

Existing regional environmental characteristics for the Scotian Shelf-Bay of Fundy [follow-up information]

DFO Maritimes response to Request for Advice from the Committee for the Regional Assessment of Offshore Wind Development in Nova Scotia

November 2023

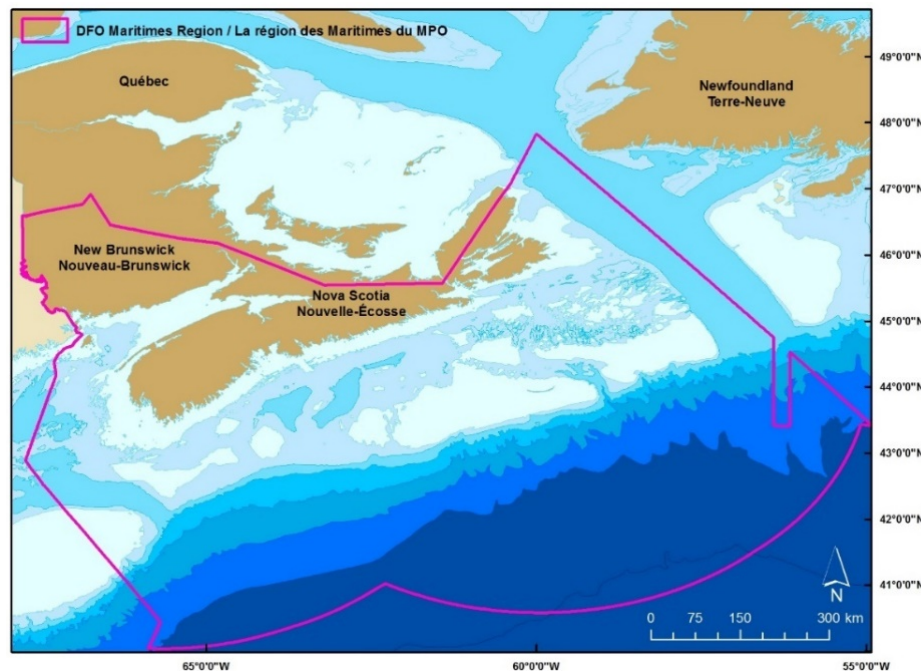
Prepared by the DFO Maritimes Marine Planning and Conservation (MPC) Directorate with input from Science Branch and Resource Management

Purpose of Document

This document serves as the follow-up to an October 31st submission from Fisheries and Oceans Canada (DFO) **Maritimes Region** in response to the Request for Advice (RFA) submitted by the Impact Assessment Agency of Canada on August 8, 2023. This document includes information that was not yet available at the time of the original submission. This response summarizes information from several sources, including published literature as well as input from several subject matter experts. Note that while what is presented here represents some outstanding information that was specifically requested (e.g., chlorophyll-a concentrations), additional information that DFO views as important has also been provided.

The information represented here should not be considered comprehensive of the entire Maritimes Region.

Finally, some additional information remains outstanding and will be provided at a later date. DFO will continue to communicate the status of this information until it is submitted.



Map of DFO Maritimes Region administrative boundary

1. Trends in Plankton

1.1 Phytoplankton

The Scotian Shelf is a dynamic meso-trophic environment (i.e., relatively productive) with strong seasonal cycles in phytoplankton biomass marked by patchiness as a result of bottom topography and physical and chemical forcing (Figure 1A in the Appendix). In brief, phytoplankton primary production occurs when there is adequate light and nutrient availability. Exponential growth of phytoplankton occurs in spring when the water column stabilizes following strong winter mixing that replenishes nutrients in the surface layer but reduces phytoplankton exposure to light (Figure 1B). Spring phytoplankton blooms occur as a result of high spring production and relatively low grazing by zooplankton, leading to a high phytoplankton biomass in surface waters until grazing rates catch up to production rates and nutrients become depleted. In spring, the entire shelf sees high concentrations of phytoplankton biomass dominated by lipid-rich diatoms. An increase in stratification and shallowing of the mixed layer depth in summer results in nutrient-limitation in surface waters and lower level of phytoplankton biomass, with a shift in community composition to dominance of flagellates (i.e., smaller, less lipid rich phytoplankton; Figure 1C). The summer season sees the deep maximum of chlorophyll-a (i.e., a proxy for phytoplankton biomass) occur between 20 and 40m depending on the nitracline depth. As fall storms mix the water column and inject nutrients back into the surface waters, a secondary bloom dominated by dinoflagellates occurs with less intensity than the spring bloom (Figure 1D). Winter surface phytoplankton production levels can vary depending on local mixing and transient water column stratification, as the water column is replenished in nutrients (Figure 1E). Regular samples collected by the Atlantic Zone Monitoring Program at the HL-02 station on the central Scotian Shelf (see Figure 1 page 29 in Casault *et al.*, 2023) provide broad information on phytoplankton taxonomic succession on the Scotian Shelf (Figure 2), with diatoms as the most abundant taxonomic group in spring followed by a rapid decrease in summer when flagellates dominate the phytoplankton assemblage. Dinoflagellates increase in Fall (September/October).

The spring bloom, a major annual event that sustains marine food webs, is both spatially and temporally variable. The spring bloom is tracked using satellite observations, and it is described by initiation (day of year), duration (number of days), amplitude (mg m^{-3}) and magnitude (mg m^{-3}) in selected regions of the Scotian Shelf to report on the state of the Northwest Atlantic using deviation from average conditions as metrics (i.e., anomaly; see Casault *et al.*, 2023 for box boundaries). Anomalies do not reveal any significant trends in the phytoplankton bloom metrics, but rather highlight the high spatio-temporal variability of the spring bloom on the Scotian Shelf (Figure 3). When looking at the annual mean of chlorophyll-a concentration as observed by ocean colour satellites (i.e., the first tens of meters), phytoplankton biomass seems to have increased in the last two decades with the largest positive anomaly observed in 2021. Analysis of phytoplankton absorption, an index of its color, from samples collected in situ, show a decrease of biomass in Spring with a slight shift towards green algae and an increase in biomass in Fall towards red algae over the last 20-years or so (Devred *et al.*, 2022).

1.1.1 A region of interest southwest of Sable Island

A satellite based study by Devred *et al.*, 2021 revealed the presence of a phytoplankton hotspot occurring from mid-February to mid-April on Sable Island Bank (Figure 4). The phytoplankton biomass in that area has been continuously increasing over the last 20-years, corresponding to an increase in the seal population on Sable Island from about 20,000 to 400,000 during the mating season. The release of nitrogen in the environment of Sable Island by seal defecation is assumed to fertilize the ocean and

contribute to sustaining phytoplankton growth at a time of year when nutrient supply may be a limiting factor.

1.2 Zooplankton

Zooplankton are the main secondary producers on the Scotian Shelf, consuming phytoplankton and other small plankton, and transferring energy from primary production into the food web when they are consumed by other invertebrates, fish, seabirds, and marine mammals. Copepods are a dominant component of the Scotian Shelf mesozooplankton, and other numerically important taxa include Appendicularia, Euphausiacea (krill), pelagic Gastropoda, and Chaetognatha (Casault *et al.*, 2023). Meroplankton (larvae of benthic adults) and other groups can be abundant locally. The large copepod species *Calanus finmarchicus* and *Calanus hyperboreus* are biomass-dominant members of the zooplankton community. These large copepods have a life cycle that includes a period of diapause (i.e., suspended development) during which they migrate to deep water for part of the year, generally from late summer to winter or early spring. During their active period of development in surface waters, *Calanus* species utilize spring bloom production to grow, develop, and store lipid for diapause and for reproduction when they emerge from diapause. Due to their high lipid content during diapause, they are a particularly important taxon contributing to energy flux through the ecosystem. These species were lower in abundance on the Scotian Shelf in the 2010s and early 2020s than in the 2000s, likely due to warming shelf temperature and changes in ocean circulation (Casault *et al.*, 2023).

Zooplankton exhibit ecologically important variability across a large range of spatial scales from fine scales (meters -10s of meters) to ocean-basin scales and across time scales (e.g., Haury *et al.*, 1978). The horizontal spatial distribution of the Scotian Shelf zooplankton and ichthyoplankton communities are strongly structured by bottom depth and large-scale temperature gradients on the shelf, with different species dominating bank, basin, and slope water areas (O’Boyle *et al.*, 1984; Pepin *et al.*, 2015; Shackell & Frank, 2000; Tremblay & Roff, 1983). *Calanus* species’ horizontal distributions shift seasonally, with high abundances on productive bank regions during the spring bloom and summer periods and in basins and slope water during their diapause period.

Sustained ocean observing programs led by DFO provide insight on regional scale spatial variability and annual to interdecadal temporal variability in the shelf environment and plankton, but they were not designed to characterize more localized hotspots of zooplankton biomass and production (Therriault *et al.* 1998). Ocean observing on the Scotian Shelf focuses mainly on variability of mesozooplankton (200 µm – 20 mm size), while variability in ichthyoplankton, macrozooplankton and micronekton less well characterized. Euphausiids, a major component of the macrozooplankton, are distributed in shelf basins > 200 m in depth (e.g., Emerald, LaHave, and Roseway Basins) and in Scotian Slope waters and are important prey for many fish and marine mammal species, including endangered blue whale (e.g., Sameoto *et al.*, 1994). Scotian Shelf warming and changes in Gulf Stream dynamics have influenced plankton abundance, biomass, and community composition on the Scotian Shelf in the 2010s and early 2020s (Casault *et al.*, 2023), but additional analysis is required to characterize mechanisms driving the changes, relationships to higher trophic levels, and future state of the Scotian Shelf plankton. Trends in Plankton Macroalgae – K. Krumhansl, C. DiBacco, T. Baker, C. Brooks, B. Lowen

2. Trends in Plankton Macroalgae

2.1. Macroalgae

Macroalgae (i.e. seaweed) are a large group of multicellular, macroscopic algae that includes species of brown (Phaeophyta), red (Rhodophyta), and green (Chlorophyta) seaweeds (Wernberg *et al.*, 2019). In Nova Scotia, the dominant macroalgal communities in the rocky intertidal and subtidal zones are composed of various species of brown algae, including kelps (Laminariales) and fucoids (Fucales), as well as understory and turfing communities of red, brown, and green seaweeds (Krumhansl *et al.*, 2023 *in press*). These seaweeds provide structural habitat for a diversity of associated organisms and support numerous ecosystem services, including carbon sequestration, support of commercial fisheries (e.g. lobster, sea urchin, rock crab, pollock), and nutrient cycling and storage in the coastal zone (Eger *et al.*, 2023).

Native kelp forests (composed mainly of *Saccharina latissima*, *Laminaria digitata*, *Alaria esculenta*, *Agarum clathratum*) dominated the rocky subtidal zones prior to the 2000s, fluctuating in abundance in relation to outbreaks of grazing sea urchins (*Strongylocentrotus droebachiensis*). In the early and mid-2000s, kelp forests experienced declines due to species invasion and climate change (Filbee-Dexter *et al.*, 2016), but are currently widely abundant on wave-exposed and semi-protected shores (Krumhansl *et al.*, 2023 *in press*). Some area where native kelp communities existed previously, however, are now dominated by communities of invasive seaweeds, mainly *Fucus serratus*, *Bonnemaisonia hamifera*, *Dasysiphona japonica*, *Codium fragile*, and *Antithamnion sparsum* (Brooks & Krumhansl 2023, Krumhansl *et al.*, 2023 *in press*). Figure 5 in the Appendix shows percent cover of two dominant species of kelp in Nova Scotia and the Bay of Fundy from camera surveys (from Krumhansl *et al.*, *in press*).

2.2 Distribution

Species distribution models for *Laminaria digitata* and *Saccharina latissima* were produced using the standalone Java application Maxent (Phillips *et al.*, 2004). The occurrence data used to calibrate these models were collated from various source including DFO survey data, publications, and online data repositories. The environmental data used include six measures of sea surface temperature (fall mean, winter mean, spring mean, summer mean, annual minimum, and annual maximum), one measure of sea surface salinity (annual mean), a relative exposure index layer, and a substrate classification layer (Greenlaw and Harvey, 2022; O'Brien, Wong; and Stanley, 2022). The species-environment relationships were modelled within Maxent using linear, quadratic, and hinge features. The resulting models were evaluated by assessing two test metrics, their test AUC (i.e., area under the receiver operating characteristic curve) and their 10th percentile training presence test omission rate (hereafter referred to as the 10th percentile omission rate). The *Laminaria digitata* model has a AUC value of 0.847 and a 10th percentile omission rate of 0.1192, while the *Saccharina latissima* model has a AUC value of 0.876 and a 10th percentile omission rate of 0.1191. To convert the continuous (i.e., cloglog) model outputs produced by Maxent into binary predictions of presence and absence, the threshold that maximized the the sum of the sensitivity and specificity of each model was applied (Liu *et al.*, 2013). For *Laminaria digitata* this threshold was determined to be 0.467, while for *Saccharina latissima* it was determined to be 0.304.

2.3 Data collection gaps

Data on macroalgal distributions is limited. Historical surveys have only covered small portions of the species range in the region and have mainly targeted native kelp communities. These survey efforts have been inconsistent spatially and have only occurred intermittently in time, creating difficulties in

understanding the trajectory of change in these communities. Moreover, only limited attention has been paid to characterizing other macroalgal species associated with kelp forests, including the occurrence and distribution of invasive species in these habitats. A recent set of surveys in 2019-2023 have worked to fill these gaps in knowledge, but ongoing monitoring is required.

3. Sea Grass

3.1 Eelgrass characteristics

Eelgrass (*Zostera marina*) is the dominant seagrass species found on all three of Canada's coasts (Murphy *et al.* 2021). This marine flowering plant, one of ~76 species of seagrasses worldwide, form vast underwater meadows in the marine nearshore. Seagrass habitats are structurally complex and highly productive, and are recognized as providing numerous valuable ecosystem services, including carbon storage, fisheries maintenance, shoreline stabilization, and water filtration (Barbier *et al.*, 2011, Nordlund *et al.* 2016).

Eelgrass is typically found in nearshore shallow waters, from the intertidal to depths of ~10m, although maximum depths depend on localized water clarity (Krumhansl *et al.* 2021). Eelgrass plants are different from macroalgae (seaweeds) in that they only root in soft-sediments and do not attach to rocks. They are highly responsive to environmental change, and as such, exhibit high spatial heterogeneity in life history, phenology, and plant and bed structure (Krumhansl *et al.* 2021). Beds can be both perennial or annual, with perennial beds persisting over winter, growing both vegetatively and through sexual reproduction (Vercaemer *et al.* 2019). Annual beds die over the winter, and reproduce the following spring through seed germination. In Atlantic Canada, eelgrass beds are typically perennial, with the relative importance of sexual reproduction being highly variable.

Eelgrass phenology in temperate regions follows a typical seasonal cycle, with highest growth rates in the spring to mid-summer, and partial senescence of beds in the late fall and winter (Wong *et al.* 2013). Given that most beds in Atlantic Canada are perennial, beds will persist through the winter, but usually have low cover and shoot density. The underground root-rhizome system is important for winter maintenance, as it provides nutrients supplies when photosynthesis is not possible. Recent work has shown that phenological patterns can vary depending on environmental conditions; beds in shallow waters with warm summer temperatures tend to have larger seasonal differences than deeper beds (Wong and Dowd in press).

Eelgrass bed properties are strongly shaped by their surrounding environment. In Atlantic Canada, beds are found across a wide gradient of environmental conditions, ranging from shallow, warm, sheltered waters with muddy/silty sediments to deeper, colder more exposed waters with sandy/gravelly sediments (Wong 2018, Wong 2019, Krumhansl *et al.* 2021, Wong and Dowd in press). Beds in shallow waters that experience warm and highly variable temperature regimes tend to have higher shoot density, higher vegetative growth, and lower morphology (fewer leaves that are shorter and thinner, and thinner rhizomes) than beds in cool and less variable temperature regimes. Eelgrass beds in Atlantic Canada thus tend to be highly heterogeneous in their properties, which influences their production and resilience capacity and ultimately their provision of ecosystem services across wide spatial scales.

3.2 Eelgrass distribution

In Atlantic Canada, eelgrass is commonly found in most estuaries, lagoons, coastal bays, and sheltered shorelines. Specific to the offshore wind (OSW) assessment area, eelgrass is found along the entire Atlantic and north coasts of Nova Scotia, including Cape Breton (Figure 8 in the Appendix). However, it does not typically occur in the Bay of Fundy, where extreme tidal heights and high sediment loads preclude eelgrass persistence.

Eelgrass presence and extent on the Atlantic coast of NS has been the focus of several recent studies. Drop camera surveys between 2019 and 2021 were conducted along the entire coastline to record eelgrass presence and percent cover (Figure 8). These surveys indicated the presence of eelgrass along coastal NS, even in regions with differing physiographic and oceanographic nearshore conditions, shown by the nine different coastline classes in Figure 8. These drop camera surveys were used to develop a high resolution (30m) species distribution model for eelgrass in this region (O'Brien *et al.* 2022). The model had good performance in predicting suitable habitat for eelgrass based on depth, exposure, and sediment type. Suitable eelgrass habitat was predicted along the entire NS coast, although it was highly spatially variable (Figure 9), reflecting heterogeneity in the model predictors (depth, exposure, sediment type). It should be noted that this SDM predicts probability of suitable eelgrass habitat, and not eelgrass extent measured in-situ or by remote sensing. The amount of suitable eelgrass habitat from the SDM in the OSW assessment area is 39560.4 Ha (Figure 9).

Mapping of eelgrass extent in the OSW assessment area has been patchy, often driven by localized projects and specific research objectives. The NETForce (National Eelgrass Task Force) project aimed to collate all available data of eelgrass extent and presence/absence across Canada to create a national eelgrass map. Mapping techniques included satellite, benthic sonar, video, aerial imagery, LiDAR, UAV imagery, and species distribution modelling. The national dataset is available at <https://open.canada.ca/data/en/dataset/a733fb88-ddaf-47f8-95bb-e107630e8e62>. Within this dataset, there are data of eelgrass extent and/or presence/absence data relevant for the OSW assessment area, including Medway Harbour, Black Point Bay, Port Joli, Kejimkujik Seaside, Cole Harbour, Musquodoboit Harbour, Petpeswick Inlet, Jeddore Harbour, Eastern Shore Island, Pugwash Harbour and Port Philip, Pictou, Caribou Harbour, Little Harbour and Merigomish, and the Bras d'Or Lakes (Figure 10). These eelgrass extent maps represent only a small portion of the likely total eelgrass coverage along coastal NS. Eelgrass extent in the OSW assessment area is 4219.4 Ha based on the in-situ mapping and remote sensing data (Figure 10), but this is in all certainty an underestimate of eelgrass coverage in the OSW area.

3.3 Spatial and temporal trends

Seagrass beds worldwide have experienced significant declines across the last few decades (Dunic *et al.* 2021). These declines are primarily linked to decreased water quality and increased habitat loss. However, trajectories of change can be highly variable, depending on localized conditions. A recent study used an ECCC dataset (ECCC 2020) to examine temporal trends across 36 eelgrass beds in Atlantic Canada (Murphy *et al.* 2021). 69% of these beds were stable or increasing in cover over time, while 31% were decreasing. This analysis provides first insights into eelgrass temporal trends for the region, but general baseline and monitoring data are lacking to provide full insights into eelgrass status in Atlantic Canada.

3.4 Knowledge gaps

Eelgrass maps of extent and cover are relatively sparse for most of Canada's coastline, including Atlantic Canada and the OSW assessment area. Estimates of eelgrass extent within the OSW area based on direct

mapping activities are currently highly underestimated, and can only be improved by increasing mapping activities. This mapping should use a combination of techniques that are useful in the varied conditions that eelgrass inhabits. Mapping activities should also be conducted at appropriate spatial and temporal scales to adequately capture changes.

Distribution of eelgrass under future climate change scenarios also requires additional attention. Eelgrass in the region is already responding to climate stressors, which will be further exacerbated by localized disturbances. Distribution shifts under further climate scenarios, particularly at spatial scales that capture the inherent heterogeneity in eelgrass properties, remain unknown. While the SDM model had good predictive capability, it can be further improved by including more climate variables and providing predictions under different climate change scenarios.

Finally, assessment of eelgrass to stressors not only depends on knowing eelgrass distribution, but also on its functioning (i.e., production and resilience capacity). Eelgrass functioning is highly heterogeneous, shaped by both local and global drivers. While eelgrass properties in Atlantic NS have been shown to change according to temperature and light regimes, further work is required to fully understand how these dynamics under baseline and future conditions.

1.6 Current knowledge of Atlantic salmon presence / migration through the Study Area.

- This information is forthcoming and will be provided at a later date, per discussions with IAAC.

1.7 Current knowledge of American eel presence / migration through the Study Area.

- This information is forthcoming and will be provided at a later date, per discussions with IAAC.

1.9 Identified gaps related to data collection within the region (e.g., areas that are data-sparse or poorly understood).

- Provided throughout.

4. Marine Mammals and Sea Turtles

4.1 Overview / summary of marine mammals and sea turtle species that could be found within the Study Area and the times of year of their presence. This can be grouped under sub-headings such as Baleen Whales, Toothed Whales, Pinnipeds, Sea turtles, etc.

4.1.1 Pinnipeds

There are 2 species of pinnipeds, grey seals (*Halichoerus grypus*) and harbour seals (*Phoca vitulina*) for which the 'Study Area' encompasses a part of their range.

Grey seals aggregate in large pupping and breeding colonies between December and February in the Northwest Atlantic (NWA). The largest grey seal breeding colony in the world is on Sable Island. It accounts for 80% of pup production in the NWA (den Heyer et al. 2021, DFO 2022). There are other smaller breeding colonies from Cape Cod to Eastern tip of Cape Breton and into the Gulf of St. Lawrence (GSL). On the Atlantic Coast of Nova Scotia, breeding colonies have been established on Hay Island and on 4 small islands in southwest Nova Scotia since the 1990s, while the breeding colonies on the eastern shore have declined. In GSL, grey seals have historically pupped on ice, but with the lack of ice have established breeding colonies along the coast of Nova Scotia (inside the Study Area) and in the center of GSL (outside the Study Area). Outside the breeding season grey seals forage from Cape Cod to Labrador. A recent comprehensive aerial summer haul out survey for Atlantic Canada was completed between

2019 and 2021 (Hamilton et al. 2023; Lidgard et al. 2023; Mosnier et al. 2023). The three technical documents that describe the summer haul out survey have recently been published and include maps of grey seal haul-out locations and counts. Satellite telemetry tags affixed to grey seals before and to a greater extent after the moult (May to June) have been used to improve understanding of the foraging ecology of grey seals (Breed et al. 2006, 2009, 2013; Lidgard et al. 2012, 2014, 2020; Nowak et al. 2020, 2023).

The grey seal population is assessed roughly every 5 years to provide harvest advice. The most recent population estimate was 366,400 seals in 2021 (DFO 2022). Commercial harvests of young of the year occur in winter at the breeding colonies in central GSL, the Northumberland Coast of Nova Scotia and to a lesser extent on breeding colonies in Cape Breton.

Harbour seals in NWA pup and breed during May and June and moult in July and August. NWA harbour seals are less abundant and less well studied in Canada than grey seals. A recent comprehensive aerial summer haul out survey for Atlantic Canada was completed between 2019 and 2021 (Hamilton et al. 2023; Lidgard et al. 2023; Mosnier et al. 2023). The three technical documents that describe the summer haul out survey have recently been published and include maps of harbour seal pupping and haul-out locations and counts.

Harbour seals in NWA are thought to have recovered after the cessation of culls and harvests in the 1980s. Notably, the harbour seals on Sable Island were well studied throughout 1990s and collapsed because of competition with the increasing grey seal population and predation (Lucas & Natanson, 2010; Lucas & Stobo, 2000; Bowen et al., 2003). A CSAS process to review estimates of total population size and provide estimates of potential biological removals was completed in October 2023. The SAR is still undergoing review and approvals but should be public in coming months.

4.2 Species listed under SARA (Schedule 1) and COSEWIC, and any associated critical habitat for those species.

- Grey seals are listed as Not at Risk under the *Species at Risk Act*
- Harbour seals (Atlantic and Eastern Arctic subspecies) are listed as Not at Risk under the *Species at Risk Act*

4.3 Other identified key areas or times for marine mammals within the Study Area (e.g., feeding, breeding, nursing, migration, etc.).

- See information provided in section 4.1.1

4.5 Discussion of recent and predicted future trends of species movements / distribution attributed to climate change factors / influence.

Grey seal breeding season has shifted earlier and this may have impacts on pup foraging success, but has not impacted maternal investment in offspring (Bowen et al. 2020). In GSL, the lack of ice and switch to terrestrial breeding sites (DFO 2022, den Heyer et al. 2021), is expected to improve survival of the pups and could support faster population growth (Hammill et al. 2017).

For harbour seals, the increase in greys seals may have had negative impacts because of competition (Lucas & Stobo, 2000; Bowen et al., 2003). The increasing grey seal population may also attract and maintain predators, which may also target harbour seals.

4.6 Data gaps around marine mammals and sea turtles, including data collection and interpretation, as well as unknown species presence / distribution.

Grey seal population size is monitored and estimated for stock assessment and harvest advice and ecosystem and multi-species models. Satellite telemetry data have been accumulated from a number of research projects that involved tagging on Sable and coastal haul-out locations (Breed et al. 2006, 2009, 2013; Lidgard et al. 2012, 2014, 2020; Nowak et al. 2020, 2023). These tracks provide indication of the foraging areas for the grey seals, but systematic surveys of distribution outside the breeding season have not been completed until 2019-2021 summer haul out survey.

Harbour seals have not been well studied in Atlantic Canada and apart from St. Lawrence Estuary (outside the Study Area e.g. Robillard et al., 2005; Renaud et al. 2023) and Sable Island (Bowen et al., 2003; Lucas & Natanson, 2010; Lucas & Stobo, 2000), little is known about trends in abundance. There is also uncertainty in the timing of pupping and moulting and very little data on foraging distribution and diet.

Mapping/data requirements

See references below:

- den Heyer, C.E., W.D. Bowen, J. Dale, J.F. Gosselin, M.O. Hammill, D.W. Johnston, S.L.C. Lang, K.T. Murray, G.B. Stenson, and S.A. Wood. 2021. Contrasting trends in gray seal (*Halichoerus grypus*) pup production throughout the increasing northwest Atlantic metapopulation, *Marine Mammal Science*. 37: 611– 630. <https://doi.org/10.1111/mms.12773>
- DFO. 2022. Stock assessment of Northwest Atlantic grey seals (*Halichoerus grypus*) in Canada in 2021. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2022/018 https://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2022/2022_018-eng.pdf.
- Hamilton CD, Goulet PJ, Stenson GB, Lang SLC. 2023. Counts and spatial distribution of harbour (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) from an aerial survey of the coast of the Newfoundland Shelf and Sandwich Bay, Labrador during the summer of 2021. *Can. Tech. Rep. Fish. Aquat. Sci.* 3566 : v + 39 p.
- Lidgard D, Dispas A, Mosnier A, Varkey P, Kehler D, den Heyer C (2023) Distribution and counts of harbour (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) on the Atlantic coast of Nova Scotia and Bay of Fundy from aerial and land surveys, 2019-2021. *Can. Tech. Rep. Fish. Aquat. Sci.* 3569: v + 88 p.
- Mosnier A, Dispas A, Hammill MO (2023) Spatial distribution and count of harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) in the Estuary and Gulf of St. Lawrence from an aerial survey conducted in June 2019. *Can. Tech. Rep. Fish. Aquat. Sci.* 3541 : v+60 p.

5. Commercial, Recreational, and Indigenous Fisheries

General overview of Commercial fishing within the region, including:

5.1 Overview of current and anticipated future moderate livelihood fisheries within the Study Area, and the temporal and spatial distribution.

- The only moderate livelihood authorizations to date are for:
 - Lobster Fishing Areas (LFA) 27-31A and 33-38

- Elver in rivers in New Brunswick and Nova Scotia
- For additional information on moderate livelihood fisheries please contact DFO directly.

6. Additional information

The points below are provided as addendums to the information in section 4.3 of DFO's first submission to IAAC sent on October 31st, 2023 on research vessel (RV) survey operations.

- Groundfish stock assessments and annual scientific catch advice provided to DFO Resource Management rely on fishery-independent data from the spring (NAFO 4X5Z; 1987+) and summer (NAFO 4VWX5Z; 1970+) Maritimes Ecosystem Surveys.
- Closing areas to surveys would affect survey design including station allocation, stratification, coverage, and overall, the continuity of these long-term time series for assessments.
- Domestic stocks affected by a change in survey design include NAFO 4X5Y Atlantic Cod, 4VsW Atlantic Cod, 4Vn Atlantic Cod, Eastern Component Pollock, Western Component Pollock, 4VWX5 Silver Hake, 4X5Y Haddock, 4VW Haddock, 4VWX Yellowtail, and 3NOPs4VWX5Zc Halibut
- The transboundary 5ZE Haddock, Atlantic Cod and Yellowtail Flounder transboundary stocks, and the current sharing agreement method for resource allocation for US and Canada, would also be affected.

Appendix

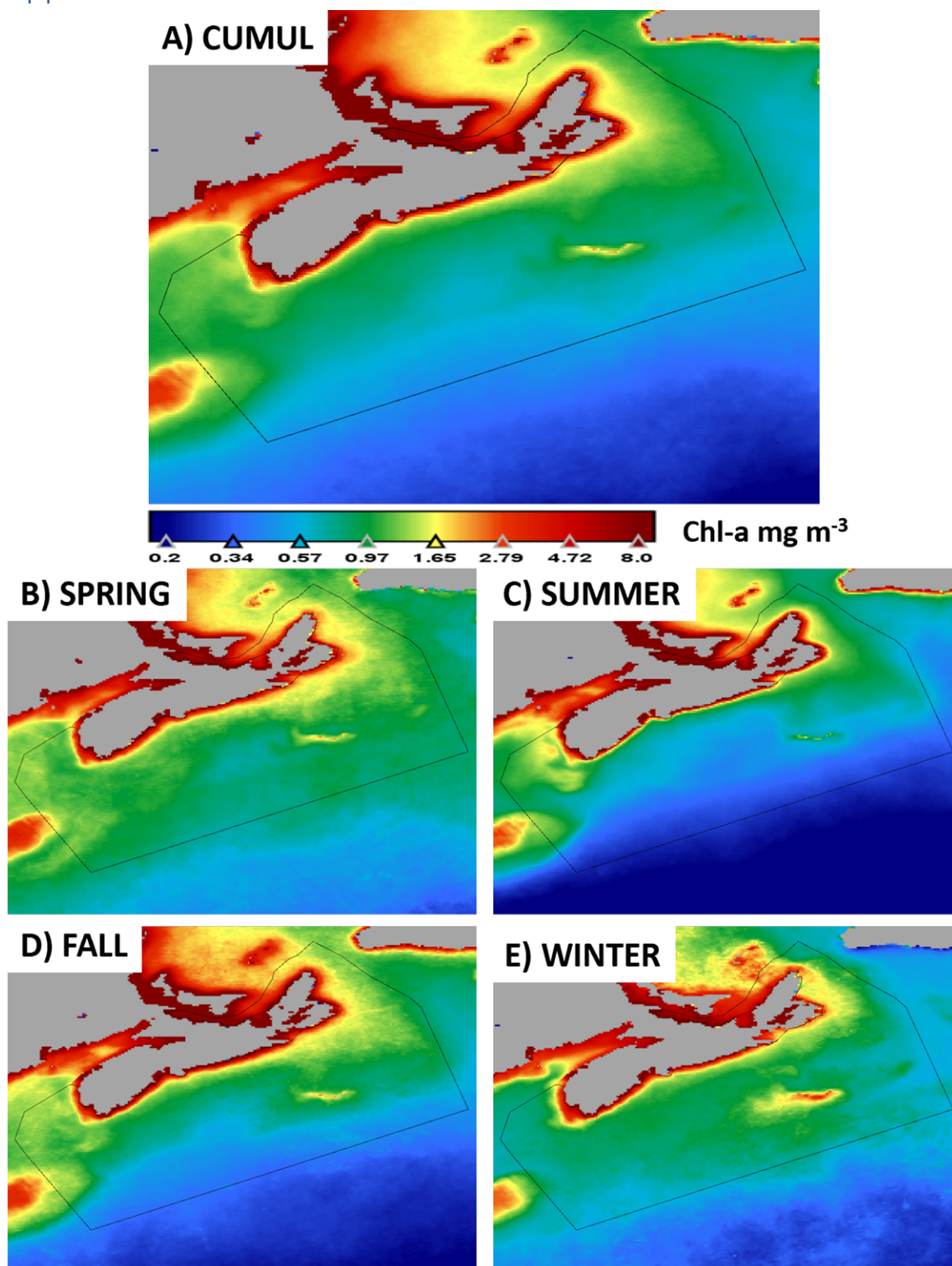


Figure 1. 2002-2023 Seasonal Climatology of chlorophyll-a concentration from MODIS-Aqua satellite using the OCx algorithm. The Black solid line represents the boundaries of the region of interest.

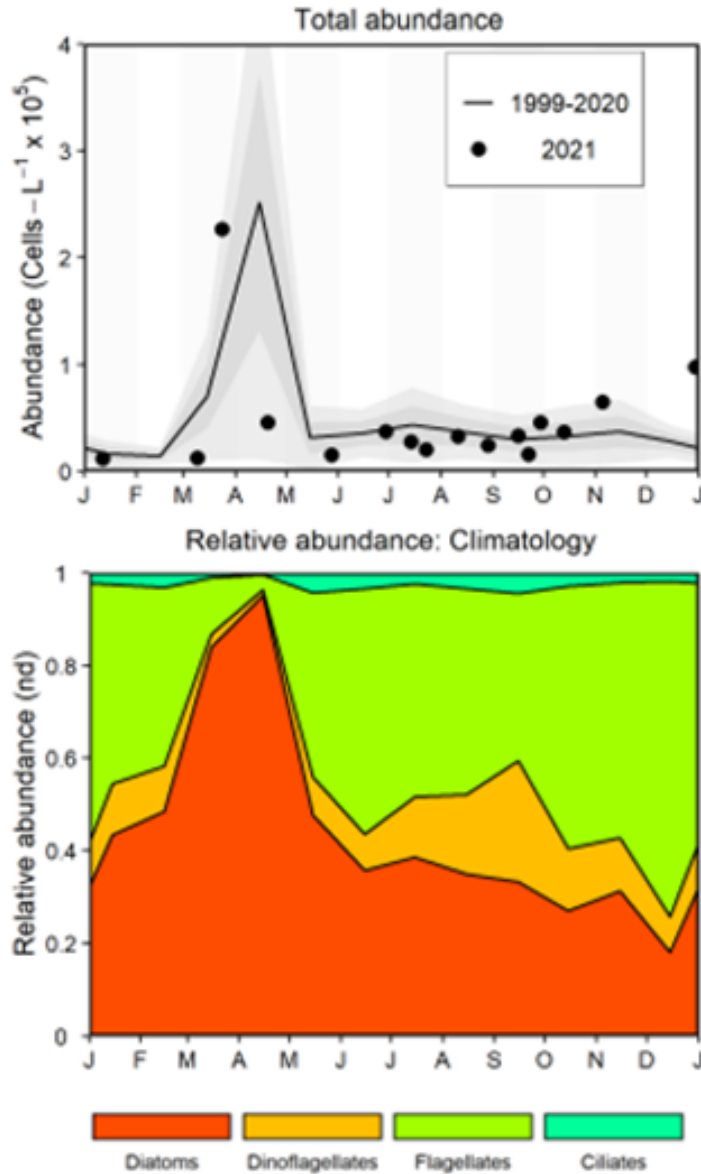


Figure 2. Climatology of total and relative abundance of diatoms, dinoflagellates, flagellates and ciliates at the HL-02 station (image reproduced from Casault *et al.*, 2023)

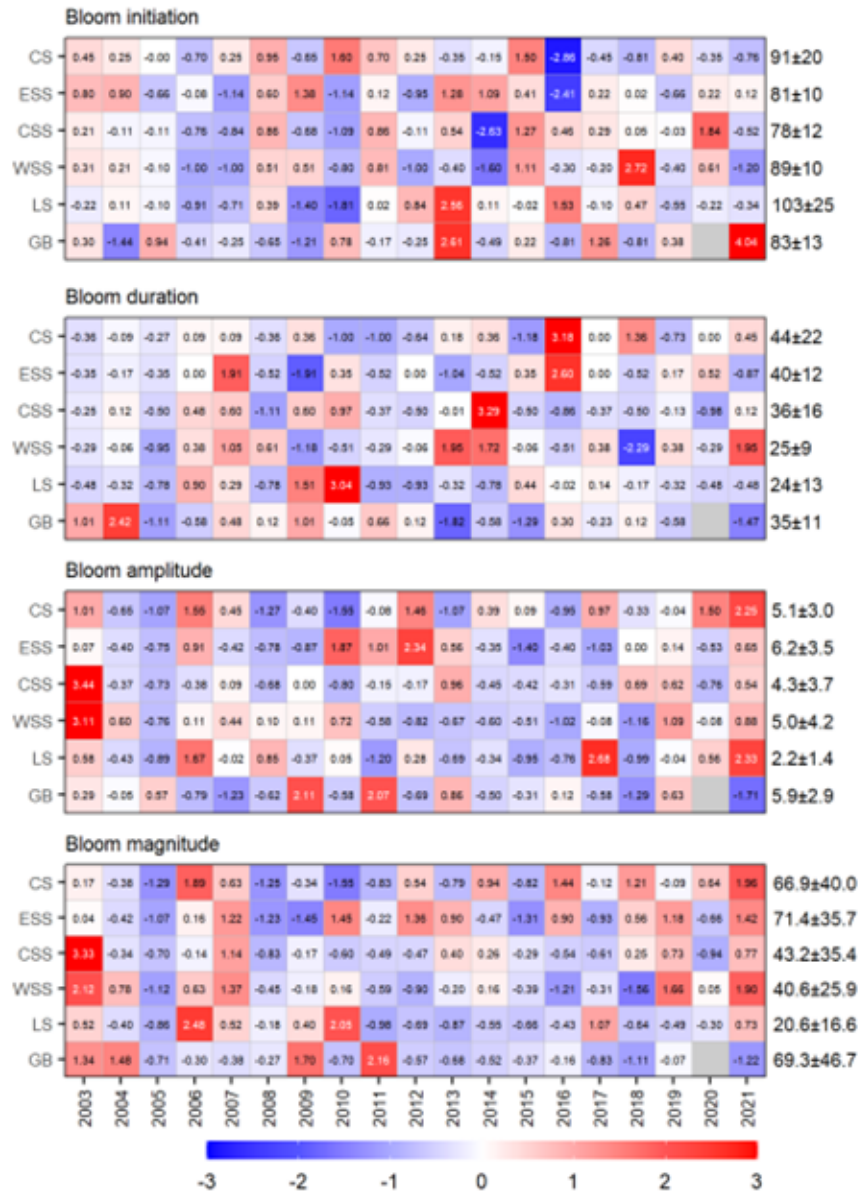


Figure 3. Standardized anomalies of spring bloom metrics in Cabot Strait (CS), Eastern Scotian Shelf (ESS), Central Scotian Shelf (CSS), Western Scotian Shelf (WSS), Lurcher Shoal (LS) and George’s Bank (GS) regions as defined in Casault et al., 2023 (Figure reproduced from Casault *et al.*, 2023)

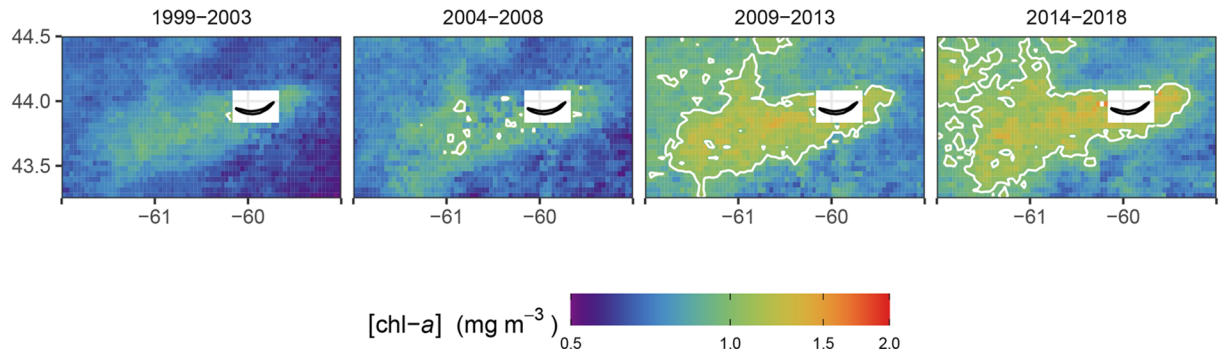


Figure 4. Phytoplankton hotspot Southwest of Sable Island for four time period. (image reproduced from Devred *et al.*, 2021)

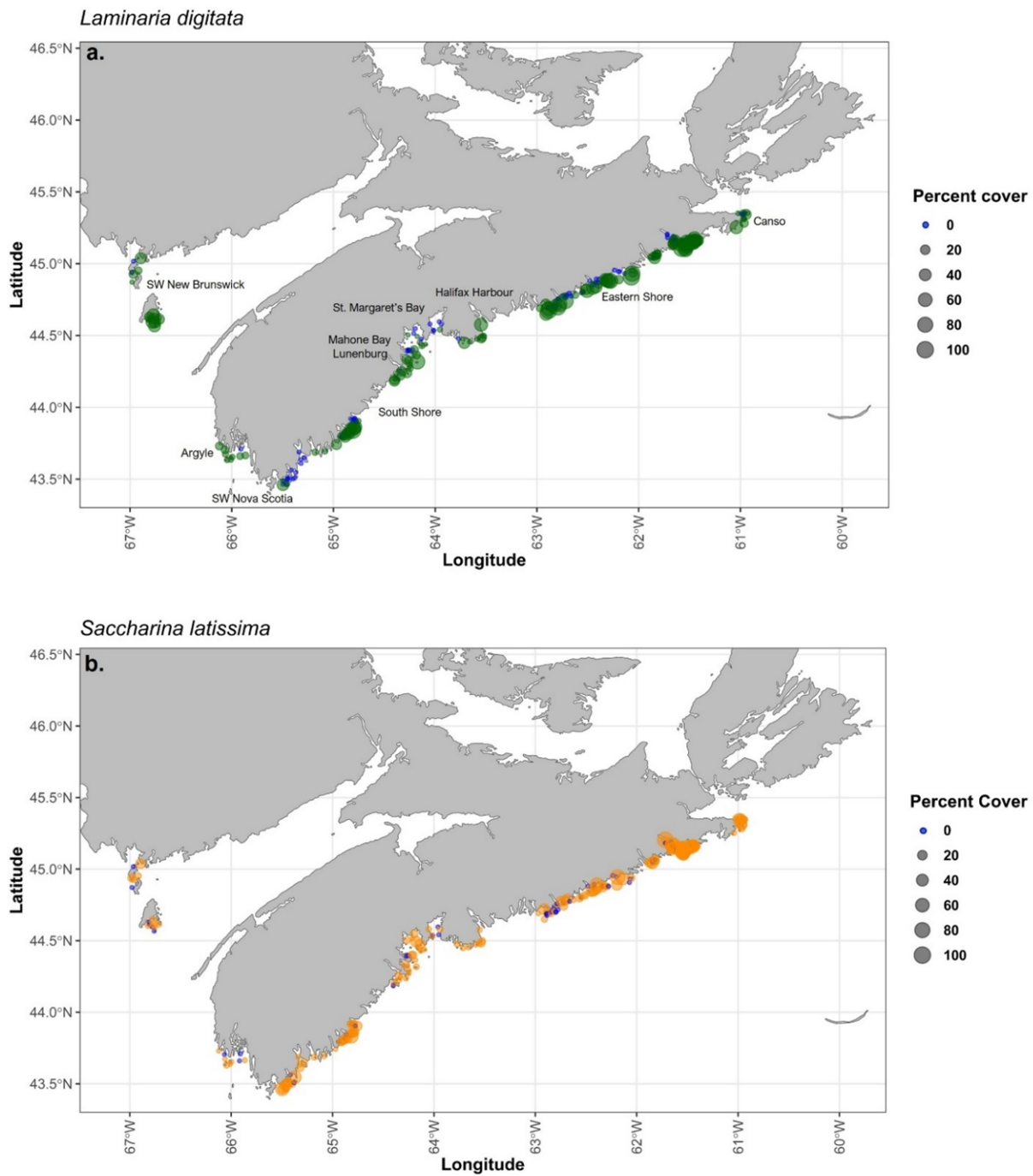
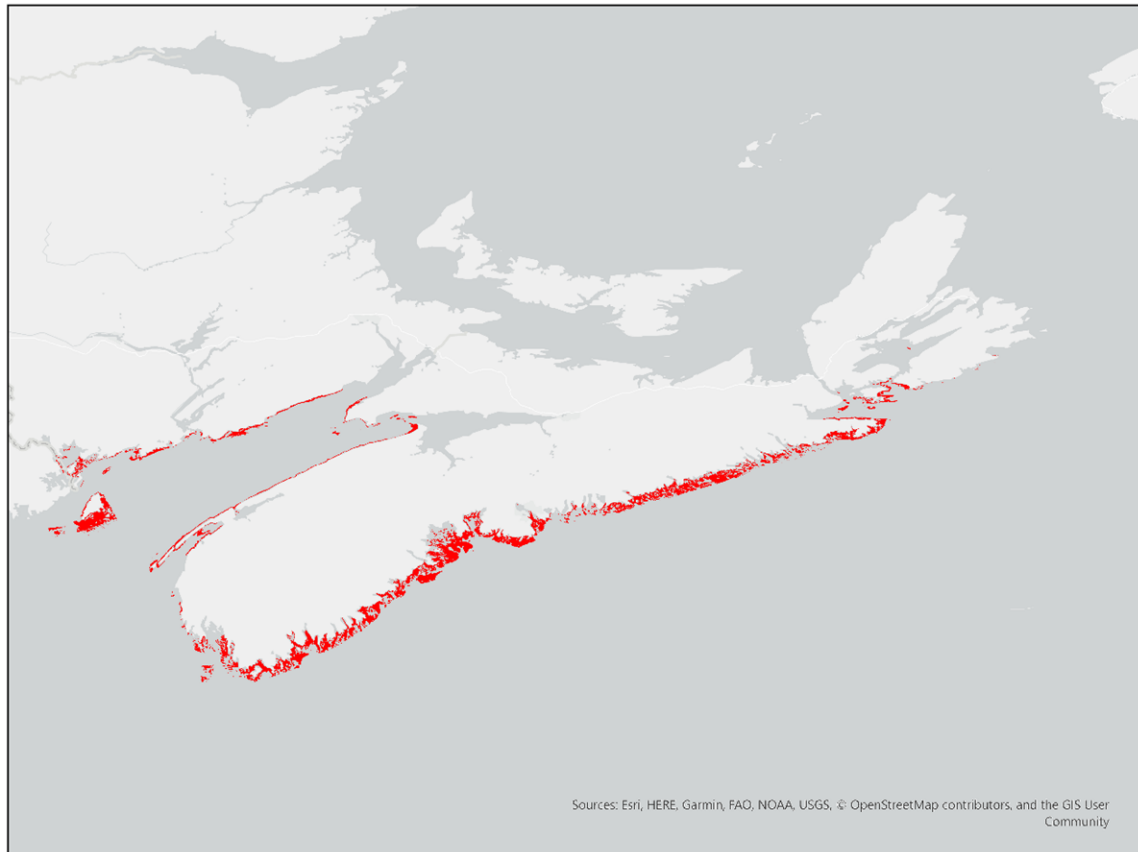
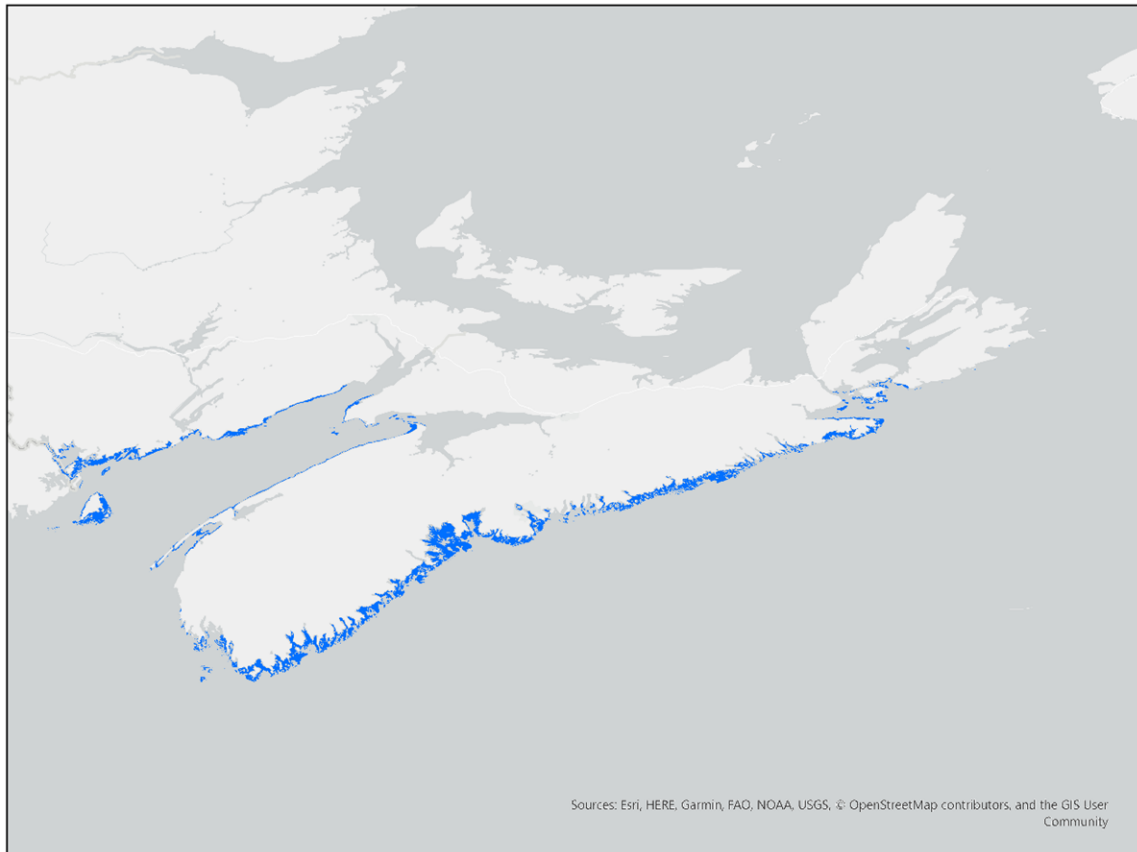


Figure 5. Percent cover of the two dominant species of kelp: a.) *Laminaria digitata* and b.) *Saccharina latissima* in camera surveys conducted from 2019-2022. Points are transparent to show overlap of sites and circle size indicates percent over. Sites where each species was absent are indicated in blue (Krumhansl *et al.*, 2023 *in press*).



Laminaria digitata SDM - Binary Output

Figure 6. Predicted current distribution (presence) of the native kelp species *Laminaria digitata* from MaxEnt species distribution modelling.



Saccharina latissima SDM - Binary Output

Figure 7. Predicted current distribution (presence) of the native kelp species *Saccharina latissima* from MaxEnt species distribution modelling.

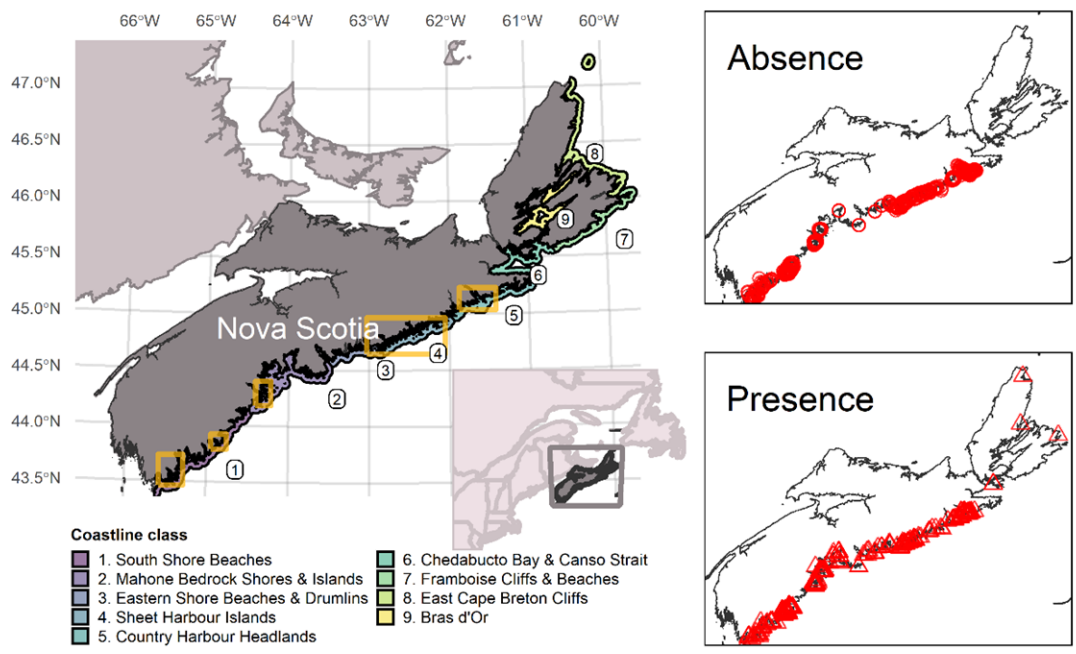


Figure 8. Coastline of Atlantic NS showing areas where drop camera surveys were conducted (yellow boxes) from 2019 – 2021. Red points (right panels) are locations of eelgrass presence and absence from these surveys. From O'Brien *et al.*, 2022.

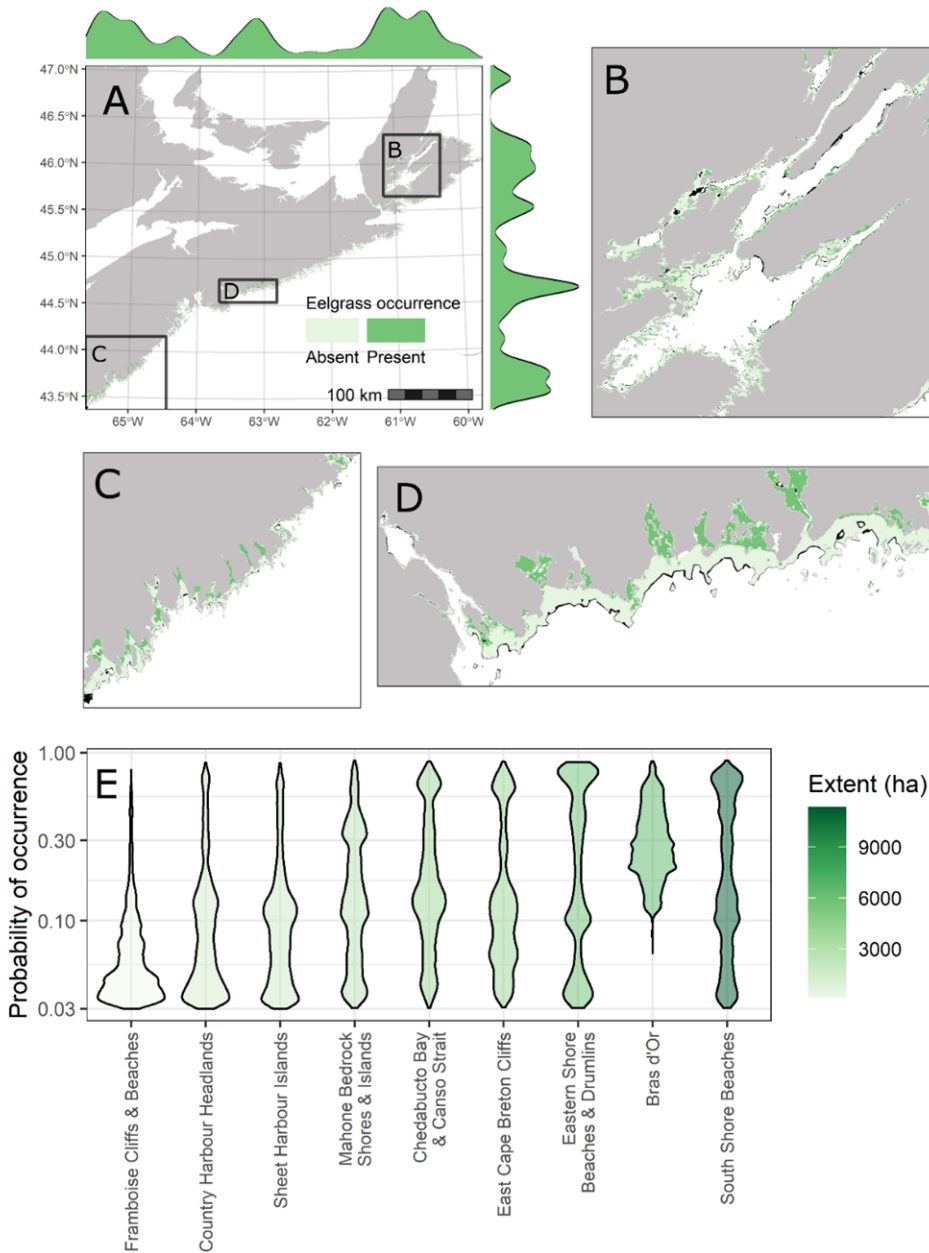


Figure 9. Coastal-scale extent of suitable eelgrass habitat and spatial variation among coastline classes on the Atlantic coast of NS. (A) Binary presence absence predictions of the ensemble eelgrass model. Light green = absent, Dark green = present. (B) Bra d'Or Lakes, (C) South Shore Beaches, (D) Eastern Shore Beaches and Drumlins. (E) Violin plots with kernel density estimates of probability of eelgrass occurrence among coastline classes. From O'Brien *et al.* 2022.

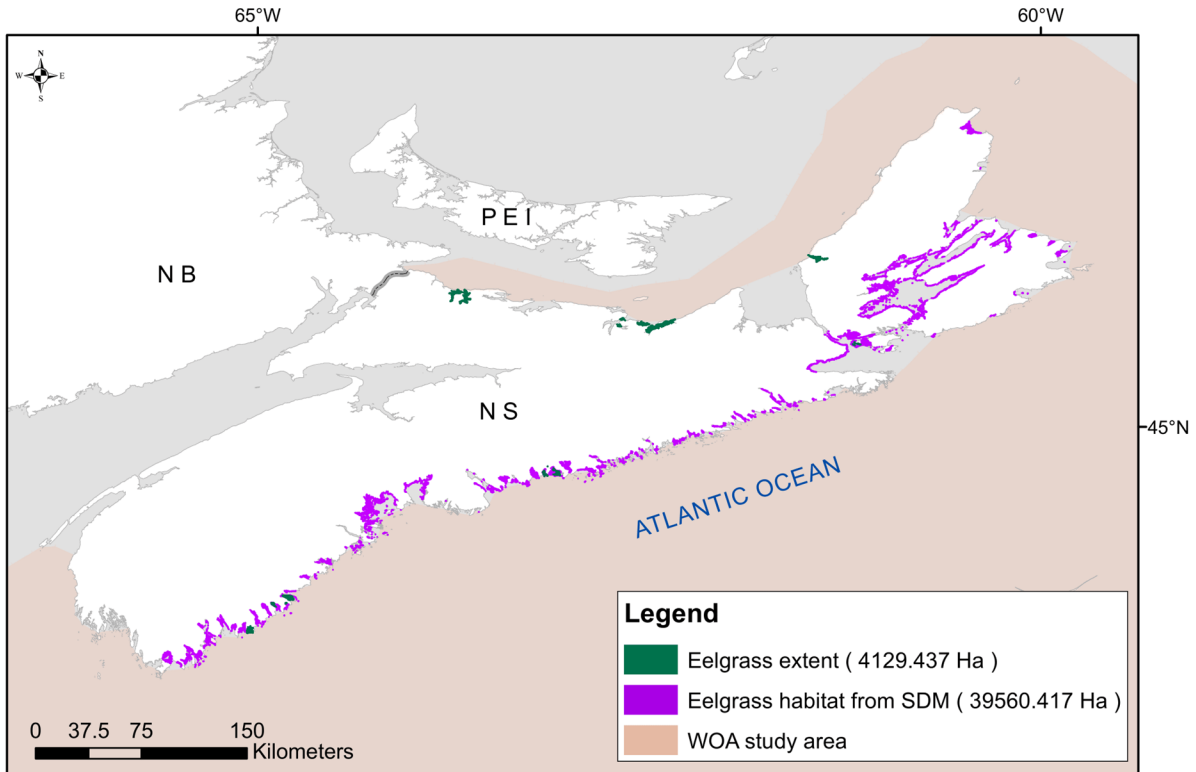


Figure 10. Eelgrass extent within the OSW assessment area, as measured from in-situ sampling and remote sensing (green), and as the area of habitat suitability predicted from the SDM model (purple). Note some areas of mapped eelgrass extent are difficult to discern at this scale. Compiled from NETForce data available at: <https://open.canada.ca/data/en/dataset/a733fb88-ddaf-47f8-95bb-e107630e8e62>

References

- Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological monographs*, 81(2), 169-193.
- Bowen, W. D., Ellis, S. L., Iverson, S. J., and Boness, D. J., 2003. Maternal and newborn life-history traits during periods of contrasting population trends: Implications for explaining the decline of harbour seals (*Phoca vitulina*), on Sable Island. *J. Zool.* 261: 155–163.
<https://doi.org/10.1017/S0952836903004047>
- Bowen, W.D., C.E. den Heyer, S.L.C. Lang, D.C. Lidgard, and S.J. Iverson. 2020. Exploring causal components of plasticity in grey seal birthdates: Effects of intrinsic traits, demography, and climate. *Ecology and Evolution*, 10(20): 11507-11522. <https://doi.org/10.1002/ece3.6787>
- Breed, G.W.D., Bowen, J.I., McMillan, Leonard, M.L., 2006. Sexual segregation of seasonal foraging habitats in a non-migratory marine mammal. *Proc. R. Soc. B* 273, 2319–2326.
- Breed, G.A., Jonsen, I.D., Myers, R.A., Bowen, W.D., Leonard, M.L., 2009. Sex-specific, seasonal foraging tactics of adult grey seals (*Halichoerus grypus*) revealed by state-space analysis. *Ecology* 11, 3209–3221
- Breed G.A., Bowen W.D., Leonard M.L., 2013. Behavioral signature of intraspecific competition and density dependence in colony-breeding marine predators. *Ecol Evol.* 3(11):3838–54. doi: 10.1002/ece3.754
- Brooks CM, Krumhansl KA. 2023. First record of the Asian *Antithamnion sparsum* Tokida, 1932 (Ceramiales, Rhodophyta) in Nova Scotia, Canada. *BioInvasion Records* 12:745-752
- Casault, B.; Johnson, C.; Devred, E.; Head, E.; and Beazley, L. 2023. Optical, Chemical, and Biological Oceanographic Conditions on the Scotian Shelf and in the eastern Gulf of Maine during 2021. *DFO Can. Sci. Advis. Sec. Res. Doc.* 2023/016. v + 74 p.
- den Heyer, C.E., W.D. Bowen, J. Dale, J.F. Gosselin, M.O. Hammill, D.W. Johnston, S.L.C. Lang, K.T. Murray, G.B. Stenson, and S.A. Wood. 2021. Contrasting trends in gray seal (*Halichoerus grypus*) pup production throughout the increasing northwest Atlantic metapopulation, *Marine Mammal Science*. 37: 611– 630. <https://doi.org/10.1111/mms.12773>
- Devred, E; Perry, T; Massicotte, P. 2022. Seasonal and decadal variations in absorption properties of phytoplankton and non-algal particulate matter in three oceanic regimes of the Northwest Atlantic. *Frontiers in Marine Sciences*.
- Devred E.; Hilborn, A; den Heyer CE. 2021. Enhanced chlorophyll-a concentration in the wake of Sable Island, eastern Canada, revealed by two decades of satellite observations: a response to grey seal population dynamics? *Biogeosciences*, vol. 18(23), p. 6115-6132
- DFO. 2022. Stock assessment of Northwest Atlantic grey seals (*Halichoerus grypus*) in Canada in 2021. *DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.* 2022/018 https://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2022/2022_018-eng.pdf.

- Dunic, J. C., Brown, C. J., Connolly, R. M., Turschwell, M. P., & Côté, I. M. (2021). Long-term declines and recovery of meadow area across the world's seagrass bioregions. *Global Change Biology*, 27(17), 4096-4109.
- Eger A, Marzinelli EM, Beas-Luna R., Blain CO, Blamey LK, Byrnes JEK, Carnell PE, Hoi CG, Hessing-Lewis M, Kim KY, Kumagai NH, Lorda J, Moore P, Nakamura Y, Perez-Matus A, Pontier O., Smale D, Steinberg PD, Verges A. 2023. The value of ecosystem services in global marine kelp forests. *Nature Communications* 14:1894.
- Environment and Climate Change Canada (2020) Canadian Environmental Sustainability Indicators: Eelgrass in Canada. Consulted on Month day, year. Available at: www.canada.ca/en/environment-climate-change/services/environmental-indicators/eelgrasscanada.html.
- Filbee-Dexter K, Feehan CJ, Scheibling RE. 2016. Large-scale degradation of a kelp ecosystem in an ocean warming hotspot. *Marine Ecology Progress Series* 543:141152
- Greenlaw, M., Harvey, C. Data of: A substrate classification for the Inshore Scotian Shelf and Bay of Fundy, Maritimes Region. Published: March 2022. Coastal Ecosystems Science Division, Fisheries and Oceans Canada, St. Andrews, N.B. <https://open.canada.ca/data/en/dataset/f2c493e4-ceaa-11eb-be59-1860247f53e3>
- Hamilton, C.D., Goulet, P.J., Stenson, G.B., Lang, S.L.C. 2023. Counts and spatial distribution of harbour (Phoca vitulina) and grey seals (Halichoerus grypus) from an aerial survey of the coast of the Newfoundland Shelf and Sandwich Bay, Labrador during the summer of 2021. *Can. Tech. Rep. Fish. Aquat. Sci.* 3566 : v + 39 p.
- Hammill, M.O., C.E. den Heyer, W.D. Bowen, and S.L.C. Lang. 2017. Grey seal population trends in Canadian waters, 1960-2016 and harvest advice. *DFO Can. Sci. Advis. Sec. Res. Doc.* 2017/052. v + 30 p.
- Haurly, L. R., McGowan, J. A., and Wiebe, P. H. 1978. Patterns and processes in the time-space scales of plankton distributions. In *Spatial Pattern in Plankton Communities*, pp. 277–327. Ed. by J. H. Steele. Plenum, New York.
- Krumhansl, K. A., Dowd, M., & Wong, M. C. 2021. Multiple metrics of temperature, light, and water motion drive gradients in eelgrass productivity and resilience. *Frontiers in Marine Science*, 8, 597707.
- Krumhansl KA, Brooks CM, Lowen B, O'Brien J, Wong M, DiBacco C. 2023. Loss, resilience, and recovery of kelp forests in a region of rapid ocean warming. *Annals of Botany*. In Press
- Lidgard, D. C., Bowen, W. D., Jonsen, I. D., & Iverson, S. J. 2012. Animal-borne acoustic transceivers reveal patterns of at-sea associations in an upper-trophic level predator. *PLoS One* 7(11), 1-8. doi:10.1371/journal.pone.0048962
- Lidgard, D. C., Bowen, W. D., Jonsen, I. D., & Iverson, S. J. 2014. Predator-borne acoustic transceivers and GPS tracking reveal spatiotemporal patterns of encounters with acoustically tagged fish in the open ocean. *Marine Ecology Progress Series*, 501, 157–168. doi:10.3354/meps10670

- Lidgard, D. C., Bowen, W. D., & Iverson, S. J. (2020). Sex-differences in fine-scale home-range use in an upper-trophic level marine predator. *Movement Ecology*, 8(1), 1–16. doi:10.1186/s40462-020-0196-y
- Lidgard D, Dispas A, Mosnier A, Varkey P, Kehler D, den Heyer C (2023) Distribution and counts of harbour (Phoca vitulina) and grey seals (Halichoerus grypus) on the Atlantic coast of Nova Scotia and Bay of Fundy from aerial and land surveys, 2019-2021. *Can. Tech. Rep. Fish. Aquat. Sci.* 3569: v + 88 p.
- Liu, C., White, M., & Newell, G. (2013). Selecting thresholds for the prediction of species occurrence with presence-only data. *Journal of Biogeography*, 40(4), 778–789. <https://doi.org/10.1111/jbi.12058>
- Lucas, Z. N., and Natanson, L. J. 2010. Two shark species involved in predation on seals at Sable Island, Nova Scotia, Canada. *Proc. Nov. Scotian Inst. Sci.* 45: 64–88. <http://ojs.library.dal.ca/nsis/article/download/3987/3648>
- Lucas, Z., and Stobo, W. T. 2000. Shark-inflicted mortality on a population of harbour seals (*Phoca vitulina*) at Sable Island, Nova Scotia. *J. Zool.* 252: 405–414.
- Mosnier A, Dispas A, Hammill MO (2023) Spatial distribution and count of harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) in the Estuary and Gulf of St. Lawrence from an aerial survey conducted in June 2019. *Can. Tech. Rep. Fish. Aquat. Sci.* 3541 : v+60 p.
- Mtwana Nordlund, L., Koch, E. W., Barbier, E. B., & Creed, J. C. (2016). Seagrass ecosystem services and their variability across genera and geographical regions. *Plos one*, 11(10), e0163091.
- Murphy, G. E., Dunic, J. C., Adamczyk, E. M., Bittick, S. J., Côté, I. M., Cristiani, J., ... & Wong, M. C. (2021). From coast to coast to coast: ecology and management of seagrass ecosystems across Canada. *Facets*, 6(1), 139-179.
- Nowak, B. V. R., Bowen, W. D., Whoriskey, K., Lidgard, D. C., Mills Flemming, J. E., & Iverson, S. J. (2020). Foraging behaviour of a continental shelf marine predator, the grey seal (*Halichoerus grypus*), is associated with in situ, subsurface oceanographic conditions. *Movement Ecology*, 8(1), 1–14. doi:10.1186/s40462-020-00225-7
- Nowak, B.N.R, W.D. Bowen, C.E. den Heyer, S.L.C Lang, and D.C. Lidgard. 2023. Ontogeny of movement behaviour during the initial foraging trips of naïve grey seal pups in a complex continental shelf ecosystem. *PLoS ONE* 18(9): e0290707. <https://doi.org/10.1371/journal.pone.0290707>
- O'Boyle, RN, M Sinclair, RJ Conover, KH Mann, AC Kohler 1984. Temporal and spatial distribution of ichthyoplankton communities of the Scotian Shelf in relation to biological, hydrological, and physiographic features. *Rapp. P.-v. Réun Cons. Int. Explor. Mer.* 183: 27-40.
- O'Brien, J.M., Wong, M.C., Stanley R.R. (2022) A relative wave exposure index for the coastal zone of the Scotian Shelf-Bay of Fundy Bioregion. *figshare*. Collection. <https://doi.org/10.6084/m9.figshare.c.5433567>
- O'Brien, J.M., Wong, M.C., & Stanley, R. R. (2022). Fine-scale ensemble species distribution modeling of eelgrass (*Zostera marina*) to inform nearshore conservation planning and habitat management. *Frontiers in Marine Science*, 9, 988858.

- Pepin, P, CL Johnson, M Harvey, B Casault, J Chassé, EB Colbourne, PS Galbraith, D Hebert, G Lazin, G Maillet, S Plourde, M Starr (2015) A multivariate evaluation of environmental effects on zooplankton community structure in the western North Atlantic. *Progress in Oceanography* 134: 197-220.
- Phillips, S. J., Dudik, M., & Schapire, R. E. (2004). A maximum entropy approach to species distribution modeling. *Proceedings of the Twenty-First International Conference on Machine Learning*, 655-662. <https://doi.org/10.1145/1015330.1015412>
- Renaud L.A., Pigeon G., Van de Walle J., Bordeleau X., Hammill M.O., Pelletier F. 2023. Spatiotemporal variation in pup abundance and preweaning survival of harbour seals (*Phoca vitulina*) in the St. Lawrence Estuary, Canada. *Can. J. Zool.* 00: 1–11.
- Robillard, A., Lesage, V., and Hammill, M. O. 2005. Distribution and abundance of harbour seals (*Phoca vitulina concolor*) and grey seals (*Halichoerus grypus*) in the Estuary and Gulf of St. Lawrence, 1994 – 2001. *Can. Tech. Rep. Fish. Aquat. Sci.* 2613: 152.
- Sameoto, D, J Neilson, D. Waldron. 1994. Zooplankton prey selection by juvenile fish in Nova Scotian Shelf basins. *J. Plankton. Res.* 16(8): 1003-1019.
- Shackell, NL, KT Frank. 2000. Larval fish diversity on the Scotian Shelf. *Ca. J. Fish. Aquat. Sci.* 57: 1747-1760.
- Therriault, J.-C., B. Petrie, P. Pepin, J. Gagnon, D. Gregory, J. Helbig, A. Herman, D. Lefavre, M. Mitchell, B. Pelchat, J. Runge et D. Sameoto. 1998. Proposal for a northwest Atlantic zonal monitoring program. *Can. Tech. Rep. Hydrogr. Ocean Sci.* 194: vii+57p.
- Tremblay, M.J., Roff, J.C., 1983. Community gradients in the Scotian Shelf zooplankton. *Canadian Journal of Fisheries and Aquatic Sciences* 40, 598-611.
- Vercaemer, B. M., Scarrow, M. A., Roethlisberger, B., Krumhansl, K. A., & Wong, M. C. (2021). Reproductive ecology of *Zostera marina* L.(eelgrass) across varying environmental conditions. *Aquatic Botany*, 175, 103444.
- Wong, M. C. (2018). Secondary production of macrobenthic communities in seagrass (*Zostera marina*, eelgrass) beds and bare soft sediments across differing environmental conditions in Atlantic Canada. *Estuaries and Coasts*, 41, 536-548.
- Wong, M. C., & Dowd, M. In Press. The role of short-term temperature variability and light in shaping the phenology and characteristics of seagrass beds. *Ecosphere*.
- Wong, M. C., Bravo, M. A., & Dowd, M. (2013). Ecological dynamics of *Zostera marina* (eelgrass) in three adjacent bays in Atlantic Canada. *Botanica Marina*, 56(5-6), 413-424.