0	0	1	0	0	0	0	0	.
Lycodes vahlii	647	0	0	1	0	0	0	0	0	.
Lumpsuckers unspecified[1]	502	0	0	0.25	0.75	0	0	0	0	a
Eumicrotremus terraenovae	10847	0	0	0.25	0.75	0	0	0	0	.
Paralepididae/Barracundinas[1]	713	0	0	0	1	0	0	0	0	a
Arctozenus risso	712	0	0	0	1	0	0	0	0	.
Paralepis coregonoides	674	0	0	0	1	0	0	0	0	a
PHYLUM: ANNELIDA	3000	0	0	0	0	0	0	0	1	a
Class: Polychaeta	3100	0	0	0	0	0	0	0	1	a
Aphrodita hastata	3200	0	0.5	0	0	0	0	0	0.5	.

Taxonomy	Code	PFI	LDFI	BF	PF	MM	DM	FI	BI	Note
Laetmonice filicornis	7725	0	0	0	0	0	0	0	1	.
Subclass: Cirripedia	2990	0	0	0	0	0	0	1	0	a
Arcoscalpellum michelottianum	7726	0	0	0	0	0	0	1	0	.
Chirona hameri	7800	0	0	0	0	0	0	1	0	.
Order: Decapoda	2100	0	0	0	0	0	1	0	0	a
Lebbeus microceros	1282	0	0	0	0	0	1	0	0	.
Pandalus borealis	2211	0	0	0	0	0	1	0	0	.
Pandalus montagui	2212	0	0	0	0	0.5	0.5	0	0	.
Atlantopandalus propinqvus	2213	0	0	0	0	0	1	0	0	.
Pasiphaea tarda	2220	0	0	0	0	1	0	0	0	.
Pasiphaea multidentata	2221	0	0	0	0	0.5	0.5	0	0	.
Eusergestes arcticus	2223	0	0	0	0	1	0	0	0	.
Lebbeus polaris	2312	0	0	0	0	0	1	0	0	.
Spirontocaris liljeborgii	2313	0	0	0	0	0	1	0	0	.
Spirontocaris phippsii	2315	0	0	0	0	0	1	0	0	.
Spirontocaris spinus	2316	0	0	0	0	0	1	0	0	.
Lebbeus groenlandicus	2319	0	0	0	0	0	1	0	0	.
Eualus macilentus	2331	0	0	0	0	0	1	0	0	.
Eualus fabricii	2332	0	0	0	0	0	1	0	0	.
Eualus gaimardii	2333	0	0	0	0	0	1	0	0	.
Argis dentata	2411	0	0	0	0	0	1	0	0	.
Sclerocrangon boreas	2414	0	0	0	0	0	1	0	0	.
Pontophilus norvegicus	2415	0	0	0	0	0	1	0	0	.
Crangon septemspinosa	2417	0	0	0	0	0	1	0	0	.
Sabinea sarsii	2419	0	0	0	0	0	1	0	0	.
Sabinea septemcarinata	2421	0	0	0	0	0	1	0	0	.
Paramphithoe hystrix	2805	0	0	0	0	0	0	0	1	b
Megamoera dentata	2812	0	0	0	0	0	0	0	1	.
Wimvadocus torelli	2821	0	0	0	0	0	0	0	1	.
Maera loveni	2825	0	0	0	0	0	0	0	1	b
Anonyx sp.	2833	0	0.33	0	0	0	0.33	0	0.34	.
Rhachotropis aculeata	2848	0	0	0	0	0	1	0	0	.
Epimeria loricata	7727	0	0	0	0	0	0	0	1	b
Stegocephalus inflatus	7746	0	0	0	0	0	0	0	1	.
Hymenopenaeus debilis	7802	0	0	0	0	0	1	0	0	b
Eualus belcheri	7805	0	0	0	0	0	1	0	0	b
Plesionika martia	7806	0	0	0	0	1	0	0	0	b
Acanthephyra pelagica	8353	0	0	0	0	1	0	0	0	b
Eusirus cuspidatus	8358	0	0	0	0	0	1	0	0	.
Infraorder: Anomura	2507	0	0.25	0	0	0	0	0	0.75	a
Lithodes maja	2523	0	0.25	0	0	0	0	0	0.75	.
Homarus americanus	2550	0	0.25	0	0	0	0	0	0.75	.

Taxonomy	Code	PFI	LDFI	BF	PF	MM	DM	FI	BI	Note
Pagurus sp.	2561	0	0.5	0	0	0	0	0	0.5	.
Munidopsis curvirostra	2566	0	0.5	0	0	0	0	0	0.5	.
Infraorder: Brachyura	2510	0	0.25	0	0	0	0	0	0.75	a
Cancer irroratus	2513	0	0.25	0	0	0	0	0	0.75	.
Hyas alutaceus	2521	0	0.25	0	0	0	0	0	0.75	.
Chionoecetes opilio	2526	0	0.25	0	0	0	0	0	0.75	.
Hyas araneus	2527	0	0.25	0	0	0	0	0	0.75	.
Class: Pycnogonida	5100	0	0	0	0	0	0	0	1	a
Nymphon sp.	2893	0	0.5	0	0	0	0	0	0.5	.
Pycnogonum litorale	5102	0	0	0	0	0	0	0	1	.
PHYLUM: BRACHIOPODA	1930	0	0	0	0	0	0	1	0	a
Terebratulina septentrionalis	7719	0	0	0	0	0	0	1	0	.
Hemithiris psittacea	7761	0	0	0	0	0	0	1	0	.
PHYLUM: BRYOZOA	1900, 1920	0	0	0	0	0	0	1	0	a
Alcyonidium gelatinosum	7745	0	0	0	0	0	0	1	0	a
Alcyonidium pachydermatum	7759	0	0	0	0	0	0	1	0	a
Securiflustra securifrons	7760	0	0	0	0	0	0	1	0	.
Leieschara sp.	8817	0	0	0	0	0	0	1	0	a
Lafoeina maxima	8818	0	0	0	0	0	0	1	0	a
PHYLUM: CNIDARIA	8200	0	0	0	0	0	0	1	0	a
SUBPHYLUM: ANTHOZOA	8300	0	0	0	0	0	0	1	0	a
Class: Hexacorallia										
Bolocera tuediae	7707	0	0	0	0	0	0	0	1	.
Actinostola callosa	7708	0	0	0	0	0	0	0	1	.
Actinauge cristata	7709	0	0	0	0	0	0	0	1	.
Liponema multicorne	7713	0	0	0	0	0	0	1	0	.
Hormathia digitata	7753	0	0	0	0	0	0	0	1	.
Cribrinopsis similis	7754	0	0	0	0	0	0	0	1	.
Urticina crassicornis	7755	0	0	0	0	0	0	0	1	.
Ptychodactis patula	7756	0	0	0	0	0	0	0	1	.
Actiniaria	8208	0	0	0	0	0	0	0	1	a
Metridium senile	8311	0	0	0	0	0	0	1	0	.
Stomphia coccinea	8313	0	0	0	0	0	0	0	1	.
Hormathia sp.	8316	0	0	0	0	0	0	0	1	a
Hormathia nodosa	8622	0	0	0	0	0	0	0	1	.
Class: Octocorallia	8327	0	0	0	0	0	0	1	0	a
Epizoathus sp.	7706	0	0	0	0	0	0	1	0	a
Duva florida	7710	0	0	0	0	0	0	1	0	.
Drifa glomerata	7711	0	0	0	0	0	0	1	0	.
Pennatula aculeata	7712	0	0	0	0	0	0	1	0	.
Halipteris finmarchica	7714	0	0	0	0	0	0	1	0	.

Taxonomy	Code	PFI	LDFI	BF	PF	MM	DM	FI	BI	Note
Epizoanthus erdmanni	7757	0	0	0	0	0	0	1	0	.
Heteropolypus sp.	7758	0	0	0	0	0	0	1	0	.
Pennatuloidea	8318	0	0	0	0	0	0	1	0	a
Epizoanthus papillosus	8321	0	0	0	0	0	0	1	0	.
Gersemia rubiformis	8324	0	0	0	0	0	0	1	0	.
Stephanauge nexilis	8351	0	0	0	0	0	0	1	0	.
Ptilella grandis	8360	0	0	0	0	0	0	1	0	.
Anthoptilum grandiflorum	8361	0	0	0	0	0	0	1	0	.
Flabellum (Ulocyathus) alabastrum	8362	0	0	0	0	0	0	0	1	.
Gersemia fruticosa	8801	0	0	0	0	0	0	1	0	a
Scleractinia	8803	0	0	0	0	0	0	1	0	a
Pennatula	8825	0	0	0	0	0	0	1	0	a
Kophobelemnon stelliferum	12213	0	0	0	0	0	0	1	0	.
SUBPHYLUM: MEDUSOZOA	8500	0.5	0	0	0	0	0	0	0.5	a
Ptychogena lactea	7702	0	0	0	0	1	0	0	0	b
Periphylla periphylla	7704	0.5	0	0	0	0	0	0	0.5	b
Atolla wyvillei	7705	0	0	0	0	1	0	0	0	b
Staurostoma mertensii	7751	0	0	0	0	1	0	0	0	b
Lucernaria quadricornis	7752	0	0	0	0	0	0	0	1	b
Aurelia aurita	8010	0	0	0	0	1	0	0	0	.
Cyanea capillata	8511	0.5	0	0	0	0	0	0	0.5	.
Stephalia corona	8700	0	0	0	0	0	0	0.5	0.5	b
PHYLUM: ECHINODERMATA	6000	0	0	0	0	0	0	0	1	a
Class: Asteroidea	6100	0	0	0	0	0	0	0	1	a
Tremaster mirabilis	1279	0	0	0	0	0	0	0	1	.
Urasterias lincki	1280	0	0.25	0	0	0	0	0	0.75	.
Ceramaster granularis	6101	0	0	0	0	0	0	0	1	.
Asterias rubens	6111	0	0	0	0	0	0	0	1	.
Leptasterias (Hexasterias) polaris	6113	0	0	0	0	0	0	0	1	.
Ctenodiscus crispatus	6115	0	1	0	0	0	0	0	0	.
Hippasteria phrygiana	6117	0	0	0	0	0	0	0	1	.
Henricia sp.	6118	0	0.25	0	0	0	0	0	0.75	.
Solaster endeca	6121	0	0	0	0	0	0	0	1	.
Crossaster papposus	6123	0	0	0	0	0	0	0	1	.
Pteraster militaris	6125	0	0	0	0	0	0	0	1	.
Diplopteraster multipes	6131	0	0	0	0	0	0	0	1	.
Poraniomorpha sp.	7729	0	1	0	0	0	0	0	0	.
Novodinia americana	7730	0	0	0	0	0	0	0	1	.
Pteraster pulvillus	7748	0	0	0	0	0	0	0	1	.
Pteraster obscurus	7810	0	0	0	0	0	0	0	1	.
Leptasterias groenlandica	7811	0	0	0	0	0	0	0	1	.
Stephanasterias albula	7812	0	0	0	0	0	0	0	1	.

Taxonomy	Code	PFI	LDFI	BF	PF	MM	DM	FI	BI	Note
Pseudarchaster parelii	8346	0	0.5	0	0	0	0	0	0.5	.
Psilaster andromeda	8347	0	0	0	0	0	0	0	1	.
Leptychaster arcticus	8348	0	1	0	0	0	0	0	0	.
Lophaster furcifer	8349	0	0.5	0	0	0	0	0	0.5	.
Class: Echinoidea	6397	0	1	0	0	0	0	0	0	a
Brisaster fragilis	6413	0	1	0	0	0	0	0	0	.
Echinarachnius parma	6511	0	1	0	0	0	0	0	0	.
Sand dollar unspecified	6500	0	1	0	0	0	0	0	0	a
Strongylocentrotus sp.	6400	0	0.25	0	0	0	0	0	0.75	.
Class: Holothuroidea	6600	0	0	0	0	0	0	1	0	a
Cucumaria frondosa	6611	0	0	0	0	0	0	1	0	.
Psolus fabricii	6713	0	0	0	0	0	0	1	0	.
Ekmania barthii	7808	0	0	0	0	0	0	1	0	.
Class: Ophiuroidea	6200	0	0.33	0	0	0	0	0.33	0.34	a
Ophiopholis aculeata	6211	0	0.33	0	0	0	0	0.33	0.34	.
Ophiura sarsii	6213	0	0.5	0	0	0	0	0	0.5	.
Ophiura robusta	6215	0	0.5	0	0	0	0	0	0.5	.
Stegophiura nodosa	6217	0	1	0	0	0	0	0	0	.
Gorgoncephalus unspecified	6310	0	0	0	0	0	0	0.5	0.5	a
Gorgonocephalus arcticus	7813	0	0	0	0	0	0	0.5	0.5	.
Ophiacantha bidentata	7814	0	0.33	0	0	0	0	0.33	0.34	.
Ophioscolex glacialis	7815	0	0	0	0	0	0	0	1	.
Heliometra glacialis	7807	0	0	0	0	0	0	1	0	.
Class: Bivalvia	4300	0	0	0	0	0	0	1	0	a
Thyasira	4302	0	1	0	0	0	0	0	0	.
Placopecten magellanicus	4321	0	0	0	0	0	0	1	0	.
Chlamys islandica	4322	0	0	0	0	0	0	1	0	.
Mytilus sp.	4331	0	0	0	0	0	0	1	0	.
Musculus sp.	4334	0	0	0	0	0	0	1	0	.
Ciliatocardium ciliatum	4342	0	0	0	0	0	0	1	0	.
Serripes groenlandicus	4343	0	0	0	0	0	0	1	0	.
Cyclocardia borealis	4344	0	0	0	0	0	0	1	0	.
Parvicardium pinnulatum	4345	0	0	0	0	0	0	1	0	.
Megayoldia thraciaeformis	4357	0	0.5	0	0	0	0	0	0.5	.
Arvella faba	7786	0	0	0	0	0	0	1	0	.
Similipecten greenlandicus	7788	0	0	0	0	0	0	1	0	.
Class: Cephalopoda	4500	0.5	0	0	0.5	0	0	0	0	a
Illex illecebrosus	4511	0.5	0	0	0.5	0	0	0	0	.
Gonatus fabricii	4599	0.5	0	0	0.5	0	0	0	0	.
Stauroteuthis syrtensis	4661	0	0	0	0.5	0	0	0	0.5	.
Stoloteuthis leucoptera	4662	0.5	0	0	0	0	0	0	0.5	.
Rossia sp.	7723	0.5	0	0	0	0	0	0	0.5	.

Taxonomy	Code	PFI	LDFI	BF	PF	MM	DM	FI	BI	Note
Bathypolypus bairdii	7724	0	0	0	0	0	0	0	1	.
Class: Gastropoda	4200	0	0	0	0	0	0	0	1	a
Buccinum sp.	4210	0	0.5	0	0	0	0	0	0.5	.
Arrhoges occidentalis	7720	0	1	0	0	0	0	0	0	.
Cryptonatica affinis	4222	0	0	0	0	0	0	0	1	.
Scaphander punctostriatus	4431	0	0	0	0	0	0	0	1	.
Lacuna vincta	7767	0	0	0	0	0	0	0	1	.
Ariadnaria borealis	7768	0	1	0	0	0	0	0	0	.
Tachyrhynchus erosus	7769	0	1	0	0	0	0	0	0	.
Solariella sp.	7766	0	0	0	0	0	0	0	1	.
Euspira pallida	7770	0	0	0	0	0	0	0	1	.
Limneria undata	7771	0	0	0	0	0	0	0	1	.
Velutina velutina	4252	0	0	0	0	0	0	0	1	.
Colus pubescens	7741	0	0.5	0	0	0	0	0	0.5	.
Plicifusus kroyeri	7742	0	0.5	0	0	0	0	0	0.5	.
Beringius turtoni	7774	0	0	0	0	0	0	0	1	.
Volutopsius norwegicus	7776	0	0.5	0	0	0	0	0	0.5	.
Neptunea despecta	7777	0	0.5	0	0	0	0	0	0.5	.
Colus stimpsoni	7778	0	0.5	0	0	0	0	0	0.5	.
Aulacofusus brevicauda	7779	0	0.5	0	0	0	0	0	0.5	.
Boreotrophon clathratus	7772	0	0	0	0	0	0	0	1	.
Scabrotrophon fabricii	7773	0	0	0	0	0	0	0	1	.
Order: Nacellida	5200	0	0	0	0	0	0	0	1	a
Lepeta caeca	7765	0	0	0	0	0	0	0	1	.
Order: Nudibranchia	4400	0	0	0	0	0	0	0	1	a
Dendronotus sp.	4410	0	0	0	0	0	0	0	1	.
Colga villosa	7782	0	0	0	0	0	0	0	1	.
Doridoxa walteri	7783	0	0	0	0	0	0	0	1	.
Order: Trochida	4255	0	0	0	0	0	0	0	1	a
Margarites costalis	4224	0	0	0	0	0	0	0	1	.
Margarites groenlandicus	4225	0	0	0	0	0	0	0	1	.
Class: Polyplacophora	4700	0	0	0	0	0	0	0	1	a
Tonicellidae	7762, 4713	0	0.5	0	0	0	0	0	0.5	.
Amicula vestita	4711	0	0	0	0	0	0	0	1	.
Hanleya hanleyi	7763	0	0	0	0	0	0	0	1	.
Stenosemus albus	7764	0	0.5	0	0	0	0	0	0.5	.
SUBPHYLUM: TUNICATA	1810	0	0	0	0	0	0	1	0	a
Ascidia sp.	1821	0	0	0	0	0	0	1	0	.
Synoicum pulmonaria	7816	0	0	0	0	0	0	1	0	.
Eudistoma vitreum	7734	0	0	0	0	0	0	1	0	.
Pelonaia corrugata	7817	0	0	0	0	0	0	1	0	.

Taxonomy	Code	PFI	LDFI	BF	PF	MM	DM	FI	BI	Note
Polycarpa fibrosa	7735	0	0	0	0	0	0	1	0	.
Boltenia ovifera	7749	0	0	0	0	0	0	1	0	.
Botrylloides aureus	.	0	0	0	0	0	0	1	0	.
Halocynthia pyriformis	1827	0	0	0	0	0	0	1	0	.

NOTES:

[1] Groupings and species identification errors are corrected according to Benoît (2006).

[a] These taxa were not included in Isabel et al. (2025a) and were assigned to the trophic guild that most frequently (or most simply) represented their trophic ecological function as identified by other taxa within the taxonomic group.

[b] Represent taxa that were not considered in identifying the trophic guild of the higher taxonomic classification, as they did not occur in the southern Gulf of St. Lawrence survey.

APPENDIX C: LENGTH-WEIGHT FACTORS FOR THE SOUTHERN GULF OF ST. LAWRENCE MULTI-SPECIES RESEARCH VESSEL SURVEY

Table C1. Parameters (intercept (ln(a)) and slope (b)) of the length-weight relationship calculated for each taxon in the southern Gulf of St. Lawrence research vessel survey included in the condition indicator calculated with length-weight data available.

English name	Latin name	ln(a)	b
Alligatorfish	*Aspidophoroides monopterygius*	-1.640	1.971
American Plaice	*Hippoglossoides platessoides*	-2.396	3.207
Atlantic Cod	*Gadus morhua*	-2.251	3.126
Atlantic Mackerel	*Scomber scombrus*	-2.365	3.262
Capelin	*Mallotus villosus*	-2.444	3.124
Daubed Shanny	*Leptoclinus maculatus*	-2.086	2.541
Greenland Halibut	*Reinhardtius hippoglossoides*	-2.429	3.228
Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	-2.219	3.174
Moustache Sculpin	*Triglops murrayi*	-1.969	2.817
Redfish	*Sebastes spp.*	-1.980	3.099
Thorny Skate	*Amblyraja radiata*	-2.129	3.101
White Hake	*Urophycis tenuis*	-2.340	3.132
Winter Flounder	*Pseudopleuronectes americanus*	-2.217	3.208
Yellowtail Flounder	*Myzopsetta ferruginea*	-2.273	3.148

APPENDIX D: FISH CONDITION FROM THE MULTI-SPECIES RESEARCH VESSEL SURVEYS

Figure D1. Condition indicator for each taxon grouped by habitat guild from the multi-species research vessel surveys in the northern Gulf of St. Lawrence (nGSL; red circle) and southern Gulf of St. Lawrence (sGSL; blue triangle).