



WESTERN AND EMERALD BANKS MARINE REFUGE (WEBMR) MONITORING REVIEW

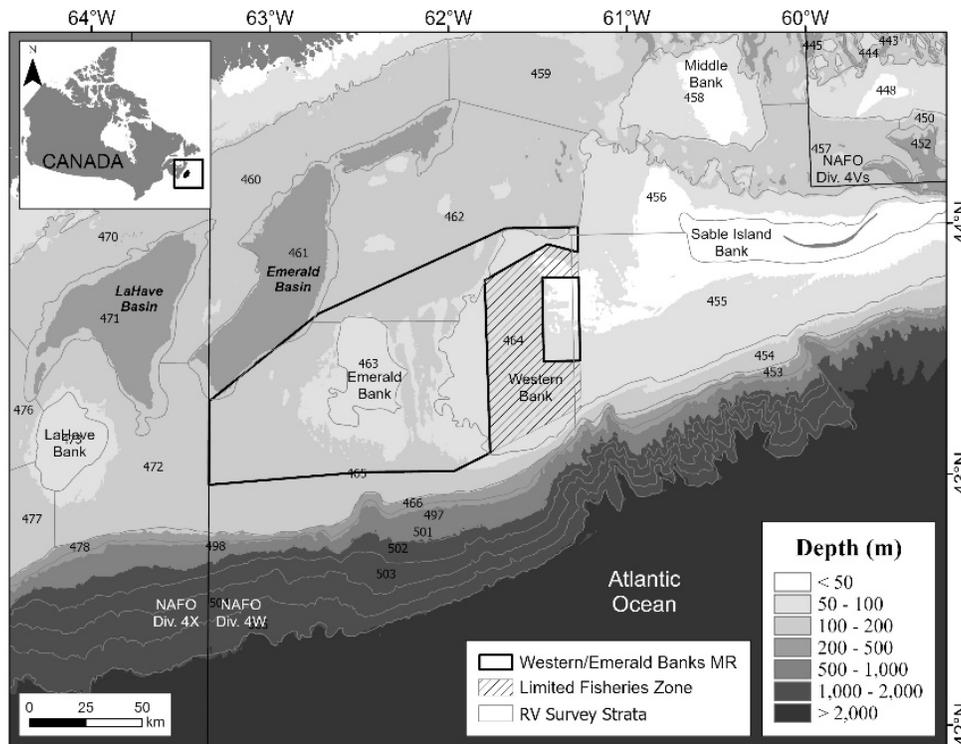


Figure 1. Western and Emerald Banks Marine Refuge (WEBMR), including the Limited Fishing Zone (dashed polygon) where only scallop fishing is allowed, and survey strata used in the DFO Maritimes Summer Ecosystem Research Vessel Survey.

CONTEXT

Fisheries and Oceans Canada (DFO) and partners implement monitoring programs in support of marine conservation area management. Western and Emerald Banks Marine Refuge (WEBMR) was originally established as a fisheries closure (the “Haddock Box”) in 1987 to protect juvenile Haddock (*Melanogrammus aeglefinus*) and support rebuilding of 4VW Haddock on the eastern Scotian Shelf. This area was subsequently proposed as an Other Effective Conservation Measure, with additional conservation objectives and management measures put in place as a result, and has been closed to all groundfish fishing since 1993. Several studies have summarized the attributes of the site and evaluated the closure, including its role in juvenile groundfish survival. However, a dedicated, long-term monitoring strategy to assess the effectiveness of the conservation area is not yet in place.

The objectives of the meeting were to review the available information on the ecological features of the site; to propose a suite of indicators for monitoring the effectiveness of the closure, identifying the key existing sampling platforms to support monitoring activities over the

long-term and information gaps; and to describe how the monitoring programs and associated indicators for WEBMR can be integrated into a regional conservation network monitoring program, and more broadly into shelf-wide ecosystem-based reporting.

This Science Advisory Report is from the regional peer review of February 25-26, 2025, on the Review of the Western and Emerald Banks Conservation Area Monitoring. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada \(DFO\) Science Advisory Schedule](#) as they become available.

SUMMARY

- Western and Emerald Banks Marine Refuge (WEBMR) lies on the eastern Scotian Shelf, encompassing an area of over 10,234 km², across depths that range from 37 to 211 m.
- Since time immemorial, the waters of the Scotian Shelf, which include the WEBMR, have provided natural resources and sustenance for the Mi'kmaq who have longstanding traditional and cultural connections to the marine environment and species.

Ecological Features

- Key ecological features of the site have been described previously, reflecting its role as an Ecologically and Biologically Significant Area, including: large areas of sand/gravel bank habitat, representing important spawning and nursery areas for a variety of groundfish and Atlantic Herring; a partial gyre, which results in retention of pelagic larvae and their food; high larval fish diversity and benthic habitat heterogeneity relative to other areas on the Scotian Shelf; and high invertebrate diversity, including structure-forming species such as sea pens, glass sponges and horse mussels, which serve as habitat for juvenile fish.
- While marine mammals are not identified as a conservation priority for this marine refuge, WEBMR occurs within the known distribution range of numerous cetacean species, including blue, fin, sei, minke, humpback, and North Atlantic right whales, as well as sperm and pilot whales, Harbour Porpoise, and a variety of dolphin species.
- The topography and geology of the site are not expected to change significantly over time; however, its oceanographic conditions, such as temperature, pH, oxygen, and nutrients are shifting as a result of climate change, which, in turn, are expected to influence its biological communities. For example, temperatures within WEBMR have shown a warming trend since 2005, with declines in both *Calanus finmarchicus* abundance and overall zooplankton biomass, which is consistent with the overall trend observed across the Scotian Shelf.

Monitoring Indicators

- A suite of indicators to support monitoring of WEBMR are proposed, building on work conducted regionally and nationally on *Oceans Act* Marine Protected Areas (MPAs), other effective conservation measures, and conservation networks more generally, along with consideration of WEBMR's unique ecological features and conservation history.
- Proposed indicators include contextual indicators, which measure oceanographic and biological conditions; effectiveness indicators related to WEBMR's three conservation objectives; and indicators to measure pressures and impacts of anthropogenic activities.

Monitoring Platforms

- A number of scientific data collection programs are in place that can and have contributed towards the long-term monitoring of WEBMR.

- The DFO Maritimes Summer Ecosystem Research Vessel Survey (RV Survey), conducted annually since 1970, follows a stratified random sampling design and includes bottom otter trawl sampling of fish and invertebrates, oceanographic sampling, as well as collection of acoustic data, which can be used to support population analysis of small pelagic fish species like Atlantic Herring and Mackerel as well as Pollock.
- The RV Survey has conducted an average of 17.5 stations per year inside WEBMR since 2020, representing an important source of information on fish diversity, abundance, and productivity. Invertebrate catch data from the RV Survey has been reported annually since 2007, when identification protocols were enhanced. It was improved again in 2017, when a more detailed sampling protocol was established, forming a basis for the delineation of WEBMR's benthic communities.
- Combining RV Survey data with environmental DNA (eDNA) sampling has the potential to enhance biodiversity monitoring, with eDNA providing additional species detections not captured by the RV Survey alone. Results to date have highlighted eDNA metabarcoding's capacity to detect taxa that are otherwise missed by traditional sampling methods.
- The Atlantic Zone Monitoring Program (AZMP) samples a broad suite of physical, chemical, and lower trophic-level biological parameters at two stations (HL4 and HL5 of the 'Halifax Line') within WEBMR during its spring and fall surveys, and evaluates satellite-derived measurements of sea surface temperature and ocean colour, representing an important source of oceanographic information on long-term ecosystem changes.
- Since 2018, AZMP has incorporated the use of ocean gliders into its monitoring program. Approximately 10 glider missions per year are conducted along the program's Halifax Line, which intersects WEBMR. These glider missions provide high spatial resolution observations on a suite of physical (e.g., temperature, salinity) and biogeochemical (e.g., chlorophyll fluorescence, oxygen) properties, that can help resolve meso- and sub-meso scale processes and boundary currents.
- Like ocean glider and satellite-derived datasets, high resolution oceanographic models are important tools that can be used to fill spatial and temporal gaps in observational data. The spatial continuity and forecasting capacity of some models makes them useful tools for evaluating species distributions and assessing change in relation to climate change.
- Other data collection programs and approaches, such as the industry/DFO halibut longline survey, acoustic telemetry, passive acoustics, and targeted benthic missions to collect benthic imagery and samples (e.g., using Campod or Videograb), have all been deployed within WEBMR, representing other potential sources of ecological information to monitor biological communities, and their associated habitats, over time.

Reporting Framework

- A hierarchical reporting framework for conservation monitoring is proposed, in which ecosystem indicators for specific conservation areas, like WEBMR, are integrated into regional conservation network reporting, and more broadly into shelf-wide, ecosystem-based reporting.
- Consistent with the application of a holistic, ecosystem approach in the Maritimes Region, this framework proposes alignment of indicators with productivity, biodiversity, and habitat objectives, emphasizing the role that conservation areas can play in maintaining ecosystem structure and function, species diversity, ecosystem resilience, and the protection or restoration of habitat.

- In addition to a monitoring framework, an analytical oceanographic modelling framework could be used to support interpretation of site-specific oceanographic indicators in the broader regional context and facilitate understanding of the trends and status of the indicators that are selected.

Knowledge Gaps

- There is currently no systematic, routine monitoring program that targets ichthyoplankton or benthic communities in the Maritimes Region. While benthic species are recorded in the annual RV Survey, additional laboratory examination is often required to identify sponges, hydroids, and sea anemones to the species level. Given the importance of WEBMR as historical spawning and nursery grounds for groundfish, and its objectives to protect benthic habitats that support Haddock and other groundfish species, a means of monitoring ichthyoplankton abundance at a regional scale, as well as benthic communities within WEBMR, would be highly beneficial for monitoring the effectiveness of WEBMR.
- In the distant past, some areas within WEBMR would have been above sea-level and could have been occupied by early Mi'kmaq peoples, representing an opportunity for future archeological investigation.

BACKGROUND

Western and Emerald Banks Marine Refuge (WEBMR) lies on the eastern Scotian Shelf, encompassing an area of over 10,234 km², across depths that range from 37 to 211 m.

Since time immemorial, the waters of the Scotian Shelf, which include the WEBMR, have provided natural resources and sustenance for the Mi'kmaq who have longstanding traditional and cultural connections to the marine environment and species.

This conservation area, originally called the “Haddock Box”, was established as a fisheries closure under the *Fisheries Act* in 1987 to protect juvenile Haddock (*Melanogrammus aeglefinus*) and support rebuilding of the 4VW Haddock stock (Fanning et al. 1987). The initial closure only prohibited mobile gear, but it has been closed to all groundfish fishing (including fixed gear) since 1993. The closure contributes to regional productivity and habitat objectives for groundfish fisheries in the Maritimes Region, as well as broader marine conservation goals.

Several documents have summarized the ecological significance of the site. For example, the Breeze et al. (2004) review of the criteria for selecting Ecologically Significant Areas of the Scotian Shelf describes the important features of the Western Bank-Emerald Bank Complex (Haddock Box). In a subsequent review by King et al. (2016), using bioregional-scale ecological and biological data layers available at the time, a revised Ecologically and Biologically Significant Area (EBSA) encompassing all of Emerald Bank and Western Bank and a portion Sable Island Bank was defined.

In 2017, the Western Emerald Bank Marine Refuge was proposed as an Other Effective area-based Conservation Measure (OECM), encompassing the original fisheries closure except for an area (2,548 km²) where an active bottom-contact scallop fishery was present (see Limited Fishing Zone, Figure 1). As a result of this evaluation, and with the development of a marine conservation network for the region (King et al. 2021), the marine refuge was closed to all bottom-contact fishing gear with the following conservation objectives (DFO 2024a):

1. Protect continental shelf habitats and associated benthic and demersal communities.

2. Support productivity objectives for groundfish species of Aboriginal, commercial, and/or recreational importance, particularly North Atlantic Fisheries Organization Divisions 4VW Haddock.
3. Protect benthic habitats that support juvenile and adult Haddock and other groundfish species.

A dedicated, long-term monitoring strategy to assess the efficacy of the conservation area is not yet in place. However, several studies have been carried out to evaluate the closure, including its role in juvenile groundfish survival. Frank et al. (2000) found that while recruitment and spawning biomass of Haddock was not enhanced in the area, the closure benefitted other species such as American Plaice and Winter Flounder. Additionally, Fisher and Frank (2002) found that finfish community composition was significantly different after the implementation of the closure, with some species such as Atlantic Herring, Winter Flounder, and redfish showing dramatic increases in abundance. They also found that the Browns Bank area finfish community was coupled with those in the closure through spillover, showing positive benefits of the closure at both local and regional scales. However, despite reduced fishing mortality since 1993, Shackell et al. (2021) found that WEBMR, along with two other fishing closures, had not resulted in enhanced per capita population growth rates of the majority of common groundfish species, likely due to the widespread regional-scale pattern of diminished productivity in severely depleted groundfish populations. The causes of continued diminished productivity of depleted groundfish are not well understood. Nonetheless, the biogeographical features of the area have been linked to benefits for other species not directly identified in or associated with the original objectives.

Spatial conservation monitoring efforts in the Maritimes Region have been focused on *Oceans Act* MPAs (e.g., DFO 2022a; 2022b; 2024). A national monitoring framework for coral and sponge areas has been developed (DFO 2021), which covers most of the OECMs in the Scotian Shelf Bioregion. However, WEBMR is not covered within this monitoring framework as its conservation objectives are unique and more related to the protection of groundfish and other demersal communities, and their associated habitats.

The objectives of this CSAS process are to:

1. review the available information on the ecological features of WEBMR;
2. propose a suite of indicators for monitoring the effectiveness of the closure;
3. identify the key existing sampling platforms supporting monitoring activities over the long-term and information gaps; and
4. describe how the monitoring program and associated indicators for WEBMR can be integrated into a regional conservation network monitoring program, and more broadly into shelf-wide ecosystem-based reporting.

The details of these objectives are presented in Murillo et al. (In prep.)¹.

¹ Murillo, F.J., Stanley, R., Beazley, L., Harbin, J., Daigle, R., and Shackell, N. In prep. Review of Monitoring Platforms, Indicators and Reporting Framework for Western and Emerald Banks Marine Refuge. DFO Can. Sci. Advis. Sec. Res. Doc.

ASSESSMENT

Ecological Features of Western and Emerald Banks

WEBMR is located on the eastern Scotian Shelf, approximately 65 nautical miles off Halifax. It includes Emerald Bank and a part of Western Bank (Figure 1), ranging in depth from 37 to 211 m. Deeper waters are found at the northwest tip of the closure, south of Emerald Basin.

Key ecological features of the site have been described previously, reflecting its role as an Ecologically and Biologically Significant Area (EBSA), including: large areas of sand/gravel bank habitat, representing an important spawning and nursery area for a variety of groundfish species; an Atlantic Herring spawning site; a partial gyre, which results in retention of pelagic larvae and their food; high larval fish diversity and benthic habitat heterogeneity relative to other areas on the Scotian Shelf; and high invertebrate diversity, including structure-forming species such as sea pens, glass sponges and horse mussels, which serve as habitat for juvenile fish.

WEBMR is located at the interface between the eastern and western Scotian Shelf and is a highly dynamic area with seasonally distinct water mass characteristics, influenced by both cooler, fresher shelf waters of Labrador origin, and warmer, saltier Warm Slope Water.

Grain size data from samples collected by Natural Resources Canada show a dominance of sand in most of the area, with gravel patches, and silt dominating in a few northern locations. Epibenthic communities within WEBMR identified from samples collected during DFO Maritimes Summer Ecosystem Research Vessel Survey (RV Survey) are characterized by species with shelf-wide distributions that are associated with a general ability to cope with high disturbance. Some small Significant Benthic Areas (SiBAs) associated with sea pens occur in the deeper areas of WEBMR, whereas the western part of the closure represents suitable habitat for the Glass Sponge *Vazella pourtalesii*. Some areas within WEBMR also represent suitable habitat for Horse Mussel, *Modiolus modiolus*.

In the distant past, some areas within WEBMR would have been above sea level and could have been occupied by early Mi'kmaw peoples, representing an opportunity for future archeological investigation.

High diversity and abundance of fish larvae in the Western – Sable Island Banks has been associated with the oceanographic circulation of the area, where a large partial gyre serves as a potential retentive mechanism, concentrating both larval fish and their prey. Historically, WEBMR represented 30% of the spatial extent and 80% of the observed Haddock larvae based on data collected during the Scotian Shelf Ichthyoplankton Program (SSIP) from 1978 to 1982. WEBMR has also been identified as a key spawning location for other species, including Atlantic Cod, Silver Hake and Atlantic Herring.

WEBMR has historically been associated with high fish biomass, particularly Haddock. Although, there has been a shift in the distribution of fish functional group hotspots over time, with these hotspots becoming more concentrated in localized areas within WEBMR in recent years, the distribution of large benthivores, which includes Haddock, and to a lesser extent, medium sized benthivores (e.g., Winter Flounder, Witch Flounder, Little Skate) remained fairly constant around WEBMR.

Analysis of the gut content composition from fish collected with otter trawls in the scallop restricted fishing area reveals strong coupling between benthic invertebrate and demersal fish communities in WEBMR.

While marine mammals are not identified as a conservation priority for this marine refuge, WEBMR occurs within the known distribution range of numerous cetacean species, including

blue, fin, sei, minke, humpback, and North Atlantic right whales, as well as sperm and pilot whales, harbour porpoise, and a variety of dolphin species.

Recent analysis suggests that WEBMR may represent the highest proportion of sedimentary organic carbon stock within the conservation network plan, with a coverage of approximately 4% of the regional carbon stock (Epstein et al. 2024).

WEBMR provides a key transitional habitat demarking known climate-associated species assemblage transitions and the distribution of certain populations or taxa. While the topography and geology of the site are not expected to change significantly over time, its oceanographic conditions, such as temperature, pH, oxygen, and nutrients are shifting as a result of climate change, which, in turn, are expected to influence its biological communities. Warming temperatures, for example, have been linked to habitat loss based on the thermal niches of species. Analysis of how projected warming could reduce habitat extent for four priority groundfish species (Haddock, Atlantic Cod, American Plaice, and Winter Skate) showed that American Plaice had the lowest upper thermal tolerance limit and commensurately showed the earliest potential habitat loss in WEBMR, with declines beginning as early as 2027 and a potential 50% reduction by mid-century (Murillo et al. In prep.¹). By 2060, Haddock was projected to experience >50% habitat loss, with the remaining habitat conditions in WEBMR likely warming beyond their thermal niche by 2075. Winter Skate and Atlantic Cod were comparatively less sensitive to projected warming, with projected thermal habitat losses associated only with the low carbon emissions mitigation scenario.

Temperatures within WEBMR have shown a warming trend since 2005, with declines in both *Calanus finmarchicus* abundance and overall zooplankton biomass, which is consistent with the overall trend observed across the Scotian Shelf. Monitoring of ocean acidification (carbonate chemistry) by AZMP since 2014, indicates that while samples collected at stations within WEBMR are not yet in the range considered to be typically corrosive to molluscs, crustaceans and corals, they are within range of possible biological impairment for larvae and juvenile fish/invertebrates.

Selection of Monitoring Indicators

Science advice was requested on the identification of ecologically-based monitoring indicators of relevance to WEBMR, which could be incorporated into a future WEBMR monitoring plan.

DFO Science advice has been provided previously on the selection of monitoring indicators, protocols and strategies for *Oceans Act* Marine Protected Areas, other effective conservation measures, and conservation networks more generally (DFO 2013, 2020, 2021, 2022a). This advice has been incorporated into the development of monitoring frameworks for MPAs in the Maritimes Region, e.g., Gully (DFO 2022b), Musquash (DFO 2011, 2022a) and St Anns Bank (DFO 2024b), while taking into account the unique locations and ecological features of each of these sites.

For the purpose of this review, DFO subject matter experts were asked to provide information on proposed indicators for WEBMR, including indicator name, type of data (selected from predefined categories), significance (high, medium, or low), required sampling method, data collection frequency, data gaps, data source, suggested analysis, geographic scope (Shelf, All, Deep, Bank), and the relevant site-level objectives, which would be practical and tractable for monitoring WEBMR's conservation objectives in the context of their contribution to regional biodiversity, habitat and productivity.

A suite of indicators to support monitoring of WEBMR are proposed, represented by the indicator categories listed below, for further development into an operational monitoring plan.

Appendix A provides a brief rationale for the selection (relevance) of these indicators to WEBMR, along with linkages to its conservation objectives, potential sources of data and their readiness for use.

Proposed indicators include contextual indicators, which measure oceanographic and biological conditions; effectiveness indicators related to WEBMR's three conservation objectives; and indicators to measure pressures and impacts of anthropogenic activities.

Contextual Indicators

Oceanographic

- Ocean conditions, e.g., temperature, salinity, oxygen, pH, calcium carbonate, nutrients.
- Ocean structure and movement, e.g., vertical structure; water mass distribution and transport.

Biological

- Primary production, e.g., chlorophyll *a*, phytoplankton production, spring bloom phenology.
- Secondary production, e.g., zooplankton biomass and community composition.
- Marine mammals and other top predators, including cetaceans, seals, large pelagic fish (e.g., sharks and tunas), and seabirds.
- Trophic structure and function, e.g. trophic structure, species diversity, aquatic invasive species.

Effectiveness Indicators

Benthic Environment

- Benthic habitat, e.g., spatial distribution of distinctive seabed types and their associated epibenthic and infaunal benthic communities (biotypes).
- Habitat-forming species, e.g., abundance, biomass and size composition of habitat-forming species such as sea pens, *Vazella pourtalesii*, and horse mussels.
- Benthic productivity and diversity, e.g., abundance/biomass of benthic invertebrates known as prey species for groundfish; eibenthic and infaunal richness.
- Benthic ecosystem function, e.g., biomass of benthic bioturbators.

Fish and Fishery Resources

- Groundfish productivity, e.g., relative abundance, biomass, size distribution, condition, and fecundity of selected groundfish species, including species of Indigenous interest, with a particular emphasis on the species named in the objectives of WEBMR, i.e., Haddock, Atlantic Cod, American Plaice, Atlantic Halibut, and Winter Skate.
- Groundfish diversity, e.g., community composition of demersal fish.
- Groundfish habitat use, e.g., distribution of juvenile Haddock and other key groundfish.

Anthropogenic Pressure and Impact Indicators

- Fisheries, including fishing activity within and close proximity to WEBMR, the amount of seabed area in the vicinity of WEBMR swept by bottom-tending mobile fishing gear, and total annual landings of directed groundfish fisheries and common bycatch-only stocks in NAFO Division 4W.

- Research, including the amount of seabed area within and in the vicinity of WEBMR swept by bottom-tending mobile gear for research and monitoring purposes.
- Other vessels, including sea vessel traffic intensity (e.g. frequency, speed) and pressures (e.g., noise and light) within or nearby WEBMR.
- Cables, including number and type of seabed cables.
- Offshore energy, including number and types of oil and gas, or other mineral exploration, activities (e.g., drilling wells), as well as potential future wind energy developments (structures) within and in the vicinity of WEBMR.
- Chemical contamination and marine debris, including the concentrations of contaminants (including organic chemicals and heavy metals), as well as the quantity of anthropogenic debris impacting biota, water column and seabed.
- Cumulative impacts, including changes in relative impact and spatial distribution of impacts over time.

Sampling Platforms

A number of scientific data collection programs are in place that can and have contributed towards the long-term monitoring of WEBMR. Two key existing sampling platforms supporting monitoring activities over the long-term were identified within WEBMR and are summarized here: the Atlantic Zone Monitoring Program (AZMP), and the DFO Maritimes Summer Ecosystem Research Vessel Survey (RV Survey). Other data collection programs and approaches, such as the industry/DFO halibut longline survey, acoustic telemetry, passive acoustics, and targeted benthic missions to collect benthic imagery and samples (e.g., using campod or Videograb), as well as opportunistic sightings (described in Murillo et al. In prep.¹), have all been deployed within WEBMR, representing other potential sources of ecological information to monitor biological communities, and their associated habitats, over time.

Additionally, combining RV Survey data with environmental DNA (eDNA) sampling has the potential to enhance biodiversity monitoring, with eDNA providing additional species detections not captured by the RV Survey alone. Results to date have highlighted eDNA metabarcoding's capacity to detect taxa that are otherwise missed by traditional sampling methods.

Murillo et al. (In prep.)¹ summarize the existing monitoring efforts of the AZMP within WEBMR and other DFO programs, surveys, or applications that collect or synthesize data and products describing the physical, chemical, or lower-trophic level biological conditions on the Scotian Shelf that could facilitate long-term monitoring of background indicators in WEBMR.

Atlantic Zone Monitoring Program

In the Maritimes Region, the AZMP established four hydrographic sections for long-term seasonal monitoring: Cabot Strait, Louisbourg, Cape Sable, which is now known as the Browns Bank Line, and the Halifax Section (Figure 2). Stations HL4 and HL5 of the Halifax Line are located within WEBMR, with HL4 situated over the centre of Emerald Bank at approximately 85 m depth, and HL5 located on the southwest flanks of Western Bank at approximately 100 m depth. The AZMP samples a broad suite of physical, chemical, and lower trophic-level biological parameters within WEBMR during its spring and fall surveys, representing an important source of oceanographic information on long-term ecosystem changes. In addition, the AZMP has provided the opportunity to incorporate eDNA sampling into their sampling objectives, providing an additional source of information to evaluate species diversity. The AZMP augments their ship-based field observations with more spatially- and temporally-resolved datasets, including

evaluation of satellite-derived measurements of sea surface temperatures and ocean colour (e.g., chlorophyll a, a proxy for phytoplankton biomass), and high-resolution modelled products.

Since 2018, AZMP has incorporated the use of ocean gliders into its monitoring program, further enhancing its capacity to evaluate ocean variability at higher spatial resolutions. Approximately 10 glider missions per year are conducted along the program's Halifax Line, which intersects WEBMR. These glider missions provide high spatial resolution observations on a suite of physical (e.g., temperature, salinity) and biogeochemical (e.g., chlorophyll fluorescence, oxygen) properties, that can help resolve meso- and sub-meso scale processes and boundary currents.

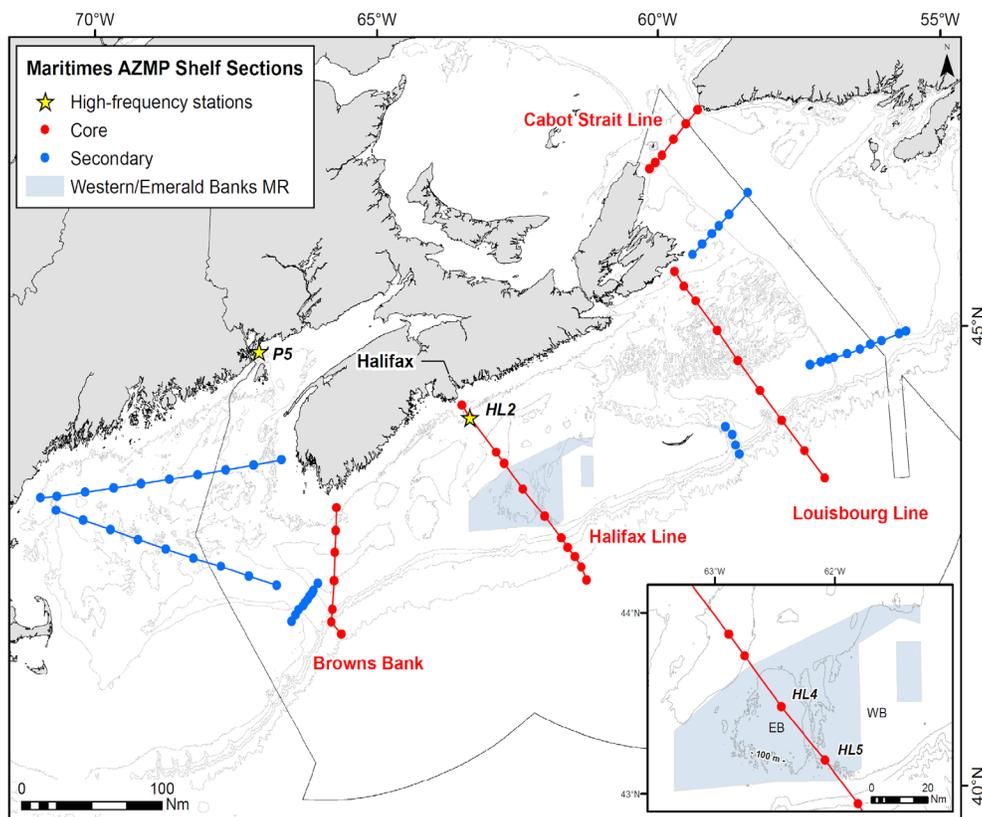


Figure 2. Location of the Atlantic Zone Monitoring Program (AZMP) high-frequency fixed stations, core (red) and secondary (blue) cross-shelf hydrographic sections sampled each spring and fall in relation to WEBMR. Inset shows the labelled AZMP stations inside WEBMR (HL4 and HL5) and in relation to Emerald Bank (EB) and Western Bank (WB).

Maritimes Summer Ecosystem Research Vessel Survey

The DFO Maritimes Summer Ecosystem Research Vessel Survey (RV Survey) has been conducted annually in the Maritimes Region since 1970. It follows a stratified random sampling design, and includes sampling of fish and invertebrates on the Scotian Shelf, Bay of Fundy and Canadian portion of Georges Bank (Northwest Atlantic Fisheries Organization Divisions 4VWX5Y), using a bottom otter trawl (Figure 3). These survey data are the primary data source for monitoring trends in fish and invertebrate species distribution, abundance, and biological condition within the region. Oceanographic data is also collected on these surveys by the AZMP and is used to support catch interpretation and the incorporation of environmental information into stock assessment processes.

The RV Survey has conducted an average of 17.5 (± 2.12) stations per year inside WEBMR since 2020. Since 1970, the RV Survey has sampled WEBMR 378 times providing the longest time series of groundfish diversity, abundance, and productivity for the area. Total numbers, total weight caught, length frequencies, and individual fish weights are collected from all successful sets. Additionally, special sampling (e.g., specimen collections) and stomach sampling on selected species, are conducted upon request and as time permits. Acoustic data is also collected using a hull-mounted multifrequency scientific echosounder, which can be used to support population analysis of pelagic fish species such as Atlantic Herring and Mackerel, as well as Pollock.

Invertebrate catch data from the RV Survey has been reported annually since 2007, when identification protocols were enhanced. It was improved again in 2017 when a more detailed sampling protocol was established, forming a basis for the delineation of WEBMR's benthic communities.

Three RV Survey strata (462, 464, and 465) encompass WEBMR and extend beyond its boundaries, while strata 463 falls completely within the boundaries of the closure (Figure 3). Fishing stations within strata 462, 464, and 465 but outside of the closure could be used to supplement the information obtained from the RV Survey-based indicators.

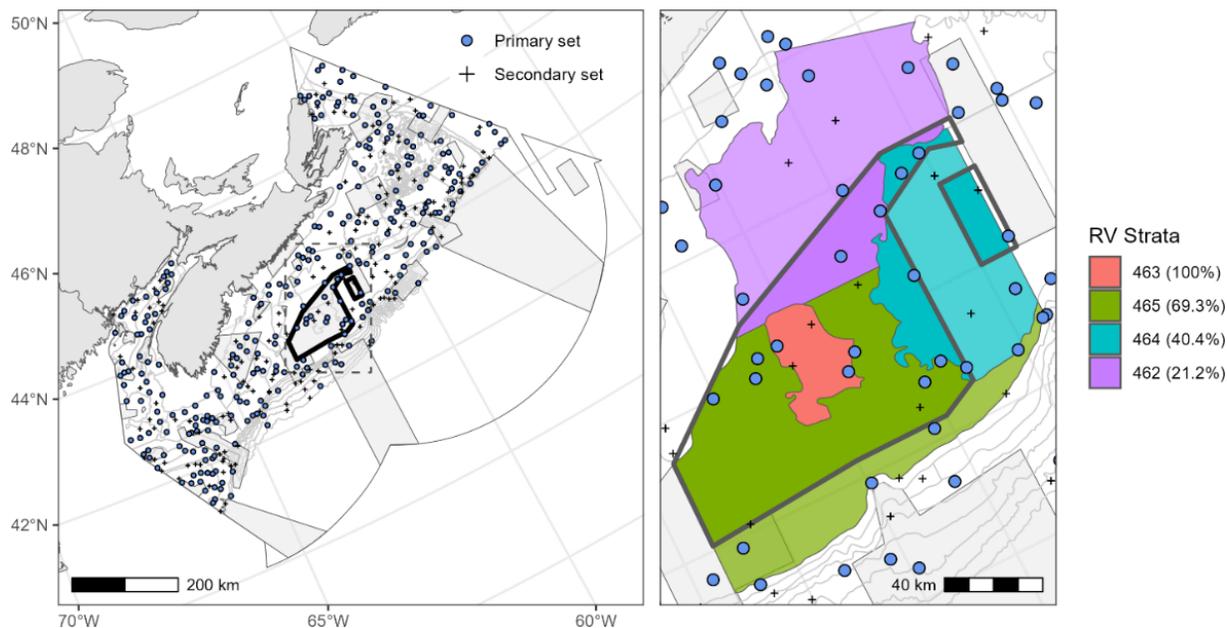


Figure 3. Location of the sampling stations planned during the 2024 RV Survey. Survey strata denoted by grey contours, Scotian Shelf-Bay of Fundy draft conservation network (as of February 2025) denoted by grey shaded polygons.

Industry-DFO Longline Halibut Survey

An industry-DFO longline halibut survey using a fixed-station design was initiated on the Scotian Shelf and Southern Grand Banks (3NOPs4VWX5Zc) in 1998 to provide estimates of the abundance and distribution of Atlantic Halibut, which are used for its assessment. These surveys are carried out with longline gear between May and July, annually. At-sea observers collect numbers, size composition of landings, bycatch, biological data (sex, maturity, and diet) and samples of otoliths, and genetic fin clips. Additionally, these surveys provide a platform for halibut tagging studies. All catch is identified to species and when time permits, length and sex

of other species are also recorded. The halibut survey (Figure 4) provides a complementary source of data for some of the indicators listed in section 3.2.2.

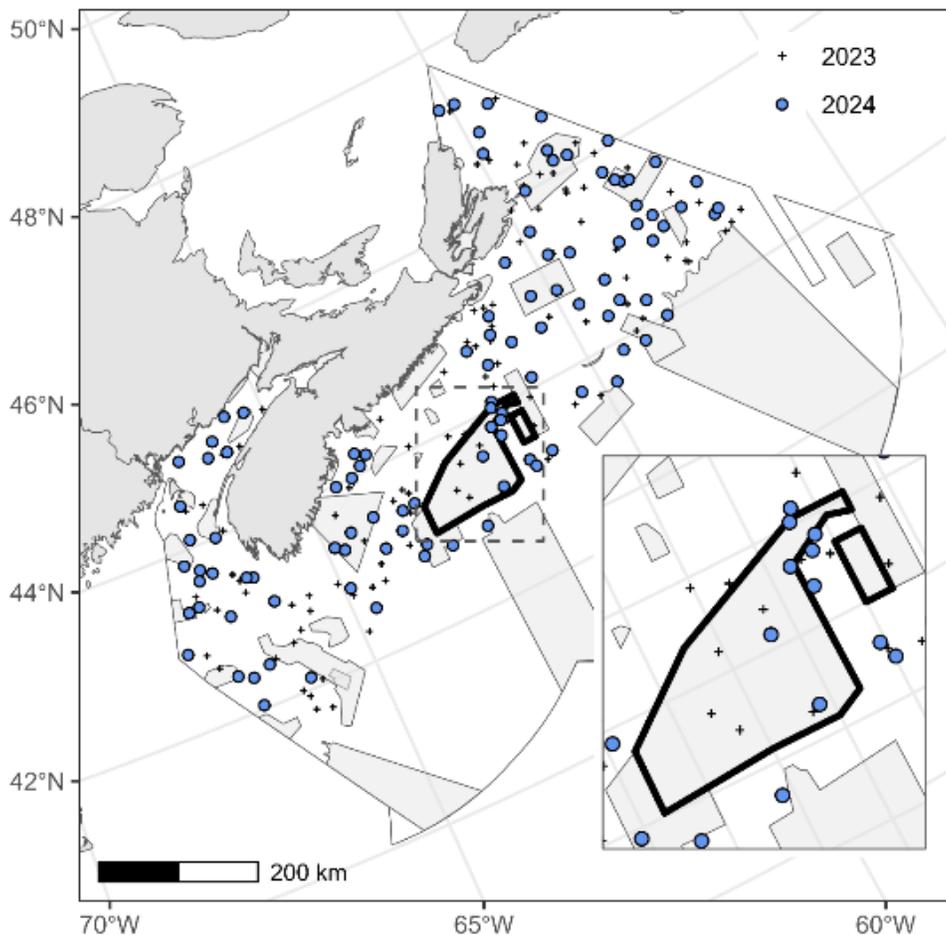


Figure 4. Location of the sampling stations conducted during the 2023 and 2024 halibut survey. Scotian Shelf-Bay of Fundy draft conservation network (as of February 2025) denoted by grey shaded polygons.

Acoustic Telemetry

Acoustic telemetry is an advanced technology for tracking the movement, residency, and behavior of aquatic animals. This technique involves attaching electronic transmitters to animals, either externally or internally via minor surgical procedures. Once released, tagged animals are detected by acoustic receivers deployed on the seabed, attached to autonomous gliders, or mounted on large animals with recoverable packages. These receivers record a unique identifier for each tag along with the date and time of detection. For transmitters equipped with additional sensors, environmental data such as depth, temperature, and activity levels are also transmitted.

Receiver deployments on the Scotian Shelf began in the mid-2000s and have since expanded into a robust monitoring system. Since 2008, Ocean Tracking Network (OTN), based at Dalhousie University, and DFO have maintained the Halifax Line, an acoustic receiver array spanning 205 km across the continental shelf in close proximity to WEBMR. This line, the largest fixed oceanographic monitoring system in the world, tracks the movements of a variety of tagged species on the Scotian Shelf. For WEBMR, acoustic telemetry offers an opportunity to

monitor ecological connectivity and habitat use in one of the Scotian Shelf's key conservation areas. Given its central location within the regional MPA network, WEBMR is uniquely positioned to serve as a node for monitoring species movement and connectivity.

Landers and Passive Acoustic Monitoring

Long-term deployments of landers mounted with a combination of different sensors can monitor changes in the environment and in species' behaviour at a high-temporal resolution. Using a combination of different sensors, such as timelapse imaging from fixed sources along with multiparametric environmental data acquisition, landers can provide insight on species' ecological niches and ecosystem functioning by directly relating animals' presence, abundance, and behavior to the fluctuating status of oceanographic and geochemical variables.

On the Scotian Shelf, landers have been deployed in several conservation areas over the last ten years. A collaboration between DFO and the Royal Netherlands Institute for Sea Research deployed a lander at 154 m depth in Sambro Bank Conservation Area from September 2017 to June 2018 to study the seasonal variability in bottom environmental conditions in the *Vazella pourtalesii* sponge grounds (Hanz et al. 2021), as well as the occurrence and behavioral rhythms of the Acadian Redfish (*Sebastes fasciatus*) in these sponge grounds (Grinyó et al., 2023). More recently, a collaboration of DFO, the University of Glasgow, and the Ocean Tracking Network, deployed and successfully recovered three benthic landers in the Sambro Bank Sponge Conservation Area (2021–2023) and the Gully Marine Protected Area (2022–2023) (Kenchington et al. 2021, De Clippele et al. 2023). These landers were equipped with camera systems and passive acoustic receivers to record the underwater soundscapes, including cetacean calls, in *Vazella pourtalesii* sponge and sea pen grounds, with the goal of quantifying fish biodiversity and habitat use within these two conservation areas.

Passive acoustic monitoring complements acoustic telemetry, and a small amount of this was conducted in a portion of WEBMR between 2015 and 2017, as part of larger studies, including a study designed to characterize the acoustic occurrence of North Atlantic right whales in northwest Atlantic Canadian waters, and evaluate the acoustic occurrence of blue, fin, sei, minke, and humpback whales (Delarue et al. 2022, Durette-Morin et al. 2022).

Ecosystem-based Reporting Framework

A hierarchical reporting framework for conservation monitoring is proposed, in which ecosystem indicators for specific conservation areas, like WEBMR, are integrated into regional conservation network reporting, and more broadly into shelf-wide, ecosystem-based reporting.

A regional conservation network has been developed in the Scotian Shelf-Bay of Fundy Bioregion. This network currently includes 10 established measures under the *Oceans Act* (MPAs) and *Fisheries Act* (Marine Refuges), with an additional 31 draft conservation sites spanning approximately 132,000 km² or 26% of the bioregion (Figure 5).

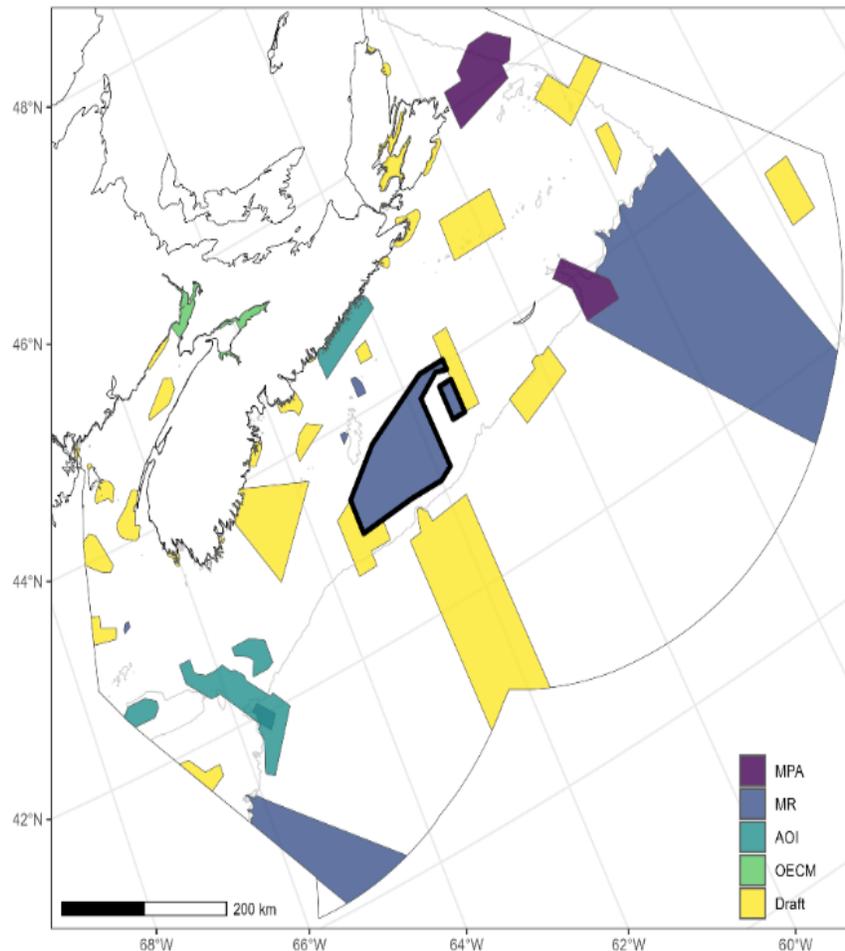


Figure 5. Map depicting the Scotian Shelf-Bay of Fundy Bioregional draft conservation network (as of February 2025). Thin grey line denotes the 250 m isobath.

National advice for MPA network monitoring emphasized the importance of shared monitoring principles to ensure consistent reporting on conservation outcomes across regional networks (DFO 2020). At the site level, this suggests that monitoring should be aligned with site-specific conservation priorities while also supporting broader network objectives. At the network level, monitoring can help to ensure that sites collectively advance regional conservation targets. Regional reporting can also be used to inform progress towards overarching national marine conservation targets and biodiversity commitments, ensuring alignment with national policies and international agreements. This nested approach can help to ensure that conservation areas are evaluated not only on their individual objectives but also on their contributions to the regional, national, and international conservation objectives.

Version 1.0 of an Ecosystem-Based Management (EBM) framework proposed for implementation in the Maritimes Region includes ecological objectives related to the maintenance and protection of habitat, biodiversity, and productivity, along with more recently developed socio-cultural, economic and governance objectives (Bundy et al. 2025). The ecological objectives of this framework, which have been in use by DFO for the last several decades (DFO 2001), are intended to support the conservation of ecosystem structure and function, species diversity, ecosystem resilience, and the protection or restoration of critical habitats, such as fish habitats. Aligning site-specific monitoring efforts with these objectives may

strengthen the connection between marine conservation activities and broader regional management goals.

The Maritimes Conservation Network Monitoring app is a pilot initiative aimed at providing an interactive, digital platform to:

1. Report ongoing scientific work on conservation sites within the regional network.
2. Assess how scientific efforts contribute to key indicators and conservation objectives.
3. Evaluate the status of individual sites based on existing data.
4. Visualize how each site contributes to broader network objectives.
5. Measure the impact of science projects on network-wide goals.
6. Provide scientific data to support status assessments.

This is being implemented using an R-Shiny tool to support shared indicator development and reproducible reporting for conservation measures in the Scotian Shelf-Bay of Fundy Bioregional conservation network. The tool reproducibly generates reports that detail sampling locations for various types of monitoring data, both within a conservation area and beyond its boundaries. It provides an overview of what is known about the area's status based on the latest available data, contextualized currently within the EBM ecological objectives ("bins") related to habitat, productivity, and biodiversity, as well as network- and site-level objectives. It also differentiates between those indicators that are used to inform the effectiveness of management measures (effectiveness indicators), our understanding of threats (threats indicators), and the broader ecological context (contextual indicators). The report includes analysis of each indicator, highlighting its status and trends, including interpretation through a climate change lens.

Results are visualized using a "flower plot" (Figure 6). Scored indicators are used to generate scores for thematic indicator bins, broader conservation objectives, and an overall assessment at the site or network level. Given the variation in conservation objectives across different scales—whether at the network, site, or thematic level—this approach provides a flexible structure for aligning ecological goals with specific indicators while maintaining comparability across sites.

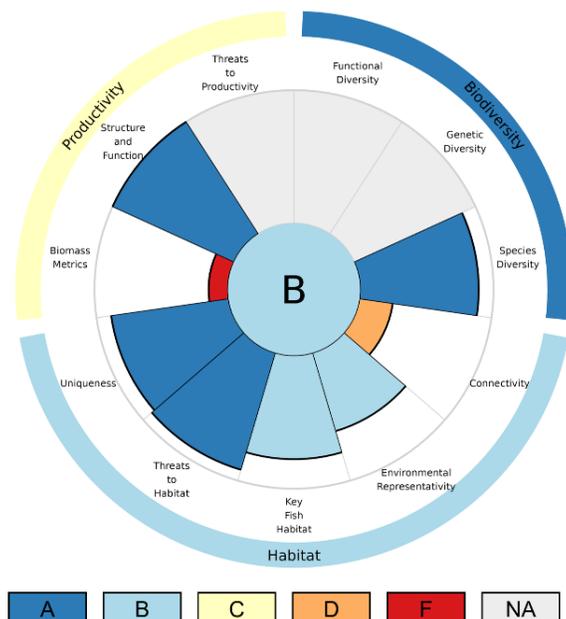


Figure 6. Example of a “flower plot” where the length of each petal is proportional to the bin score, and their width is proportional to their weight. The letter grade in the center is an example overall score (for illustration purposes only). The scores shown do not represent a finalized or authoritative assessment of status. Apparent data gaps may reflect datasets that have not yet been incorporated into the app, and do not necessarily indicate that data were not collected. Outer labels represent the EBM ecological pillars of Productivity, Biodiversity, and Habitat, and the inner labels represent thematic indicator bins.

By integrating an ecosystem-based thematic structure with adaptable yet standardized methodologies, it provides a pragmatic path for developing a long-term, reproducible, and scalable conservation reporting strategy. This integration is intended to help ensure monitoring programs of individual conservation areas align with the broader regional conservation network and establishes a foundation for consistency that will be helpful as the network expands. WEBMR was used as a case study, to demonstrate the value of this approach. More details on what has been achieved to date, using WEBMR as a pilot, can be found in Murillo et al. (In prep.)¹.

Sources of Uncertainty

Indicators proposed for monitoring in this review are focused on existing platforms and data collection approaches that have been used by DFO Science, and other partners, to date, in the Maritimes Region. Other monitoring approaches are possible, with different outcomes, which could be explored during future reviews. A lack of baseline and recent data exists for many aspects of the WEBMR ecosystem; thus, the proposed indicators are intended as a general guide as new information is collected and our understanding of the ecosystem, its ecological features, and its threats advances, along with our abilities to monitor these over time. The proposed indicators will require additional considerations for specificity, sensitivity, measurability, and redundancy (e.g., see analysis prepared for St Anns Bank, DFO 2024b) to ensure their effectiveness in monitoring the WEBMR ecosystem, as they are incorporated into a WEBMR monitoring plan.

As detailed in this report, the Scotian Shelf bioregion is experiencing shifts in climate and increasing variability in many ocean and ecosystem parameters. Consideration of past trends as

a predictor of species responses to future conditions can help to contextualize uncertainty associated with the impacts of environmental changes on species.

There is currently no systematic, routine monitoring program that targets ichthyoplankton or benthic communities in the Maritimes Region, though these have been studied in this area in the past. While benthos is recorded in, for example, the RV Survey, additional laboratory examination is often required to identify sponges, hydroids, and sea anemones, for example, to the species level. Given the importance of WEBMR as historical spawning and nursery grounds, and its objective to protect benthic habitats that support Haddock and other groundfish species, a means of monitoring of ichthyoplankton abundance at a regional scale, as well as benthic communities within WEBMR, would be highly beneficial for monitoring the effectiveness of WEBMR.

CONCLUSIONS AND ADVICE

Situated at the interface between the eastern and western Scotian Shelf, WEBMR provides a key transitional habitat demarking known climate-associated species assemblage transitions and the distribution of certain populations and/or taxa. With projected oceanographic changes driven by climate, its role as a transitional zone may become increasingly important in shaping future ecosystem dynamics, further strengthening the overall design and effectiveness of the regional conservation network.

The objective of WEBMR has always been closely tied to groundfish, with the Summer RV Survey at the heart of its monitoring and management efforts. As the longest-running dataset on groundfish diversity, abundance, and productivity in the area, the survey provides a benchmark for assessing ecological change and informing management. This survey provides the only platform for the broad-scale, standardized collection of data and samples in support of stomach content analysis, size frequency distributions, biomass estimates, and age structures across the entire Scotian Shelf. With a history of sampling across the shelf spanning over five decades, the survey offers an invaluable baseline against which shifts in biodiversity, ecosystem function, and environmental conditions can be gauged. Additionally, this survey incorporates environmental monitoring via the AZMP and supports many other complementary monitoring tools, such as eDNA sampling, further underscoring its foundational role. This survey remains an important source of data for managing and understanding this conservation area.

A suite of indicators to support monitoring of WEBMR are proposed, building on work conducted regionally and nationally on *Oceans Act* Marine Protected Areas (MPAs), other effective conservation measures, and conservation networks more generally, along with consideration of WEBMR's unique ecological features and conservation history. These include contextual indicators, which measure oceanographic and biological conditions, state/effectiveness indicators related to the three conservation objectives, and indicators to measure pressure and impact of anthropogenic activities.

A hierarchical reporting framework is also proposed, in which the monitoring indicators identified for WEBMR are integrated into regional conservation network reporting, and more broadly into shelf-wide, ecosystem-based reporting. Consistent with the application of a holistic, ecosystem approach in the Maritimes Region, this framework proposes alignment of indicators with productivity, biodiversity, and habitat objectives, emphasizing the role that conservation areas can play in maintaining ecosystem structure and function, species diversity, ecosystem resilience, and the protection or restoration of habitat.

Integration of WEBMR into the regional conservation network monitoring program emphasizes the importance of a hierarchical monitoring strategy that aligns with EBM principles (Figure 7). This approach not only allows for the tracking of key ecological processes within WEBMR but

also situates local-scale monitoring within the larger regional network context. As additional sites are incorporated into the conservation network, it may become increasingly important to implement integrated and consistent monitoring approaches across these areas to ensure efficient and effective reporting on biodiversity status and trends, while still maintaining site specificity.

In addition to a monitoring framework, an analytical oceanographic modelling framework could be used to support interpretation of site-specific oceanographic indicators in the broader regional context and facilitate understanding of the trends and status of the indicators that are selected. Linking trends to targets and thresholds can help to assess when conservation objectives are being met and when adaptive management interventions can alter negative trajectories. By integrating targets and thresholds into the broader monitoring framework, the system shifts from merely tracking ecological trends to actively guiding management interventions based on ecological health, noting that only fishing pressure and, to some, extent vessel traffic are manageable activities in this area. This approach can help to ensure that the monitoring program is not just informative but operational, supporting the long-term success of WEBMR and contributing to broader regional and global conservation goals, including the protection of biodiversity.

While targets guide the design of the network, indicator thresholds help to define the limits within which ecological conditions are considered acceptable at the site level. At the site level, performance measures should be aligned with these thresholds, linking indicators such as habitat quality, species diversity, and ecosystem processes to defined values that guide when action is required and can mitigate the situation. Decision criteria serve as benchmarks to trigger actions if an indicator's trajectory deviates from desired outcomes.

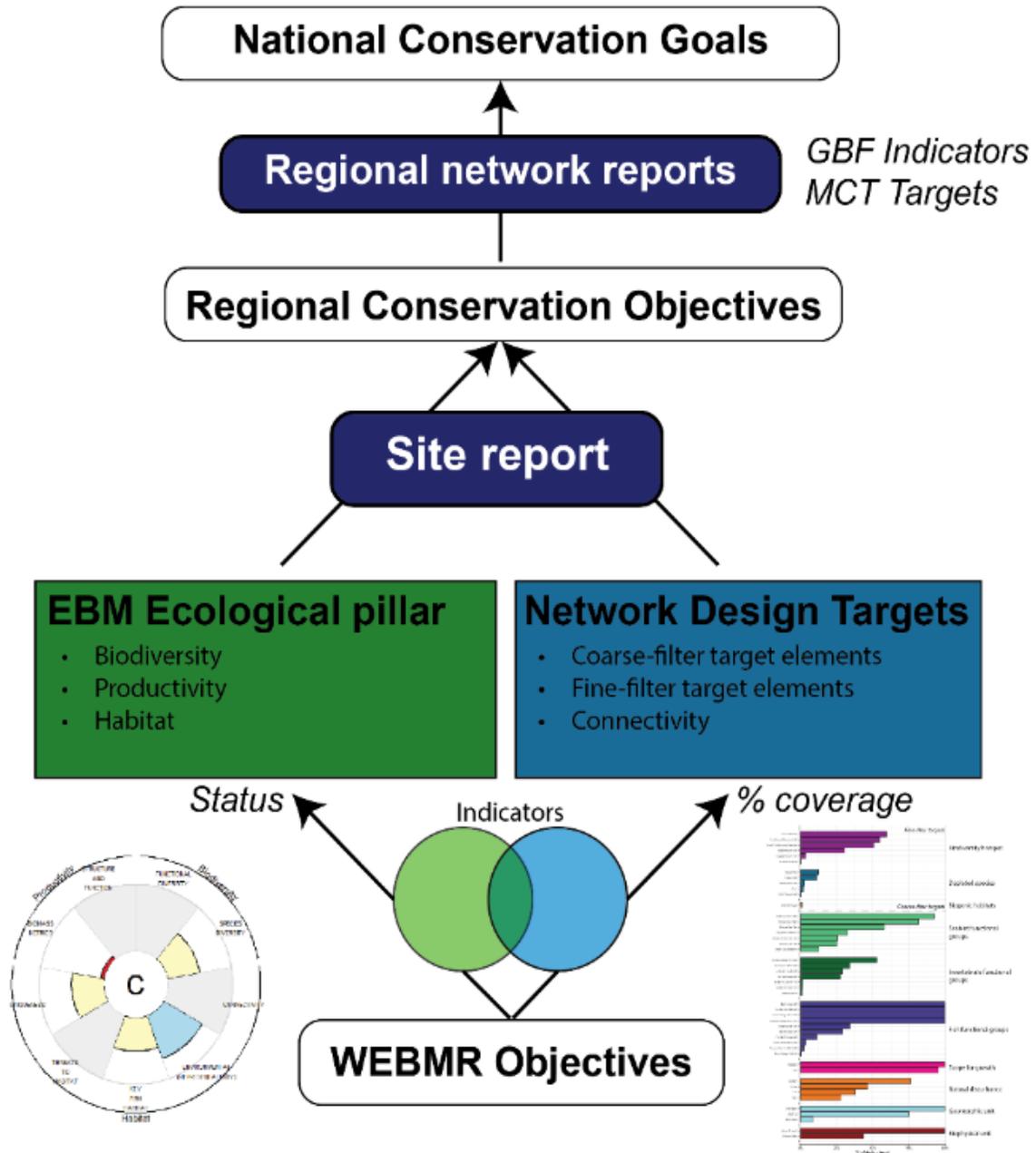


Figure 7. Flow chart depicting conservation objective hierarchy and reporting structure that nests site specific conservation objectives within the regional EBM and conservation network design.

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SOURCES OF INFORMATION

- Bowlby, H.D., McMahon, M., Li, L., den Heyer, C.E., and Harper, D. 2024. [Estimating Incidental Catch of Non-Target Species from the Commercial Fishery for Atlantic Halibut in Maritimes Region](#). DFO Can. Sci. Advis. Sec. Res. Doc. 2024/003. iv + 80 p.
- Breeze, H. 2004. Review of criteria for selecting ecologically significant areas of the Scotian Shelf and Slope: A discussion paper. Ocean. Coast. Manage. Rep. 2004-04. 88 p.
- Bundy, A., Eger, S.L., Stephenson, R.L., Westhead, M., the Maritimes Ecosystem-Based Management (EBM) Working Group and EBM Task Group Members. 2025. [Fisheries and Oceans Canada's Maritimes Region Ecosystem-Based Management Framework for Sustainable Management](#). Can. Tech. Rep. Fish. Aquat. Sci. 3716: vii + 175 p.
- De Clippele, L.H., Xu, J., Nozères, C., Whoriskey, F., Barthelotte, J., Phelan, K., MacDonald, B., Lirette, C., and Kenchington, E. 2024. Cruise Report in Support of Maritimes Region Research Project 'Use of Passive Acoustics to Quantify Fish Biodiversity and Habitat Use': Ocean Observation Systems in the Gully MPA and Scotian Shelf 2023. Can. Manuscr. Rep. Fish. Aquat. Sci. 3288: iii + 14 p.
- Delarue, J.J.-Y., Moors-Murphy, H., Kowarski, K.A., Davis, G.E., Urazghildiiev, I.R., and Martin, B.S. 2022. Acoustic occurrence of baleen whales, particularly blue, fin and humpback whales, off eastern Canada, 2015-2017. Endanger. Species Res. 47: 265-289.
- DFO. 2001. Proceedings of the National Workshop on Objectives and Indicators for Ecosystem-Based Management. Sidney, British Columbia. 27- February – 2 March 2001. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2001/09.
- DFO. 2011. [Musquash Estuary: A Proposed Monitoring Framework for the Marine Protected Area and Intertidal Area Administered by Fisheries and Oceans Canada](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/040.
- DFO. 2013. [Guidance on the Formulation of Conservation Objectives and Identification of Indicators, Monitoring Protocols and Strategies for Bioregional Marine Protected Area Networks](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/081.
- DFO. 2018. [Framework to support decisions on authorizing scientific surveys with bottom-contacting gears in protected areas with defined benthic conservation objectives](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/043.
- DFO. 2020. [Science Guidance on Approaches for Marine Bioregional Network Monitoring and Evaluation](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/035.
- DFO. 2021. [A National Monitoring Framework for Coral and Sponge Areas Identified as Other Effective Area-Based Conservation Measures](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/048.
- DFO. 2022a. [2021 Review of Musquash Marine Protected Area Monitoring](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2022/016.
- DFO. 2022b. [Glass Sponge Reef Adaptive Management Zones for the Hecate Strait and Queen Charlotte Sound Marine Protected Area, British Columbia](#). DFO Can. Sci. Advis. Sec. Sci. Resp. 2022/007.
- DFO. 2022b. [2021 Review of Baseline Information, Monitoring Indicators, and Trends in the Gully Marine Protected Area](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2022/017.

- DFO. 2024a. Scotian Shelf – Bay of Fundy Bioregional Marine Refuge Management Plan 2024: Part 1: Marine Refuge Management. Marine Planning and Conservation, Fisheries and Oceans Canada.
- DFO. 2024b. [Review of St. Anns Bank Marine Protected Area Monitoring: Selected Research Activities, Indicators, and Guidance on Next Steps](#). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2024/059.
- Durette-Morin, D., Evers, C., Johnson, H.D., Kowarski, K., Delarue, J., Moors-Murphy, H., Maxner, E., Lawson, J.W., and Davies, K.T.A. 2022. [The distribution of North Atlantic right whales in Canadian waters from 2015-2017 revealed by passive acoustic monitoring](#). Front. Mar. Sci. 9: 976044.
- Fanning, P., Zwanenburg, K., and Showell, M. 1987. [Haddock Nursery Closed Areas: Delineation and Impact](#). Can. Atl. Fish. Sci. Advis. Comm. Res. Doc. 1987/059. 46 p.
- Fisher, J.A.D., and Frank, K.T. 2002. Changes in finfish community structure associated with an offshore fishery closed area on the Scotian Shelf. Mar. Ecol. Prog. Ser. 240: 249-265.
- Frank, K.T., Shackell, N.L., and Simon, J.E. 2000. An evaluation of the Emerald/Western Bank juvenile haddock closed area. ICES J. Mar. Sci. 57: 1023-1034.
- Kenchington, E., Lirette, C., and De Clippele, L.H. 2021. Cruise Report in Support of Maritimes Region Research Project: Use of Passive Acoustics to Quantify Fish Biodiversity and Habitat Use. Can. Manuscr. Rep. Fish. Aquat. Sci. 3231: iv + 52 p.
- King, M., Fenton, D., Aker, J. and Serdynska, A. 2016. [Offshore Ecologically and Biologically Significant Areas in the Scotian Shelf Bioregion](#). DFO Can. Sci. Advis. Sec. Res. Doc. 2016/007. viii + 92 p.
- King, M., Koropatnick, T., Gerhartz Abraham, A., Pardy, G., Serdynska, A., Will, E., Breeze, H., Bundy, A., Edmondson, E., and Allard, K. 2021. [Design Strategies for the Scotian Shelf Bioregional Marine Protected Area Network](#). DFO Can. Sci. Advis. Sec. Res. Doc. 2019/067. vi + 122 p.
- Murphy, G.; and Kelly, N. 2023. [Cumulative human impact maps for the Bay of Fundy and Scotian Shelf](#). Open Science and Data Platform. Published September 2023. Coastal Ecosystems Science Division, Fisheries and Oceans Canada, Dartmouth, N.S.
- Shackell, N.L., Keith, D.M., and Lotze, H.K., 2021. Challenges of gauging the impact of area-based fishery closures and OECMs: a case study using long-standing Canadian groundfish closures. Front. Mar. Sci. 8, p.612859.

APPENDIX A: RATIONALE FOR THE SELECTION OF MONITORING INDICATORS FOR WEBMR, INCLUDING SOURCES OF DATA, READINESS, & LINKAGES TO CONSERVATION OBJECTIVES

Conservation Objectives (COs) for WEBMR:

1. Protect continental shelf habitats and associated benthic and demersal communities.
2. Support productivity objectives for groundfish species of Aboriginal, commercial, and recreational importance, particularly 4VW Haddock.
3. Protect benthic habitats that support juvenile and adult Haddock and other groundfish species.

Contextual Indicators			
Ocean Conditions (captured under Habitat - Representativity in the Flower Plot)			
<p>Understanding oceanographic conditions can help interpret the status of WEBMR's continental shelf habitats, and potential effects of climate change on associated benthic and demersal communities, which are identified as priorities as per WEBMR's CO 1. Oceanographic variables, such as temperature and salinity, serve as foundational indicators of habitat condition, providing context for understanding changes in biodiversity and productivity in the WEBMR ecosystem. Oceanographic conditions can also help to define habitat suitability for species of interest, such as Haddock, identified in CO 2; for example, many species have an oxygen threshold below which they experience reduced productivity and survival.</p>			
Variables	Example Indicators	Relationship to Conservation Objectives	Sources of Data / Readiness
Temperature	Sea Surface Temperature (SST) Temperature at Depth	Temperature can help to delineate water masses and the distribution of species associated with these water masses. Temperature also affects growth and development rates, generation times and productivity of all species. Heat waves may also cause direct mortality of temperature-sensitive species.	Available Now: AZMP, Gliders, RV Survey, and model results (e.g., BNAM)
Salinity	Sea Surface Salinity Subsurface Salinity	Salinity changes can impact ocean biological functions and may produce community shifts including trophic cascades. Changes in salinity can also adversely affect the temperature tolerance of aquatic organisms.	Available Now: AZMP, Gliders, RV Survey, BNAM
Oxygen	Oxygen saturation	Deoxygenation can impact marine life and its ecosystem directly and indirectly, and lead to changes in the abundance and distribution of fish, which, in turn, affects fisheries and productivity. This variable may be particularly important to monitor in deep habitats, where oxygen levels may be depleted.	Available Now: AZMP, Gliders, RV Survey
pH	Average pH levels	Reduction in seawater pH as a consequence of ocean acidification may	Available Now: AZMP

		cause behavioral and physiological effects on fish.	
Calcium carbonate	Aragonite and calcite saturation state	Ocean acidification can decrease calcium carbonate saturation affecting calcifying invertebrates such as echinoderms, mollusks, corals and crustaceans, that will experience difficulty maintaining their calcium carbonate exoskeleton and shells.	Available Now: AZMP
Nutrients	Nitrate concentration	Changes in nutrient levels can affect biological productivity.	Available Now: AZMP Readily Available: Glider nitrate sensors
<p>Ocean Structure and Movement (captured under Habitat - Connectivity in the Flower Plot)</p> <p>Ocean circulation is important for movement of eggs and larvae of fishes, as well as its role in habitat connectivity, structure and function (e.g., stratification, benthic/pelagic coupling). Ocean circulation is well modelled on the Scotian Shelf using models such as BNAM. Indicators can be measured directly through ocean observations made by programs such as AMZP or derived through models that are, in turn, validated through ocean observations.</p>			
Vertical structure	Stratification Mixed layer depth Wind speed Wave height	Ocean stratification plays a key role in many ocean processes, including the strength of benthic/pelagic coupling (i.e., the connectivity of benthic and pelagic ecosystems), as well as on phytoplankton blooms.	Available Now: AZMP, BNAM, Gliders, Environmental Canada weather stations
	Ocean mixing	Water turbulence has been linked to the feeding success of various species of fish larvae, as well as influences on seafloor habitat characteristics, reflecting the connection between physical and biological processes at the sea surface through the water column to the sea floor.	Readily Available: Gliders
Water mass distribution and transport	Average position of the shelf-slope front	The position of the shelf-slope front along the Scotian Slope can influence the interannual variability of phytoplankton bloom characteristics.	Available Now: Model-derived (BNAM), Gliders, AZMP
<p>Primary Production (captured under Productivity – Structure and Function in the Flower Plot)</p> <p>Phytoplankton constitutes the base of the marine food web and, consequently, their production sets an upper limit on the production of higher trophic levels, including groundfish (objective 2). Decreases in chlorophyll <i>a</i> can lead to a decrease in marine productivity and a negative impact on marine energy flow, which may have implications for the food availability to marine fish at different levels. Climate change can modify the timing of plankton blooms, which can produce a mismatch with fish spawning phenology.</p>			
Chlorophyll <i>a</i>	Chlorophyll <i>a</i>	Chlorophyll <i>a</i> measurements are typically used as a cost effective proxy for phytoplankton biomass at the ocean surface, which, in turn, can influence	Available Now: AZMP, remote sensing; Gliders, Phytofit app

		ocean bottom conditions through benthic/pelagic coupling.	
Phytoplankton production	Phytoplankton biomass	Phytoplankton constitutes the base of the marine food web and, consequently, their production sets an upper limit on the production of all higher trophic levels.	Needs Dev: models under development
Spring bloom phenology	Start date of the spring bloom	The timing of the spring bloom can directly influence the survival success of fish larvae. For example, the spring peak in phytoplankton production, along with high rates of <i>C. finmarchicus</i> reproduction, have been shown to occur within the historical Haddock spawning period.	Available Now: AZMP: remote sensing
<p>Secondary Production (captured under Productivity – Structure and Function in the Flower Plot)</p> <p>Zooplankton provides the main link between the phytoplankton and higher trophic levels. It can constitute an important and complex regulator of the fate of primary production and alter pelagic-benthic coupling. On the Western and Emerald banks, <i>Calanus finmarchicus</i> is an important food source for pre-settled juvenile Haddock. Zooplankton shifts driven by climate change can cause declines in food quality for fish. On the Scotian Shelf, mesozooplankton communities are consumed directly by larval and juvenile groundfish, juvenile and adult pelagic fish, baleen whales, and seabirds.</p>			
Zooplankton biomass	Biomass of <i>Calanus finmarchicus</i>	In the Western and Emerald Banks, <i>Calanus finmarchicus</i> is an important food source for pre-settled juvenile Haddock.	Available Now: AZMP, RV Survey
Zooplankton community composition	Comparison of 4 zooplankton abundance indices: total copepods, <i>C. finmarchicus</i> , <i>Pseudocalanus</i> spp., and non-copepods	Zooplankton shifts, which can be driven by climate change, can cause declines in food quality for fish. <i>C. finmarchicus</i> is a large copepod that dominates zooplankton biomass throughout most of the Scotian Shelf. It develops large energy reserves in later developmental stages and is a rich source of food for pelagic fish. <i>Pseudocalanus</i> spp. are small copepods that have smaller energy reserves relative to <i>C. finmarchicus</i> .	Available Now: AZMP, RV Survey
<p>Marine Mammals and Other Top Predators (captured under Productivity – Structure and Function [occurrence metrics] or Biodiversity – Species Diversity [diversity metrics] in the Flower Plot)</p> <p>Marine mammals are top predators that feed on a variety of prey, from Atlantic Cod to calanoid copepods. Changes in marine mammal distribution or abundance may indirectly affect conservation priorities of WEBMR. Similarly, other large, migratory and predatory species such as seals, sharks, tunas, and seabirds consume invertebrates and fish such as Atlantic Herring, competing with groundfish species like Haddock and Atlantic Cod.</p>			
Cetaceans	Seasonal occurrence	Cetaceans feed on a variety of species found within WEBMR, and, while not a conservation priority for WEBMR, are conservation priorities for the broader conservation network.	Available Now: Passive acoustics, dedicated surveys

Seals	Seasonal occurrence	Seals feed on a variety of species, including groundfish found in WEBMR.	Available Now: Tagging
Large Pelagic Fish	Seasonal occurrence	Large pelagic fish, including sharks and tunas, are top predators that feed on a variety of species found with WEBMR.	Available Now: Tagging
Seabirds	Seasonal occurrence	Seabirds are outside the scope of DFO mandate and so are not assessed here; however, indicators have been developed and are monitored by the Canadian Wildlife Service of Environment and Climate Change Canada.	Available Now: CWS data
<p>Trophic Structure and Function (captured under Biodiversity – Functional Diversity [functional groupings] and Species Diversity [species groupings] in the Flower Plot)</p> <p>The trophic structure and function of the eastern Scotian Shelf ecosystem changed after the collapse of the Atlantic Cod fishery in the early 1990s, from a community dominated by large-bodied demersal fish to one dominated by small demersal and pelagic fish species and benthic macroinvertebrates. Climate change is now also influencing the distribution of species, and hence ecological community composition. Monitoring predator-prey dynamics using functional groups, in addition to changes in species composition, including aquatic invasive species, can enhance our understanding of ecosystem structure and function, and its resilience to change.</p>			
Trophic Structure	Proportion of large and small demersal fish species	Monitoring predator-prey dynamics using functional groups (such as large versus small demersal fish species) can inform changes in ecosystem structure and function, which in turn can be linked to changes in overall productivity of the system.	Available Now: RV Survey
Species Diversity	Species richness	While demersal invertebrate and groundfish diversity metrics are listed below as potential effectiveness indicators, there may be value in tracking overall species diversity within the MPA using new and existing tools, such as eDNA, RV surveys, and visual/acoustic sampling, within species groups.	Available Now: RV Survey, CWS bird surveys, cetacean and seal visual (e.g., aerial) surveys, telemetry Under Dev: eDNA
Aquatic Invasive Species (AIS)	Occurrence and abundance of Aquatic Invasive Species in WEBMR	Presence of AIS is starting to be detected in offshore environments. While the focus of AIS mitigation and management has been in the coastal zone, consideration of their potential future impact on offshore environments is worth considering. Indicators included here would be related to impacts on ecosystem structure and function, while direct measures of human-contributions to their spreads would be included under the Pressures Indicators.	Readily Available: RV Survey; benthic landers; dedicated surveys
Effectiveness Indicators			

Benthic Environment (captured under Key Fish Habitat in the Flower Plot)			
Indicators related to the benthic environment, including benthic habitat, as well as the productivity and diversity of benthic organisms, can be used to inform COs 1 (Protect continental shelf habitats and associated benthic and demersal communities) and 3 (Protect benthic habitats that support juvenile and adult haddock and other groundfish species).			
Benthic Habitat	Distribution of biotypes within WEBMR Distribution of epibenthic and infaunal benthic communities	A hierarchical marine ecological classification system is being used by DFO to classify the structure and distribution of Canada's marine biota and habitats at multiple spatial scales. Data from trawl surveys are used to define biophysical units and biotopes of epibenthic species. However, they integrate data at scales of kilometers and so are not able to resolve biological facies, which are groups of biogenic habitat or foundation species identified by one or more indicator species resolved at spatial scales of hundreds of meters.	Available Now: RV Survey, multibeam Needs Dev: Finer-scale resolution sampling within biotopes would require additional effort or dedicated sampling, such as ROVs, stomach sampling, drop cameras, or grabs
Habitat-Forming Species	Abundance, biomass, and possibly size composition of habitat-forming species (e.g., sea pens, <i>Vazella pourtalesii</i> , horse mussels) within WEBMR	Sea pen (Pennatulioidea) fields, Horse Mussel (<i>Modiolus modiolus</i>) reefs, and Sand Dollar (<i>Echinarachnius parma</i>) beds are structure-forming benthic biogenic habitats listed as notable in the Scotian Shelf - Bay of Fundy Bioregional Marine Refuge Management Plan. Another ecologically and biologically important species recorded in the area is the Russian Hat Sponge (<i>Vazella pourtalesii</i>).	Available Now: RV Survey (dedicated surveys are also possible) Needs dev: dedicated visual surveys
Benthic Invertebrates	Abundance/biomass of benthic invertebrates, including prey species for groundfish within WEBMR (also a Productivity metric)	Haddock, Atlantic Cod, American Plaice, and Winter Skate feed on many benthic organisms. Recording the abundance and/or biomass of the main benthic phyla or class can provide a metric of the food supply and quality for groundfish.	Available Now: RV Survey (dedicated surveys are also possible)
	Richness of epibenthic and infaunal communities within WEBMR	Changes in benthic diversity could lead a changes in the benthic communities. This might not change quickly and so may not need to be assessed very often. The exception to this might be a heatwave that	Readily Available: RV Survey (epibenthos), dedicated surveys

	(also a Biodiversity metric)	could result in a mass mortality event and which cannot be monitored under the current monitoring approach.	
Benthic ecosystem function	Biomass of benthic bioturbators (also a Productivity metric)	Ecosystem function and services provided by benthic organisms, including bioturbation, habitat provision, and pelagic-benthic coupling, can be mapped and monitored at different spatial scales. These functions will be related to the abundance/ biomass of species with specific biological traits.	Available Now: RV Survey (some species) Needs Dev: dedicated sampling and analysis (expanded # of species and metrics of bioturbation)
<p>Fish and Fishery Resources</p> <p>A key reason for the establishment of the Haddock Box fisheries closure was to protect juvenile Haddock. In addition, the groundfish community on the eastern half of the Scotian Shelf collapsed in the early 1990s, with changes in community structure, including widespread decline in body size of groundfish and other ecosystem changes that have persisted. These are both reflected in WEBMR's Conservation Objectives 2: support productivity objectives for groundfish species of Aboriginal, commercial, and recreational importance, particularly 4VW Haddock.</p>			
Groundfish Productivity (captured under Productivity - Biomass Metrics in the Flower Plot)	Relative abundance and biomass of select groundfish species	Monitoring of the relative abundance and biomass of Haddock, Atlantic Cod, American Plaice, Atlantic Halibut, and Winter Skate may serve as direct measures of the effectiveness of the WEBMR marine refuge, noting that these populations extend beyond the boundaries of the site and thus are also impacted by other activities, such as fishing. DFO's RV Survey has provide effective sampling of groundfish abundance and biomass across the Scotian Shelf since the 1970s. Four of the RV Survey strata are included within the current WEBMR boundary, with 3 of these extending beyond the boundary.	Available Now: RV Survey Under Dev: eDNA
	Size distribution of select groundfish species	Relative size distribution of Haddock, Atlantic Cod, American Plaice, Atlantic Halibut, and Winter Skate.	Available Now: RV Survey
	Condition of select groundfish species	Fish condition is the relation between fish length and weight, measured during the RV Survey. It is a measure of how healthy these species are, in terms of availability of food, for example.	Available Now: RV Survey

	Fecundity of select groundfish species	Fecundity is a measure of the reproductive success, which can indicate the health of groundfish populations.	Available Now: RV Survey
	Abundance (by type) of fish eggs and larvae during spawning times	Spawning, egg production, and survival of early life stages are important steps along the pathway leading to fish recruitment, which is one of the dominant processes regulating fish population productivity.	Needs Dev: Dedicated surveys would be required
Groundfish Diversity (captured under Biodiversity - Species Diversity in the Flower Plot)	Community composition of demersal fish	Characterization of assemblages of demersal fish and benthic invertebrates on the Scotian Shelf using RV Survey data from 2007 to 2017.	Available Now: RV Survey Under Dev: eDNA
Groundfish Habitat Use (captured under Habitat - Key Fish Habitat in the Flower Plot)	Distribution of juvenile Haddock, as an indication of habitat use	One of the initial reasons for the establishment of WEBMR was to protect juvenile Haddock and their habitat. One way to delineate fish habitat is through mapping of the distribution and movement of the species themselves (in addition of mapping of habitat features), which is why this indicator is included in this fish and fishery resources section.	Available Now: RV Survey distribution of juvenile haddock; Needs Dev: Habitat Suitability Models
	Distribution of other key groundfish species, as an indication of their habitat use	Mapping of the distribution and movement of key groundfish species, including Atlantic Cod, American Plaice, and Winter Skate, can provide an indication of habitat use.	Available Now: RV Survey distribution of key fish species Needs Dev: Habitat Suitability Models
Anthropogenic Pressure and Impacts (captured under Threats to Productivity or Threats to Habitat in the Flower Plot)			
Fisheries	Amount of fishing, including unauthorized fishing	Fishing, including unauthorized fishing, has direct and indirect effects on habitat, and on the diversity, structure and productivity of fish and invertebrate communities.	Available Now: C&P data
	Area of seabed within and in the vicinity of WEBMR swept by bottom-tending mobile fishing gears	While bottom-tending commercial fishing gear are currently excluded from WEBMR, it is recommended that this indicator be retained to capture any fishing, including unauthorized fishing, that occurs now or in the future.	Available Now: AIS data

	Total annual landings from 4W for directed groundfish fisheries and common bycatch-only stocks	Directed groundfish fisheries include Atlantic Halibut, Atlantic Cod, Cusk, Dogfish, flounder, Haddock, Monkfish, Pollock, redfish, Silver Hake, skates, sculpin, White Hake, and wolffish. This indicator can be used to compare to productivity outside the site.	Available Now: Commercial catch data
Research	Area of seabed within and in the vicinity of WEBMR swept by bottom-tending mobile fishing gear used for research and monitoring	Although the effects of RV survey are more limited, they can still affect some of the benthic communities in the area and this effort needs to be quantified.	Available Now: Various sources, research platform dependent
Other Vessels	Sea vessel traffic intensity Ocean sound	Frequency and speed of transits within or nearby WEBMR by vessels other than pleasure craft, broken down into naval vessels, fishing vessels not fishing in the marine refuge, and other vessels, as well as indicators of impact (e.g. noise, light). Use of VMS or AIS. Underwater noise generated by human activities can have an impact on the behavior and physiology of fish and invertebrate populations. Similarly, artificial light at night can cause changes in animals predation patterns or inhibition of zooplankton diel vertical migration. Traffic intensity using VMS data can be used as a proxy for underwater noise an light if not direct measurements are available.	Available Now: VMS or AIS data
Cables	Number of seabed cables by type	The use of submarine power cables is expected to increase due to the growth of the marine renewable energy sector. Their impacts include physical disturbance, noise, chemical pollution, heat and electromagnetic field emissions between others.	Available Now: Natural Resources Canada
Offshore Energy	Number of drilling wells in proximity to WEBMR	Exposure to petroleum can cause biological effects, changes in behavior and modify benthic communities.	Available Now: Offshore Energy Regulator
	Number of offshore wind developments within and in the vicinity of WEBMR	Wind farms installations have several effects on the ecosystem, which include habitat loss or alteration of trophic webs.	Available Now: Offshore Energy Regulator

<p>Chemical Contamination & Marine Debris</p>	<p>Concentrations of contaminants, by type, including organic chemicals and heavy metals, in biota, water column and seabed</p>	<p>Invertebrates and fish are vulnerable to the toxic effects of pollutants such as pharmaceuticals, heavy metals, pesticides, and microplastics. These pollutants can lead to physiological changes or reproductive issues.</p>	<p>Available Now: Ecosystem Stressors Program</p>
	<p>Quantity of anthropogenic debris, including plastic and microplastic, on the seabed.</p>	<p>Anthropogenic debris, such as microplastics, plastic waste, or fishing gear pose a substantial risk to marine organisms, food webs and the ecosystem. They can produce chemical leaching, organism rafting, physical disturbance, ingestion, and entanglement.</p>	<p>Available Now: Ecosystem Stressors Program</p>
<p>Cumulative Impacts</p>	<p>Change in relative cumulative impact</p>	<p>Models of cumulative impacts are being developed for the offshore Scotian Shelf, which could be used to generate relative metrics of impacts, including changes in the relative distribution of impacts over time.</p>	<p>Available Now: Murphy and Kelly (2023)</p>

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