Offshore Ecological and Human Use Information considered in Marine Protected Area Network Design in the Scotian Shelf Bioregion

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Serdynska, A.R., Pardy, G.S., and King, M.C. 2021. Offshore Ecological and Human Use Information considered in Marine Protected Area Network Design in the Scotian Shelf Bioregion. Can. Tech. Rep. Fish. Aquat. Sci. 3382: xi + 100 p.

Canada has made domestic and international commitments to increase the protection of its coastal and marine areas through the establishment of networks of Marine Protected Areas (MPAs). The Department of Fisheries and Oceans (DFO) is responsible for leading the development of a national network of MPAs on behalf of the Government of Canada. Several bioregional-scale MPA network planning processes are currently underway across the country. In 2016-17, DFO Maritimes Region undertook an MPA network analysis for the Scotian Shelf-Bay of Fundy Bioregion. The analysis considered available bioregional-scale ecological and human use data in an effort to identify a draft MPA network design that would protect biodiversity while minimizing any potential impacts on commercial fishing and other industries. This report contains a summary of the data layers used for the offshore component of the MPA network analysis. The ecological data layers have been organized into coarse-filter (i.e., ecological classifications and functional groups for fishes, invertebrates, and seabirds) and fine-filter (i.e., areas of high species richness, biogenic habitats, and depleted species) conservation priorities. The ecological section of this report contains descriptions of how the different layers were created and the rationale for their inclusion in the MPA network analysis. Human use data (i.e., fisheries landings, oil and gas activity, and shipping activity) were also considered. The human use section of this report contains descriptions of all the socio-economic layers considered in the development of the draft MPA network design.

RÉSUMÉ

Serdynska, A.R., Pardy, G.S., and King, M.C. 2021. Offshore Ecological and Human Use Information considered in Marine Protected Area Network Design in the Scotian Shelf Bioregion. Can. Tech. Rep. Fish. Aquat. Sci. 3382: xi + 100 p.

Le Canada a pris des engagements nationaux et internationaux pour accroître la protection de ses zones côtières et marines grâce à l'établissement de réseaux de zones de protection marines (ZPM). Le ministère des Pêches et des Océans (MPO) est chargé de diriger la création d'un réseau national de ZPM au nom du gouvernement du Canada. Plusieurs processus de planification du réseau de ZPM à l'échelle biorégionale sont en cours dans l'ensemble du pays. En 2016-2017, la région des Maritimes du MPO a entrepris une analyse du réseau de ZPM pour la biorégion du plateau néo-écossais et de la baie de Fundy. Les données disponibles sur l'utilisation écologique et humaine à l'échelle biorégionale ont été prises en compte dans le cadre de l'analyse afin de tracer l'ébauche d'un réseau de ZPM qui protégerait la biodiversité tout en minimisant les répercussions potentielles sur la pêche commerciale et les autres industries. Le présent rapport présente un résumé des couches de données utilisées pour la composante hauturière de l'analyse du réseau de ZPM. Les couches de données écologiques ont été organisées selon les priorités de conservation du filtre grossier (c.-à-d. classifications écologiques et groupes fonctionnels pour les poissons, les invertébrés et les oiseaux de mer) et du filtre fin (c.-à-d. zones caractérisées par une grande richesse en espèces, habitats biogéniques et espèces en déclin). La section de ce rapport qui porte sur l'écologie décrit la manière dont les différentes couches ont été créées et justifie leur inclusion dans l'analyse du réseau de ZPM. Les données relatives à l'utilisation humaine (c.-à-d. les débarquements de la pêche, les activités pétrolières et gazières et l'activité de transport maritime) ont également été prises en compte. La section de ce rapport qui est consacrée à l'utilisation humaine fournit quant à elle une description de toutes les couches socioéconomiques prises en compte dans la conception du réseau de ZPM.

1.0 INTRODUCTION

Canada has made domestic and international commitments to increase the protection of its coastal and marine areas through the establishment of a national network of Marine Protected Areas (MPAs)[1]. In the Summer of 2019, Canada announced that it had surpassed the target of protecting 10% of its oceans by 2020[2]. More recently, the Minister of Fisheries and Oceans was tasked with developing a plan to conserve 25% of Canada's oceans by 2025, working toward 30% by 2030[3].

Fisheries and Oceans Canada (DFO) is leading the development of the national MPA network[4] on behalf of the Government of Canada. Network development is guided by the 2011 *National Framework for Canada's Network of MPAs* (Government of Canada 2011), which states that MPA network planning and design will take place at the bioregional scale and will involve federal, provincial and territorial government departments, First Nations and Indigenous groups, stakeholders, and other interested parties.

Over the last decade, DFO Maritimes Region has made significant progress on the development of an MPA network plan for the Scotian Shelf-Bay of Fundy Bioregion. Available ecological and human use data have been compiled, MPA network objectives and conservation priorities have been set, and a preliminary MPA network analysis was completed (Horsman et al. 2011). The network design process has followed the general approach and principles of systematic conservation planning (Margules and Pressey 2000). A draft MPA network design has been developed and, following consultation, will be crafted into a long-term MPA network plan for the bioregion.

The DFO Maritimes Region boundary represents the MPA network planning area for the Scotian Shelf-Bay of Fundy Bioregion. The planning area includes the waters of Scotian Shelf and Slope, the Bay of Fundy, the Canadian portion of Georges Bank and the Gulf of Maine, and the deep-water area out to the extent of the Canadian Exclusive Economic Zone (Figure 1). Due to differences in available data, the planning area has been divided into coastal and offshore components. The coastal component includes the Atlantic coast of Nova Scotia (roughly defined as the area inshore of the 100 m isobath) and the Bay of Fundy, while the offshore component encompasses the remaining waters. For the shallower portion (< 1500 m depth) of the offshore

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[1] A network of marine protected areas (MPAs) is a collection of MPAs and other conserved areas that operate cooperatively to safeguard important ecological components of the ocean and marine biodiversity as a whole (https://www.dfo-mpo.gc.ca/oceans/networks-reseaux/info-eng.html).

[2] https://www.dfo-mpo.gc.ca/oceans/conservation/achievement-realisations/index-eng.html

[3] https://pm.gc.ca/en/mandate-letters/2019/12/13/minister-fisheries-oceans-and-canadian-coast-guard-mandate-letter

[4] The Department of Fisheries and Oceans recently decided to replace the term *MPA network* with *conservation network*. However, the term MPA network will be used in this document to maintain consistency with previous publications related to the network planning process in the Scotian Shelf-Bay of Fundy Bioregion.

area, systematic, long-term surveys such as the DFO Research Vessel (RV) Survey provide region-wide datasets that allow for a data-driven approach to MPA network design. In contrast, there is no regular long-term monitoring of the coastal zone in the bioregion so the information that is available is patchy and more descriptive in nature, making this part of the region less suitable for a data-driven approach to network design.

The purpose of this background paper is to present the offshore ecological and human use information that was considered in the development of an MPA network design for the Scotian Shelf-Bay of Fundy Bioregion. The spatial data layers presented here were inputs to a data-driven MPA network design analysis in 2017. It should be noted that many of the data layers presented in this document have been and will continue to be updated as more data become available, and additional layers may be considered in future MPA network planning exercises.

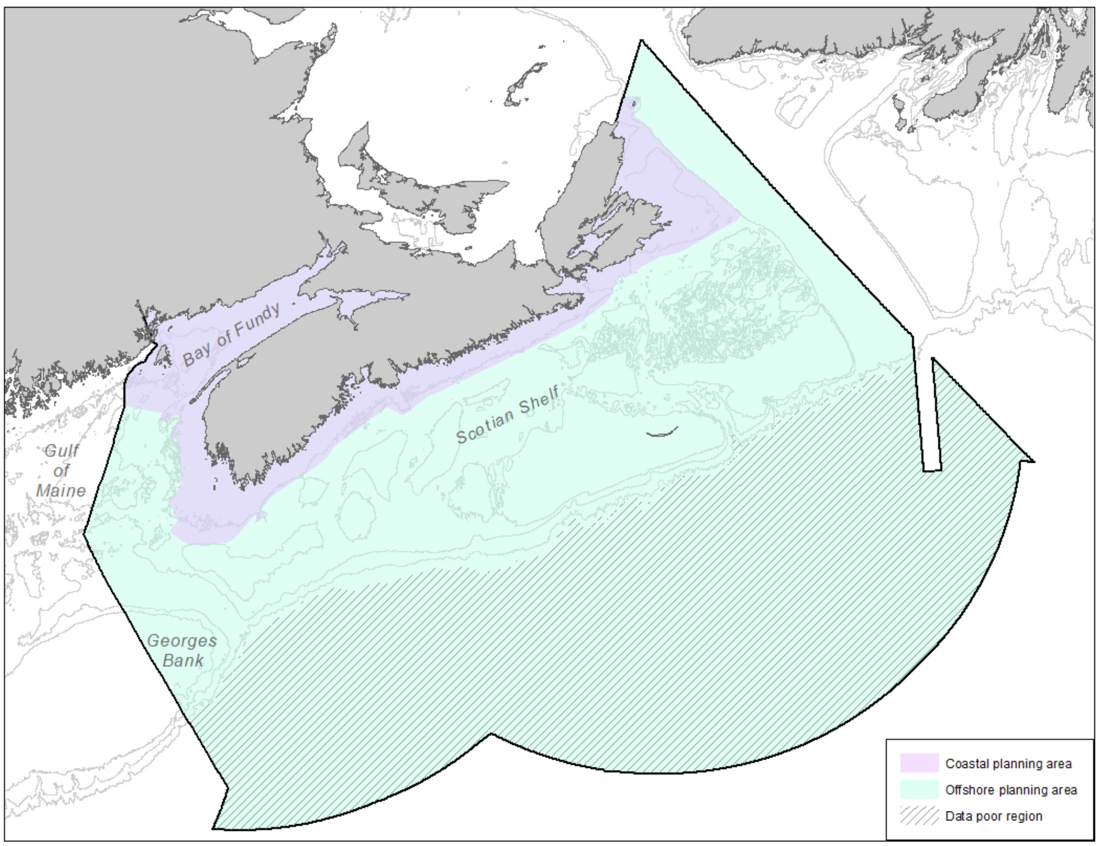

Figure 1. The DFO Maritimes Region (used to represent the Scotian Shelf-Bay of Fundy Bioregion) boundary represents the MPA network planning area and has been divided into coastal and offshore components. The areas > 1500 m depth are not covered by DFO's RV Survey and are considered data poor.

DFO Science has provided national guidance on the design of MPA networks (DFO 2010), including considerations for how to achieve representativity (DFO 2013). Additional science advice has been provided on MPA network data, objectives, and design strategies specific to the DFO Maritimes Region (DFO 2012, DFO 2014a, 2018). DFO Oceans (unpublished) has also crafted national guidance for regional MPA network development. This includes an *objectives hierarchy* to promote consistency in approach and terminology among regional MPA network development processes (Table 1).

Table 1. Objectives hierarchy for regional MPA network development in Canada.

Level in Hierarchy	**Description**
National goals	High-level statements that outline what the National MPA Network aims to achieve. Contained in the National Framework.
Strategic objectives	Relatively high-level statements that outline what a regional MPA network aims to achieve.
Conservation priorities	Specific species, habitats or other ecological features a regional MPA network aims to protect.
Operational objectives	Specific and measurable statements that indicate the desired state for each conservation priority for a regional MPA network.
Design strategies	Detailed statements that, for each operational objective, specify: (1) the types of areas or features to be conserved (e.g., significant concentrations, feeding aggregations, nursery areas, spawning areas), and; (2) the relative targets for those area types (e.g., high, medium, low).

2.0 ECOLOGICAL DATA INPUTS

This section presents the ecological data layers used to represent the different conservation priorities for the offshore component of the Scotian Shelf Bioregion. A conservation priority is a specific species, habitat or other ecological feature that an MPA network aims to protect (Table 1). Conservation priorities have been grouped into coarse-filter features, such as broad-scale seascape, ecosystem, community or habitat types, and fine-filter features, which are individual species or other smaller scale ecological features (e.g., cold-water coral reefs). Comprehensive networks of MPAs should capture representative examples of broad-scale ecosystem or habitat types in a region (coarse-filter) as well as smaller scale special natural features and priority species (fine-filter) (Noss 1987, Lieberknecht et al. 2010). Where necessary, the data layers presented in this document were clipped to exclude the coastal planning area (Figure 1), as those areas were not considered in the offshore component of the MPA network design analysis.

2.1 COARSE-FILTER CONSERVATION PRIORITIES

Coarse-filter conservation priorities are broad-scale seascape, ecosystem, community or habitat types. The theory behind a coarse-filter approach to conservation planning is that protecting representative examples of all major ecosystem or habitat types in a planning area will capture 85-90% of all species that occur in that area (Noss 1987). This approach is particularly useful in situations where comprehensive species inventories or reliable species distribution data are not available.

2.1.1 Hierarchical Marine Ecological Classification

Description: DFO (2016) developed a hierarchical classification system for the Scotian Shelf Bioregion using environmental data and other information from biological analyses in the region. Among the classifications developed were Biophysical and Geomorphic units of the bioregion. Biophysical units were defined as "distinct physiographic and oceanographic conditions and processes that shape composition". Geomorphic units were defined as "discrete geomorphological structures defined by shape, size and topographic variation on the seafloor that are associated with distinctive biological assemblages" (DFO 2016a).

Nine Biophysical Units (Figure 2) were delineated based on oceanography (bottom temperature, salinity, and current stress) and depth. Twelve Geomorphic Units (Figure 3) were delineated based on a modified version of Fader's (2007) geomorphic classification of the Scotian Shelf and Bay of Fundy. DFO (2016) also developed Physiographic units, but they were not considered for this analysis because they were very similar to the Geomorphic units. Each Biophysical and Geomorphic unit was treated as a separate coarse-filter conservation priority for the MPA network.

Rationale: DFO's (2016) ecological classifications were used as coarse-filter layers in the MPA network analysis. Various oceanographic units and geomorphic units were selected as a proxy for different ecosystems/communities in the region.

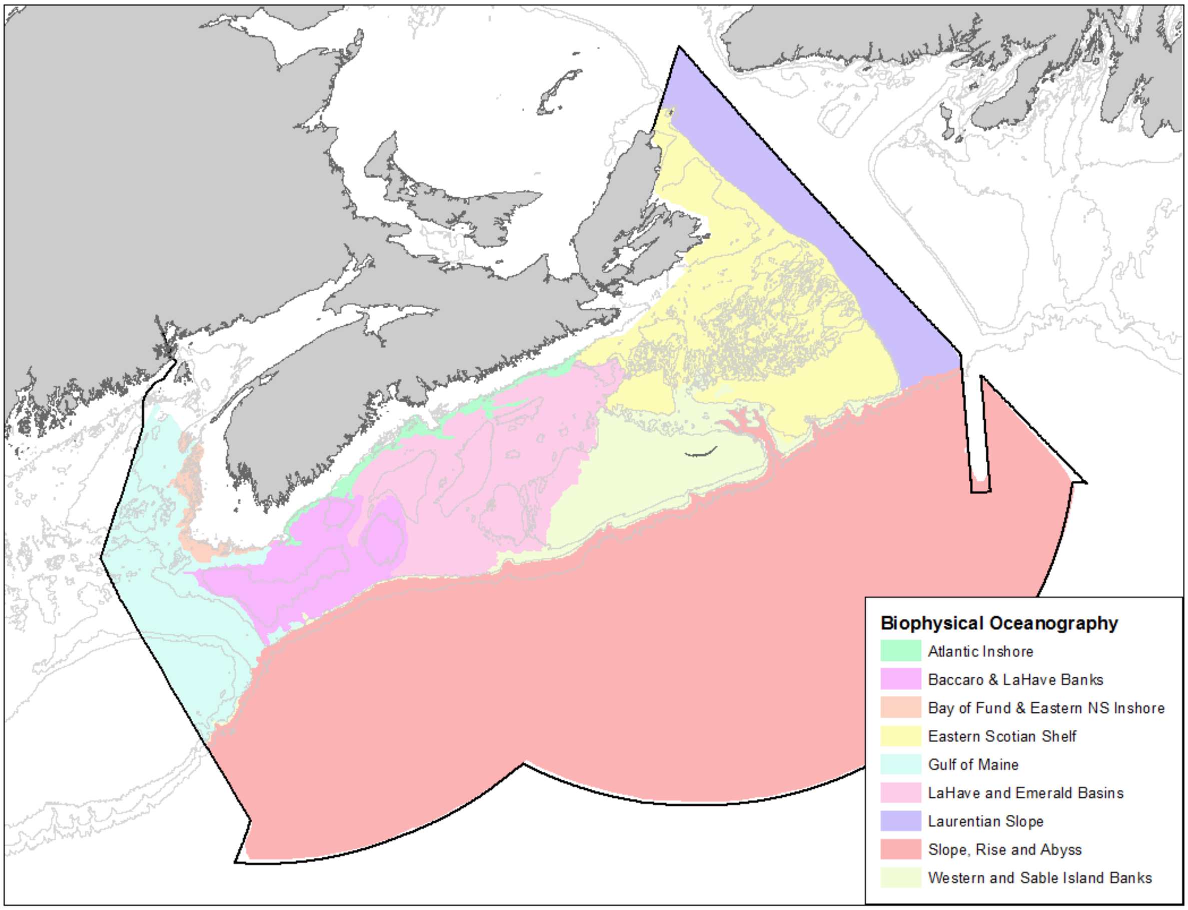

Figure 2. Nine Biophysical units defined by Greenlaw et al. (DFO 2016a), clipped to offshore planning area.

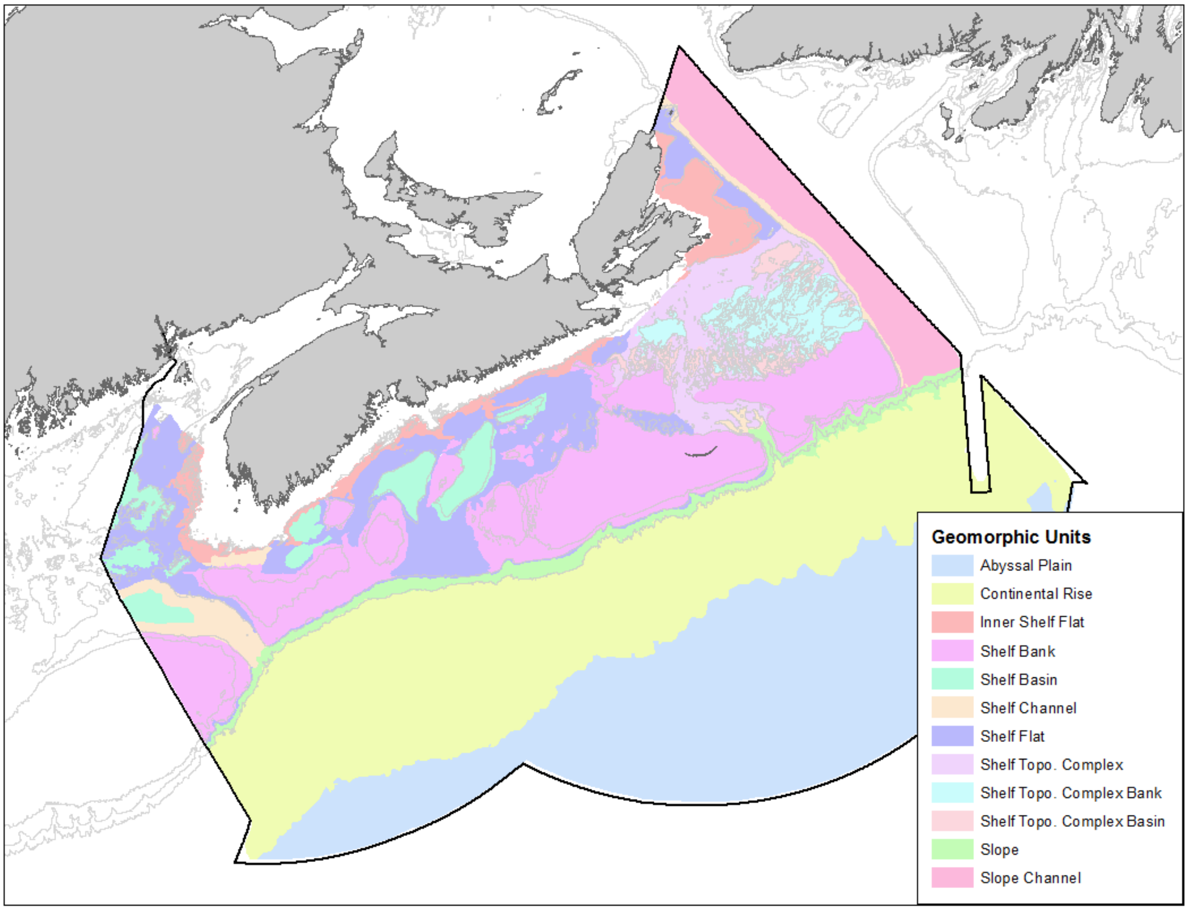

Figure 3. Twelve Geomorphic units defined by Greenlaw et al. (DFO 2016a), clipped to offshore planning area.

2.1.2 Kostylev and Hannah Habitat Template

Description: Kostylev and Hannah (2007) created benthic habitat maps for the Scotian Shelf and Bay of Fundy. They used a range of variables to describe Scope for Growth and Natural Disturbance conditions in the region. Scope for Growth, a representation of growing conditions, was estimated based on food variability, bottom temperature and variability, and oxygen saturation data. Natural disturbance, a representation of physical disturbance on the bottom, was estimated using sediment grain size and characteristic bottom stress data. Kostylev and Hannah's (2007) benthic classification was created as a spectrum of growing conditions and disturbance, rather than discrete classes. Horsman et al. (2011) delineated the classification into discrete classes: five for Scope for Growth (Figure 4) and four for Natural Disturbance (Figure 5), as they were easier to work with in an MPA network analysis. These discrete classes were also used for this analysis.

Kostylev and Hannah (2007) suggest that species life history traits are related to the properties of the environment they live in. Therefore the ecological communities found in these areas would likely be different. Areas of low scope for growth would support slow growing species (e.g. cold water corals, quahogs), while areas of high scope for growth would support fast growing species (e.g. tube building polychaetes, scallops). In addition, areas of low natural disturbance would support species with more delicate body shapes (e.g. cold water corals, tube building polychaetes), while areas of high natural disturbance would support species with more robust body shapes (e.g. scallops, quahogs).

Rationale: Kostylev and Hannah's (2007) benthic classification was used as a representative layer. The MPA network should contain a range of growing conditions and physical disturbance, as a proxy for different community types.

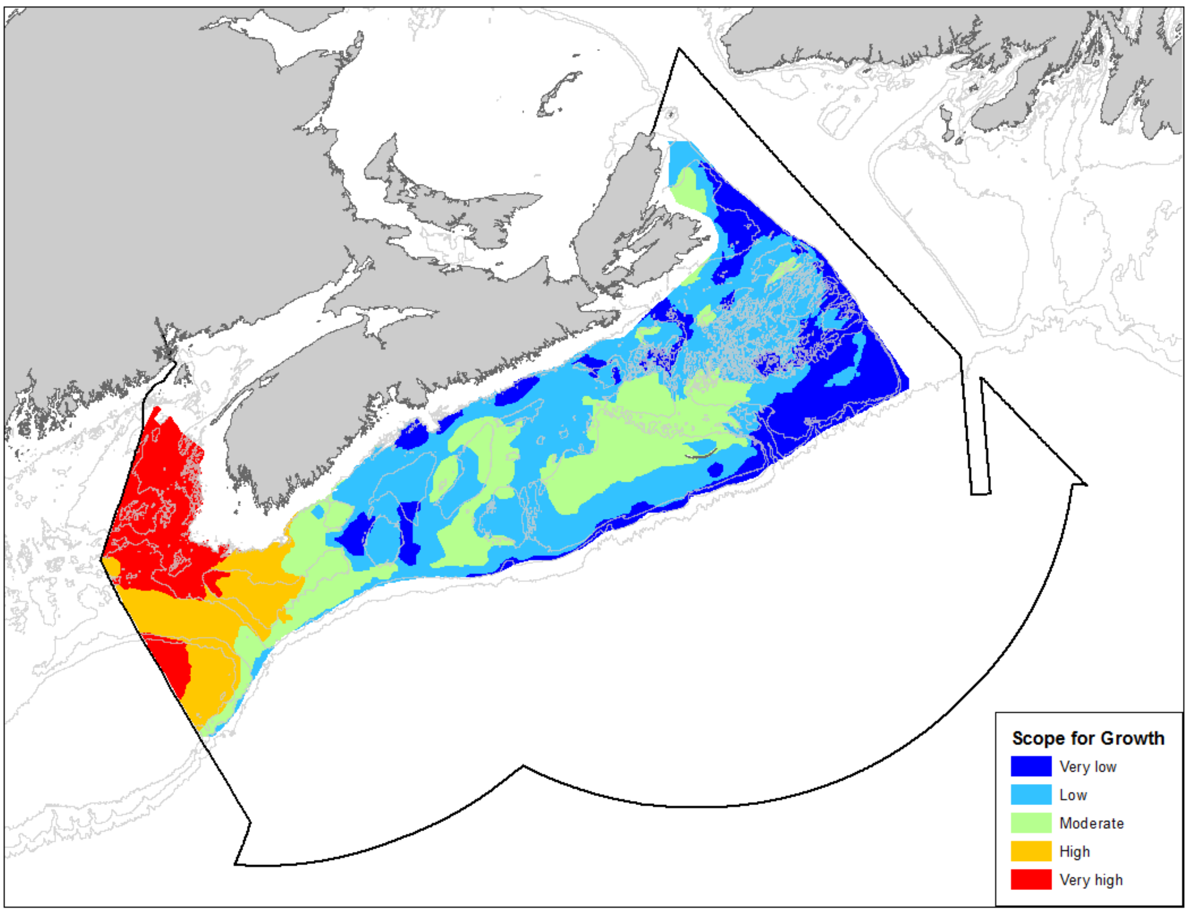

Figure 4. Scope for Growth classes defined by Kostylev and Hannah (2007) and delineated by Horsman et al. (2011). Scope for Growth represents growing conditions and was estimated based on food variability, bottom temperature and variability, and oxygen saturation data.

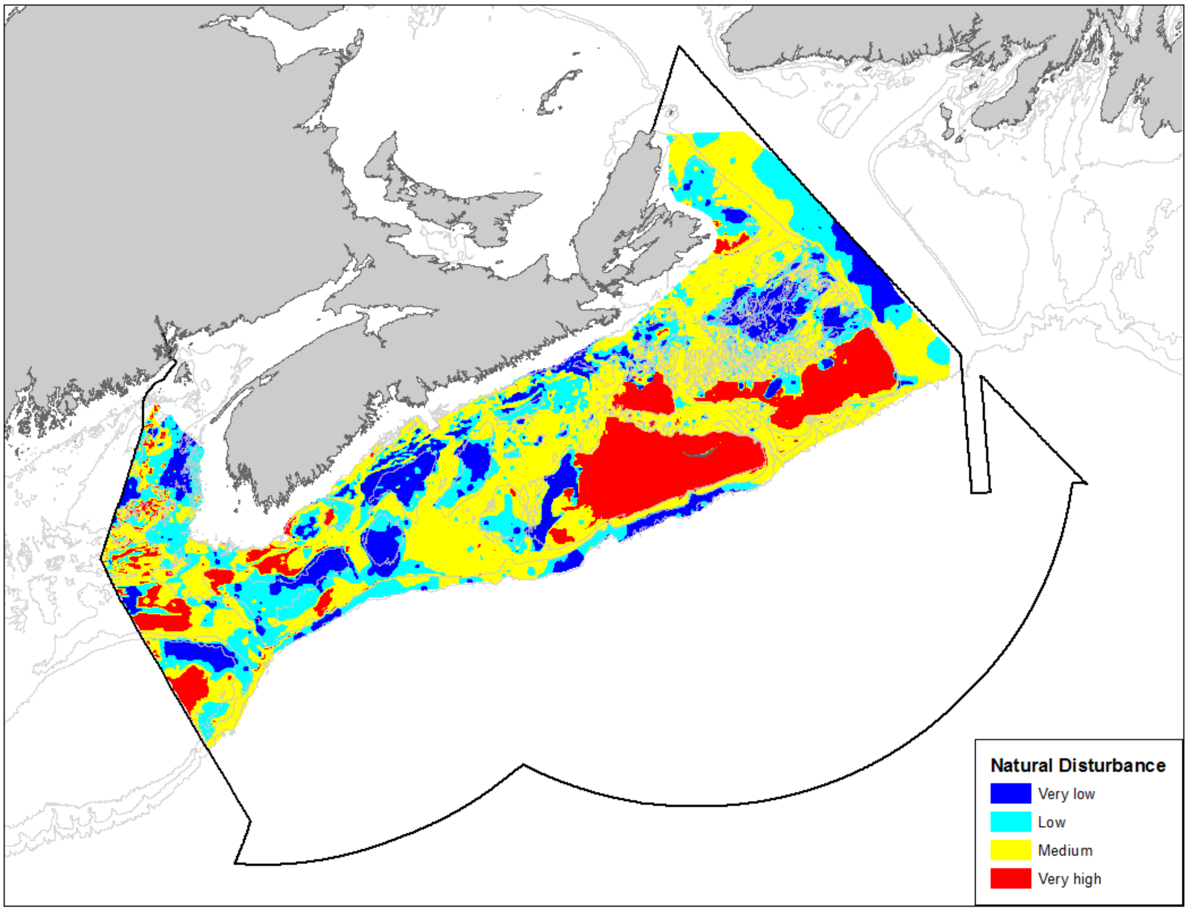

Figure 5. Natural Disturbance classes defined by Kostylev and Hannah (2007) and delineated by Horsman et al. (2011). Natural disturbance is a representation of physical disturbance on the bottom, estimated using sediment grain size and characteristic bottom stress data.

2.1.3 Functional Groups

2.1.3.1: Functional Groups: Fishes

Description: Functional Groups (collections of species that perform similar ecological functions) have been described for fishes in the Scotian Shelf Bioregion by Bundy et al. (2017). They reviewed literature to find three defining traits to group fish species: length, habitat, and feeding guild. The fish functional groups identified by Bundy et al. (2017) were as follows:

- Piscivore, Benthic, Small + Medium
- Piscivore, Benthic, Large
- Piscivore, Pelagic, Small + Medium + Large
- Benthivore, Benthic, Small
- Benthivore, Benthic, Medium
- Benthivore, Benthic, Large

- Planktivore, Pelagic, Small + Medium + Large
- Zoopiscivore, Benthic, Small + Medium + Large
- Zoopiscivore, Pelagic, Small + Medium + Large

See Table 2 in Appendix for a list of species included in each functional group.

Bundy et al. (2017) analyzed DFO's RV Survey data using Horsman and Shackell's (2009) approach to identify key areas for functional groups across different fisheries management eras (1970-1977, 1978-1985, 1986-1993, 1994-2005, and 2007-2014). Areas of high biomass were identified for each fishing era by calculating the total biomass per tow and then creating a continuous surface using an Inverse Distance Weighted interpolation. The data layers were then classified into quintiles and the areas within the top quintile (i.e., top 20%) in all five eras were considered areas of high biomass and important habitat for a particular functional group. Only the top quintiles for each functional group are shown in Figure 6 – Figure 14, as that is what was included in the network analysis. Note that each functional group has an eastern and western component to account for the fact that Eastern Scotian Shelf is markedly different in species composition from the Western Scotian Shelf.

Rationale: Bundy et al.'s (2017) functional groups were used as representative layers for fishes. Functional groups are considered to perform a similar role in the ecosystem, so they were used to represent a number of different species, rather than using individual species layers.

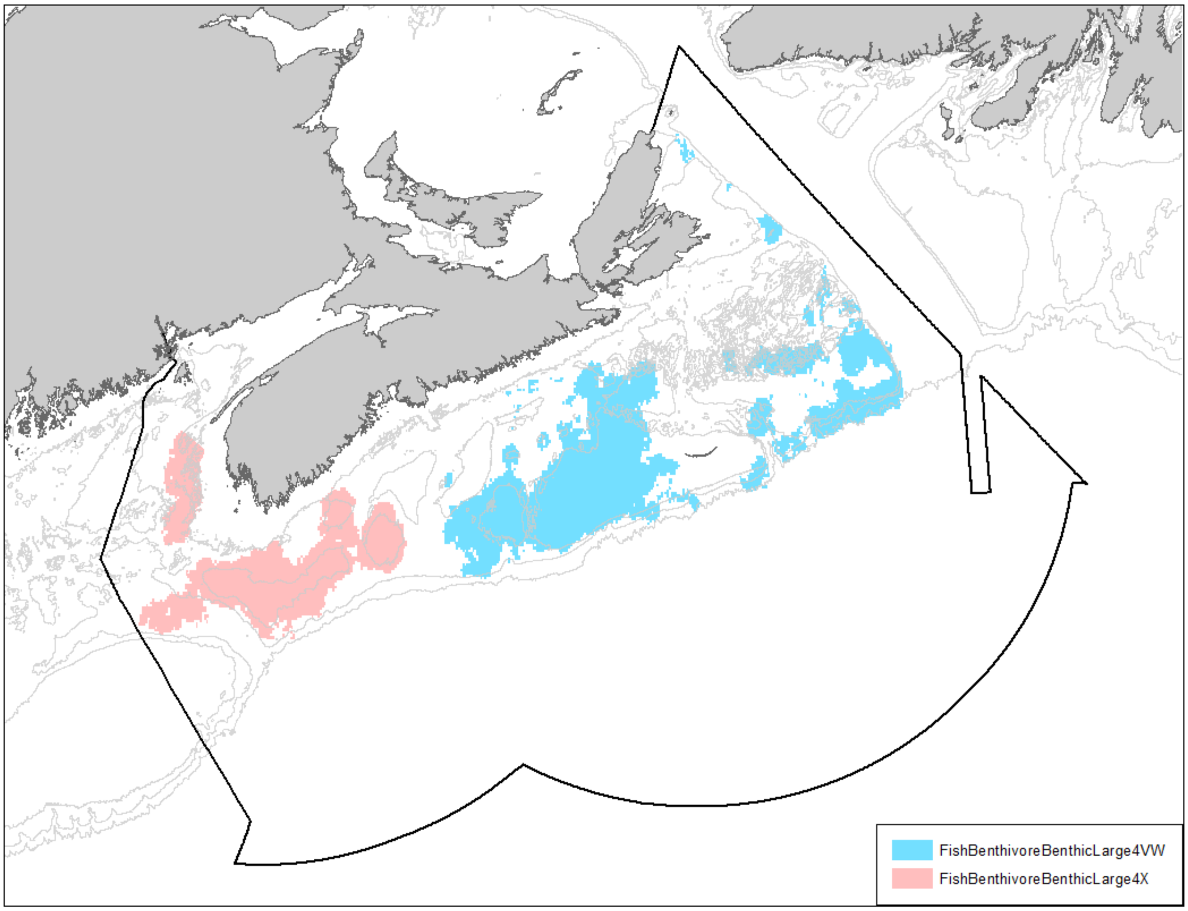

Figure 6. Fish: Benthivore, Benthic, Large functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 2 in the Appendix.

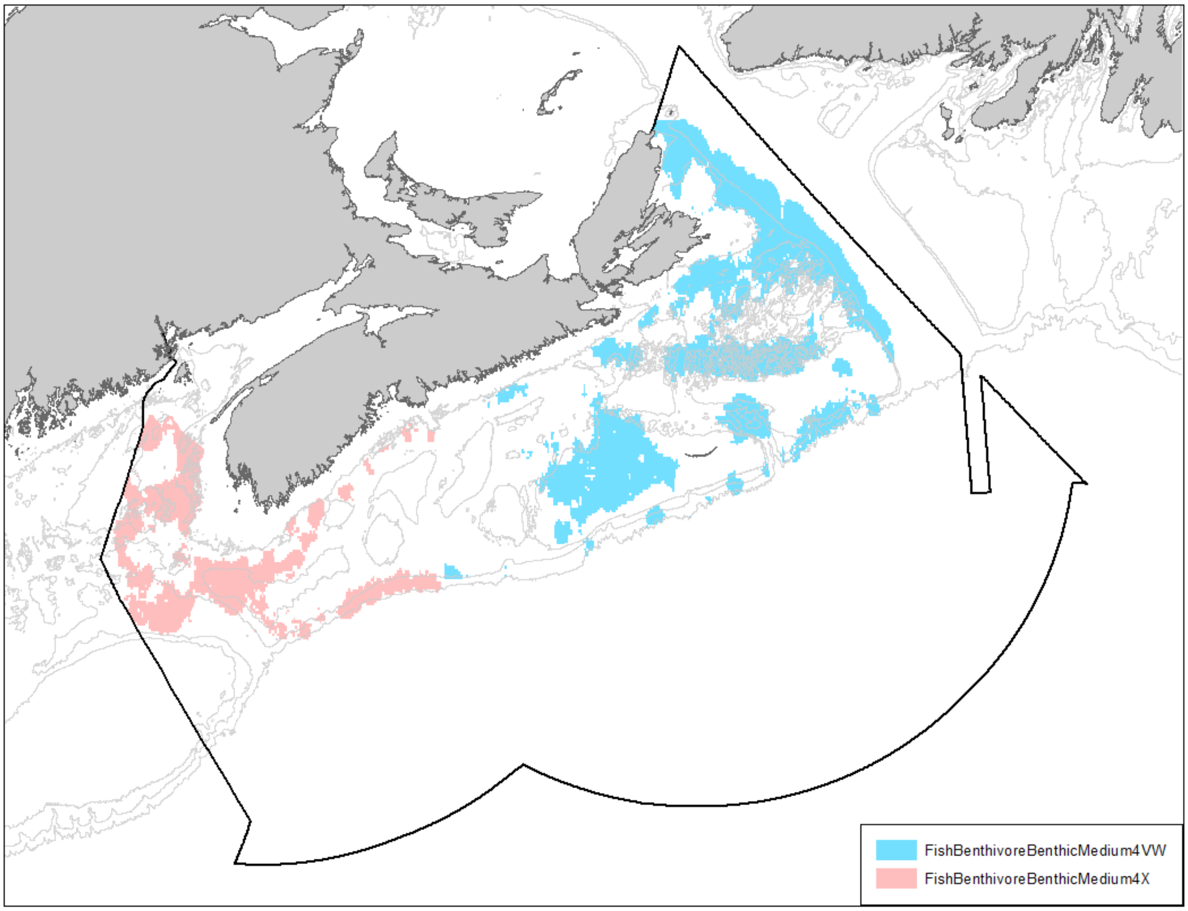

Figure 7. Fish: Benthivore, Benthic, Medium functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 2 in the Appendix.

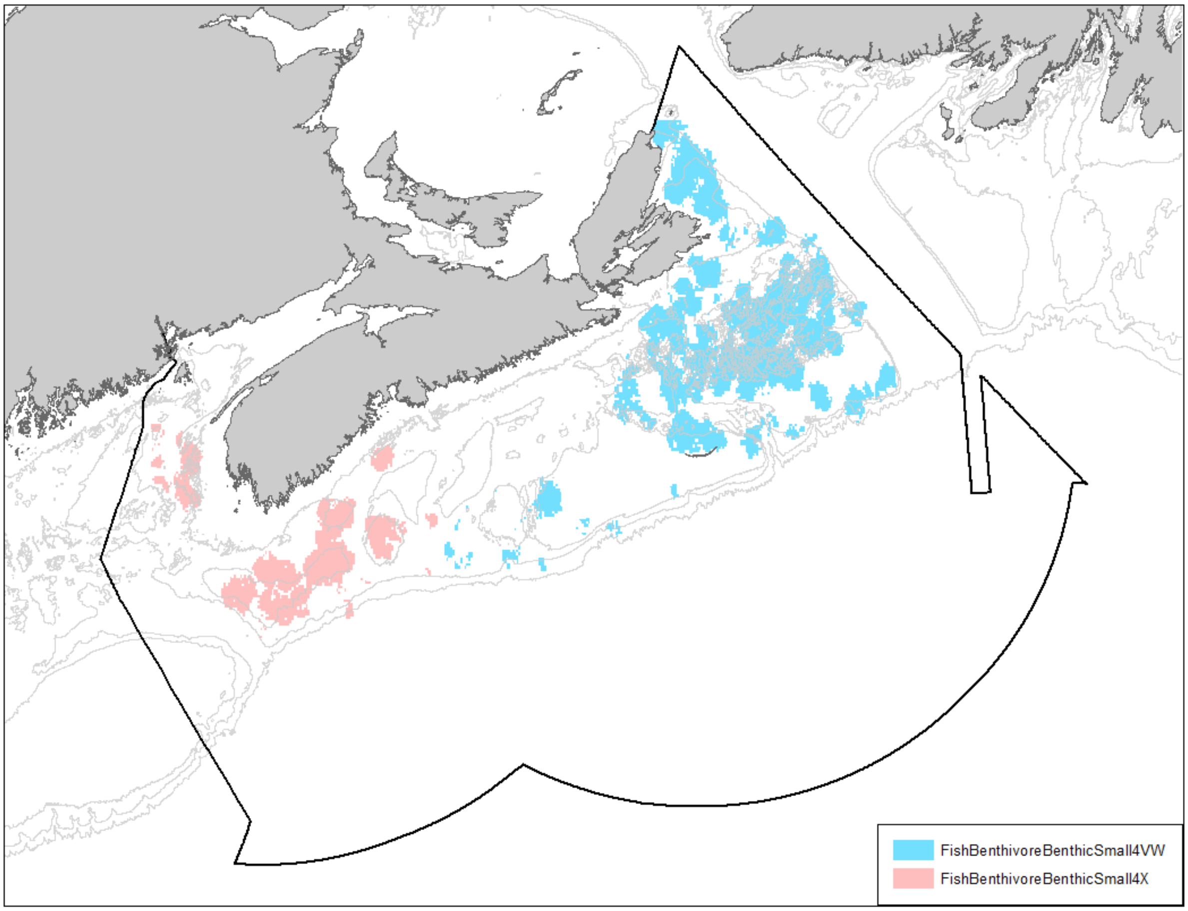

Figure 8. Fish: Benthivore, Benthic, Small functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 2 in the Appendix.

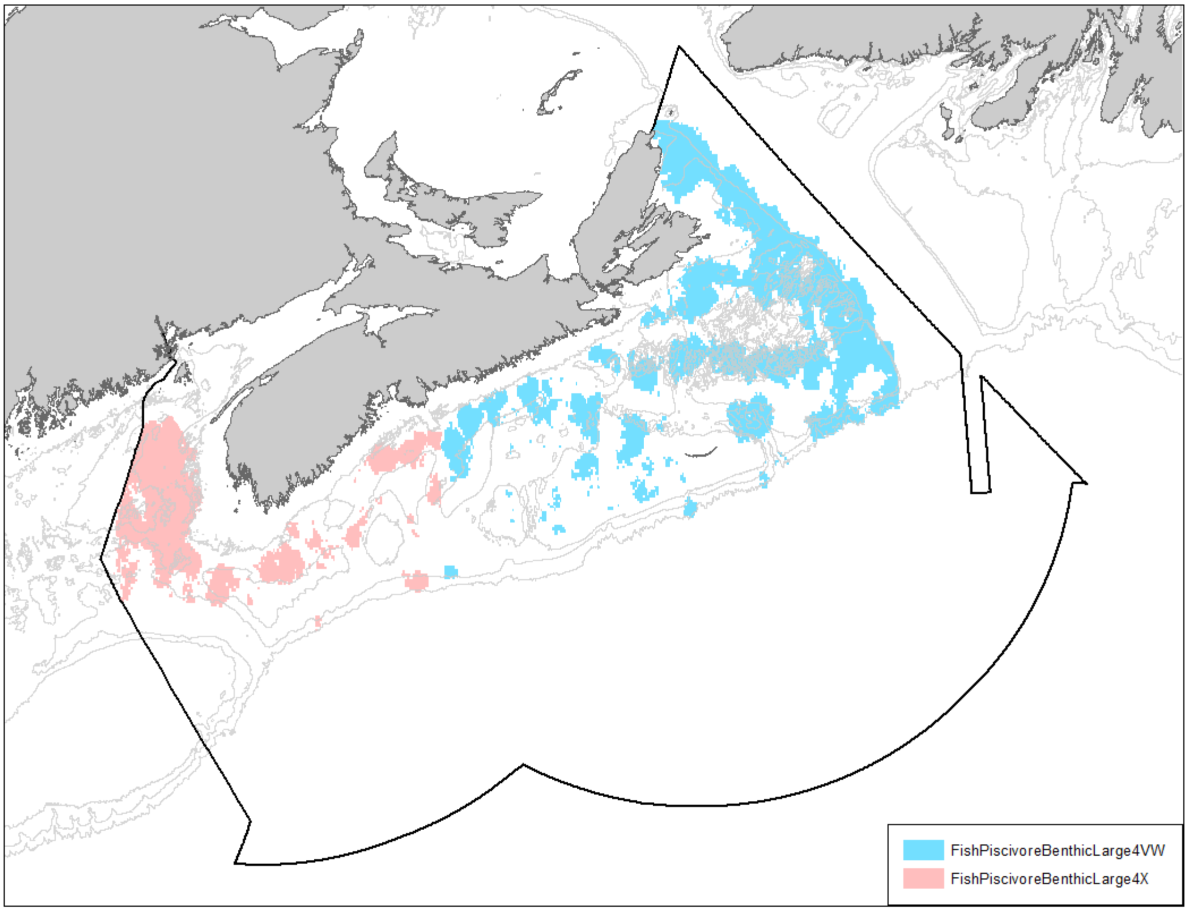

Figure 9. Fish: Piscivore, Benthic, Large functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 2 in the Appendix.

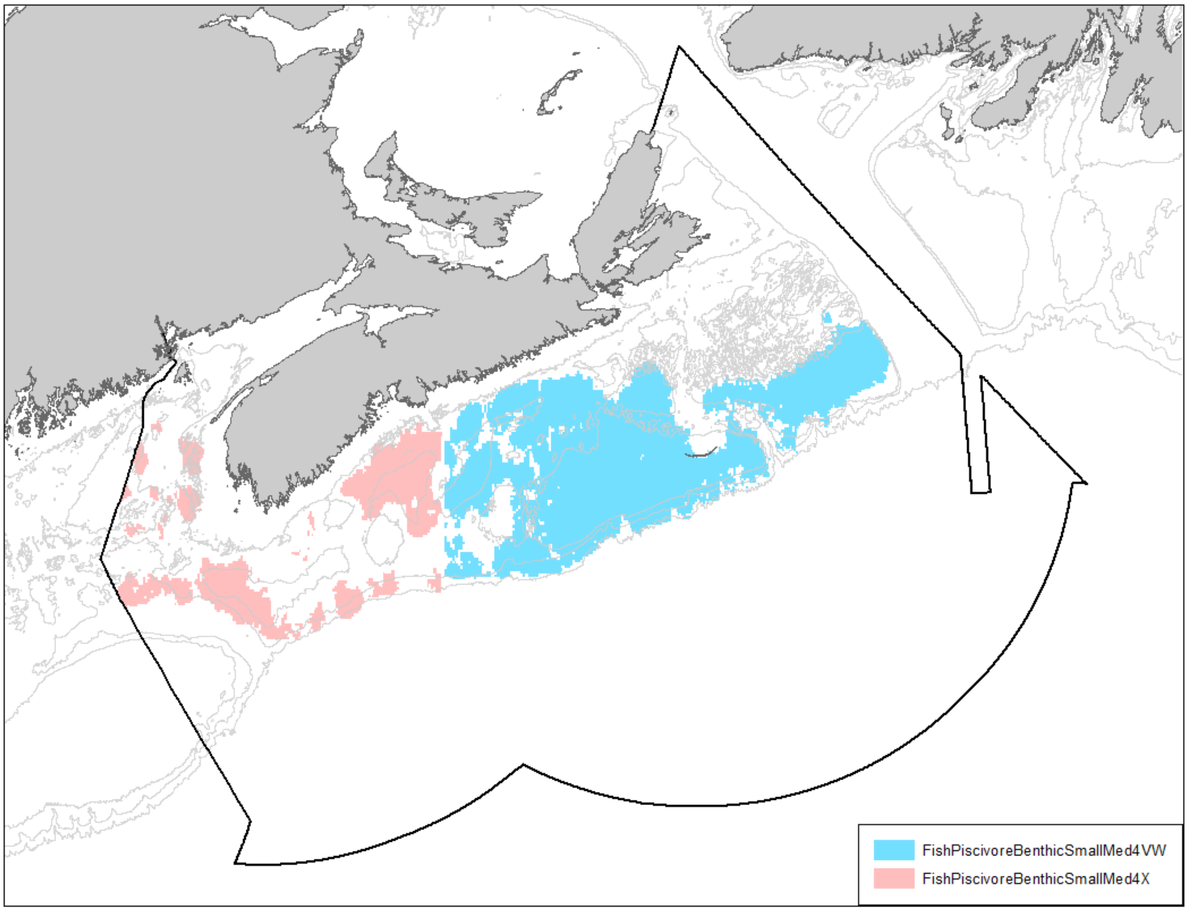

Figure 10. Fish: Piscivore, Benthic, Small + Medium functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 2 in the Appendix.

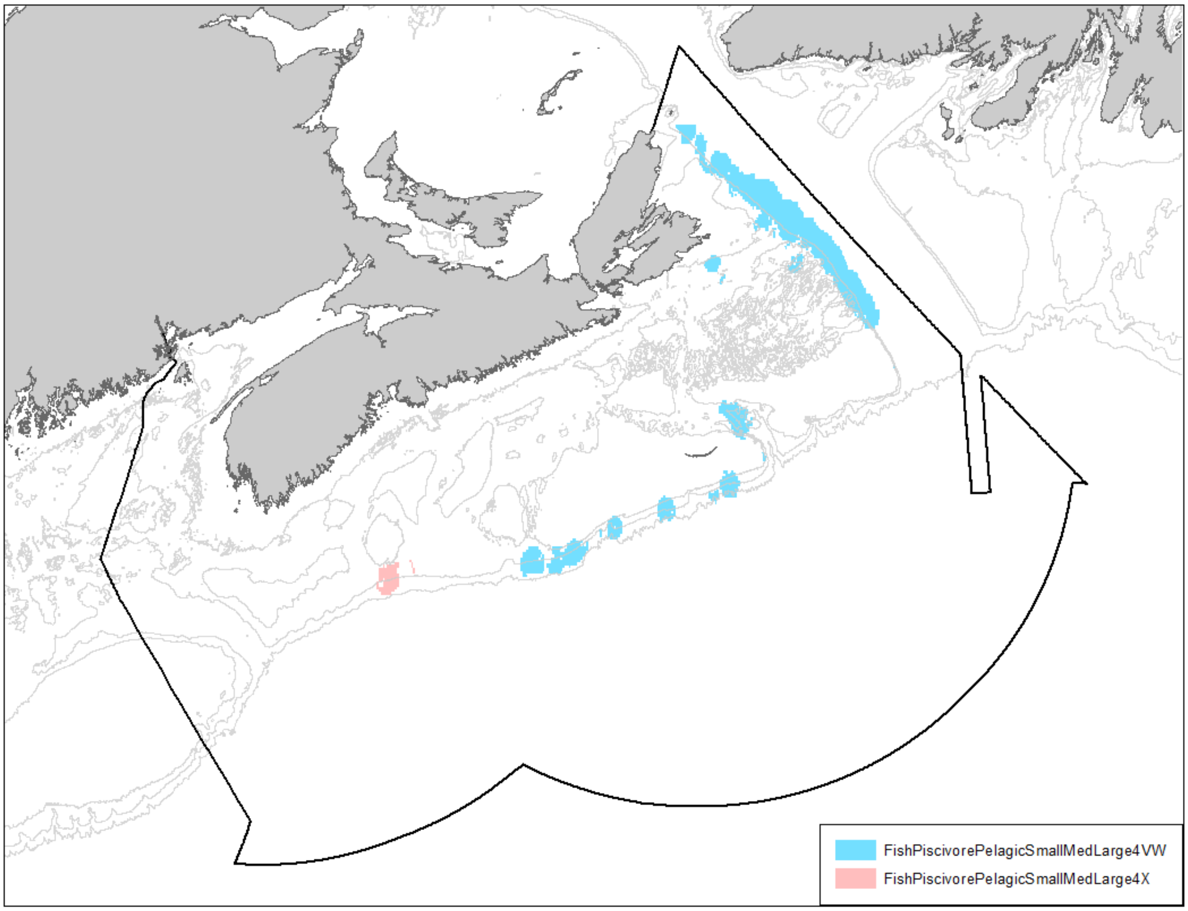

Figure 11. Fish: Piscivore, Pelagic, Small + Medium + Large functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 2 in the Appendix.

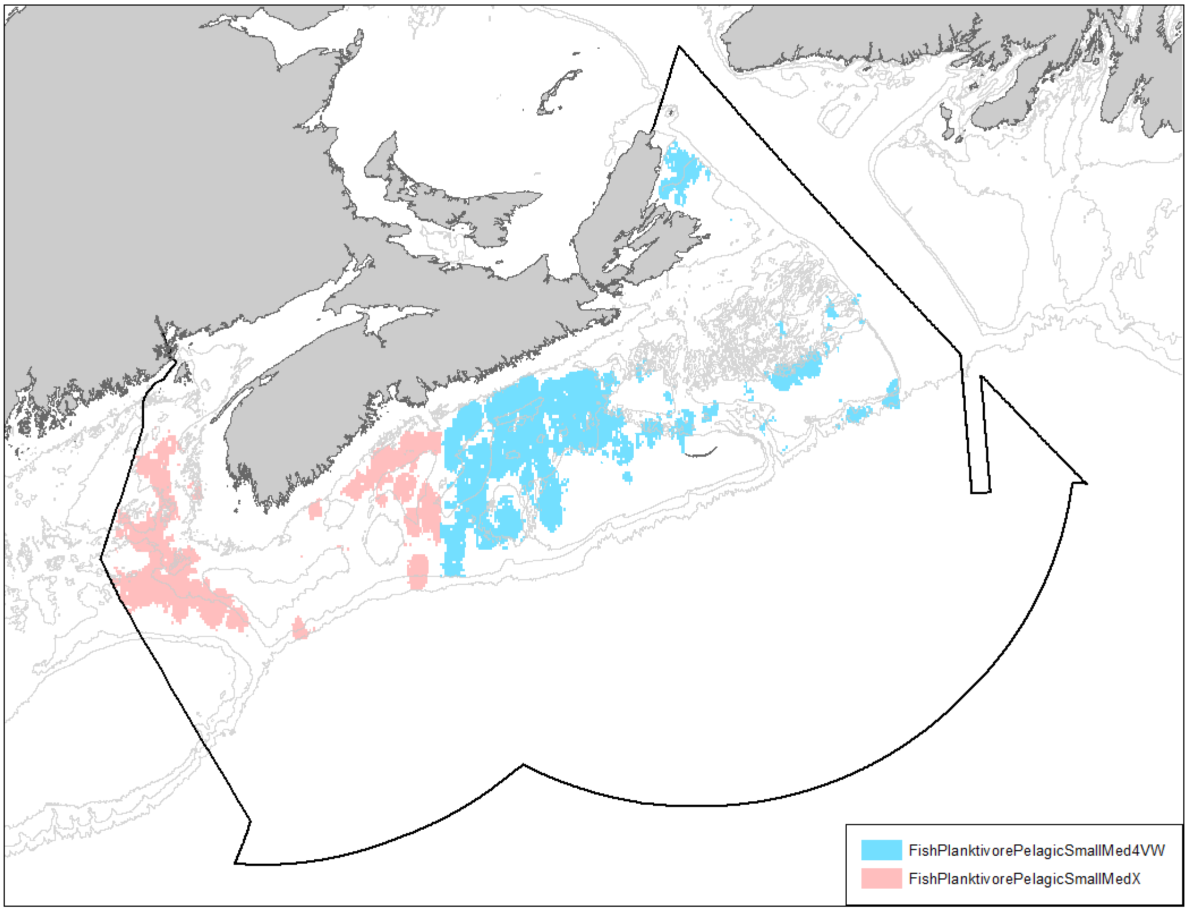

Figure 12. Fish: Planktivore, Pelagic, Small + Medium + Large functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 2 in the Appendix.

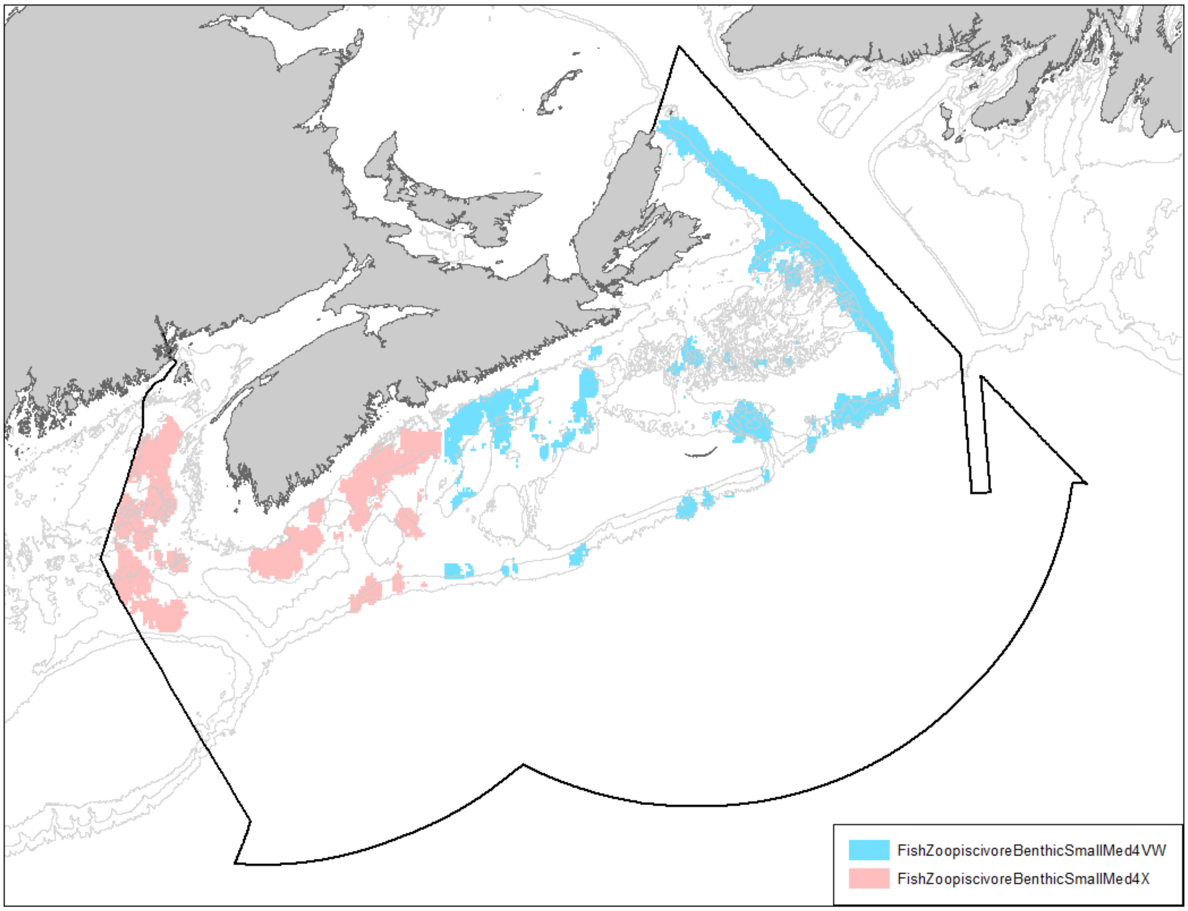

Figure 13. Fish: Zoopiscivore, Benthic, Small + Medium functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 2 in the Appendix.

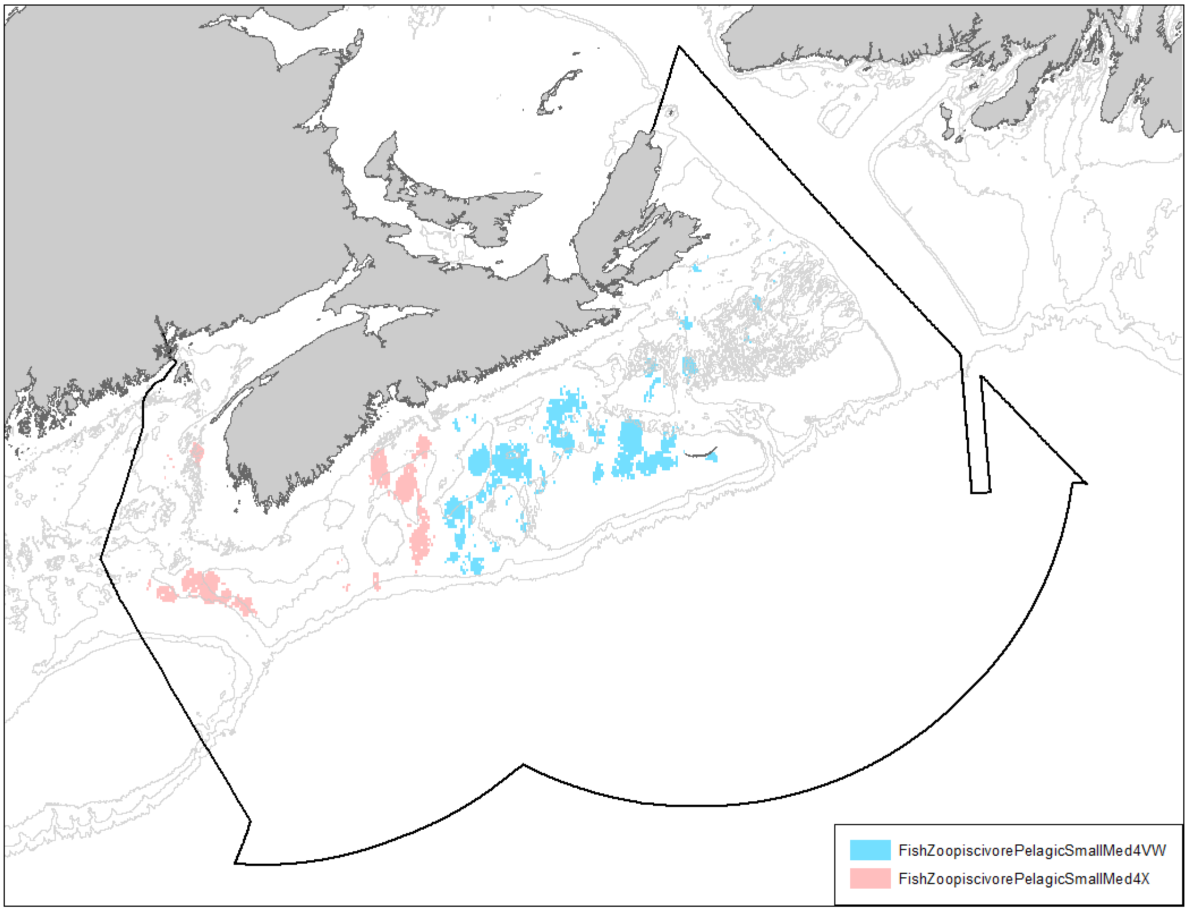

Figure 14. Fish: Zoopiscivore, Pelagic, Small + Medium functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 2 in the Appendix.

<u>2.1.3.2: Functional Groups: Invertebrates</u>

Description: Functional Groups (collections of species that perform similar ecological functions) have been described for invertebrates in the Scotian Shelf Bioregion by Bundy et al. (2017). They reviewed literature to find three defining traits to group invertebrate species: length, habitat, and feeding guild. The invertebrate functional groups identified by Bundy et al. (2017) were as follows:

- Benthivore, Benthic, Small
- Benthivore, Benthic, Medium
- Zoopiscivore, Small + Medium + Large
- Filter feeder, Benthic, Colonial
- Filter feeder, Benthic, Non-colonial
- Detritivore

See Table 3 in Appendix for a list of species included in each functional group.

For invertebrates, Bundy et al. (2017) analyzed DFO's RV Survey data using a similar approach to Horsman and Shackell (2009), but only one time period (2007-2014) was used, as invertebrates were not reliably identified in the RV survey until 2007. Areas of high biomass for each functional group were identified by calculating the total biomass per tow and then creating a continuous surface using an Inverse Distance Weighted interpolation. The data layers were then classified into quintiles and the areas within the top quintile (i.e., top 20%) were considered important habitat for a particular functional group. Only the top quintiles for each functional group are shown in Figure 6 – Figure 14, as that is what was included in the network analysis. Note that each functional group has an eastern and western component to account for the higher biomass of functional groups in the Western Scotian Shelf (Bundy et al. 2017).

Rationale: Bundy et al.'s (2017) functional groups were used as representative layers for invertebrates. Functional groups are considered to perform a similar role in the ecosystem, so they were used to represent a number of different species, rather than using individual species layers.

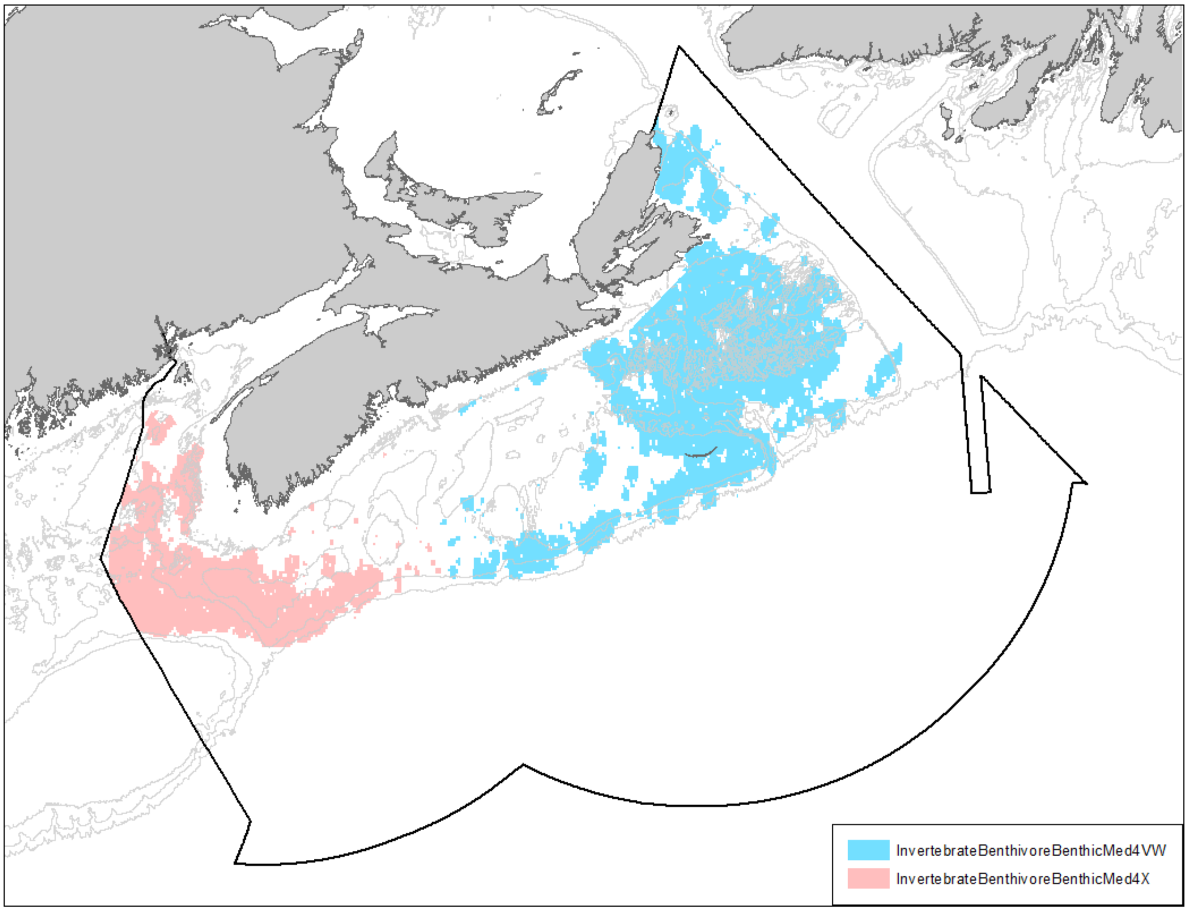

Figure 15. Invertebrate: Benthivore, Benthic, Medium functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 3 in the Appendix.

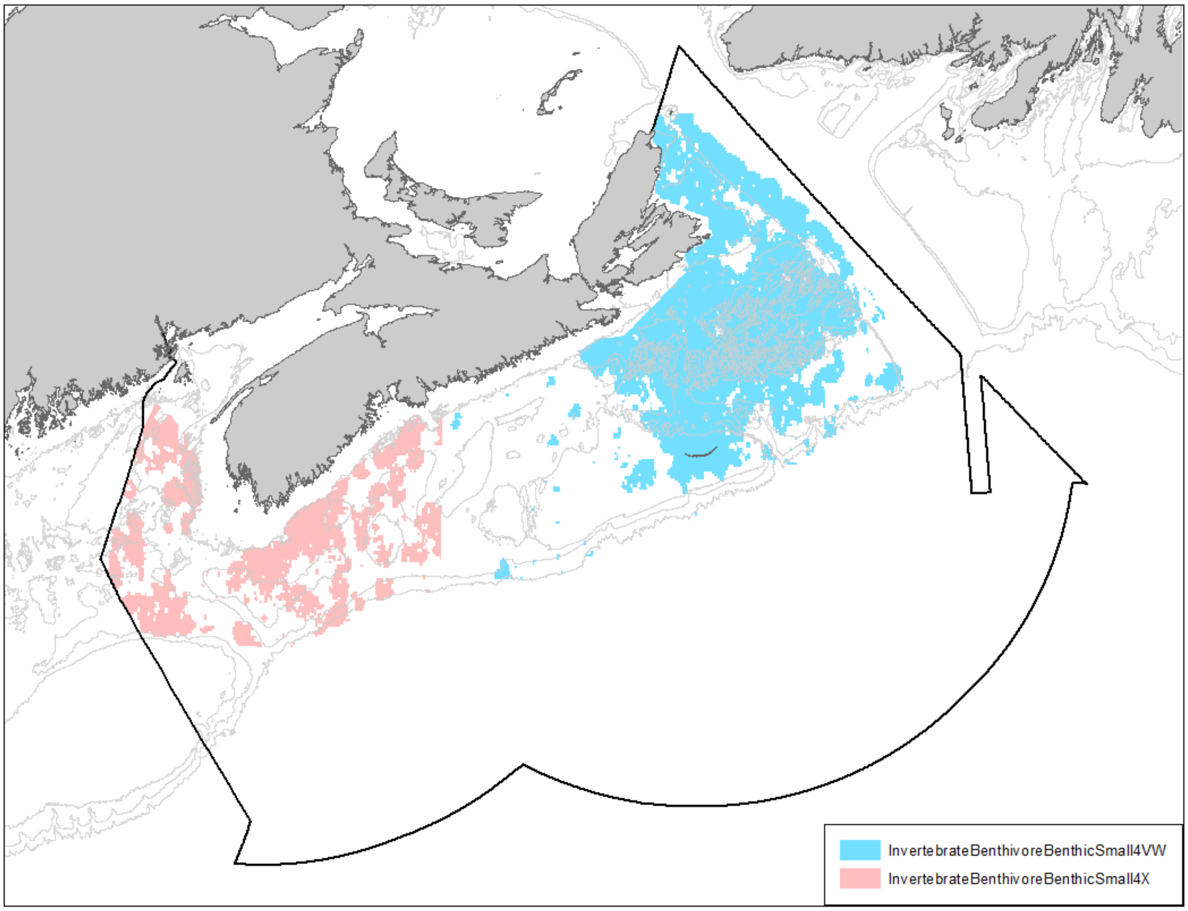

Figure 16. Invertebrate: Benthivore, Benthic, Small functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 3 in the Appendix.

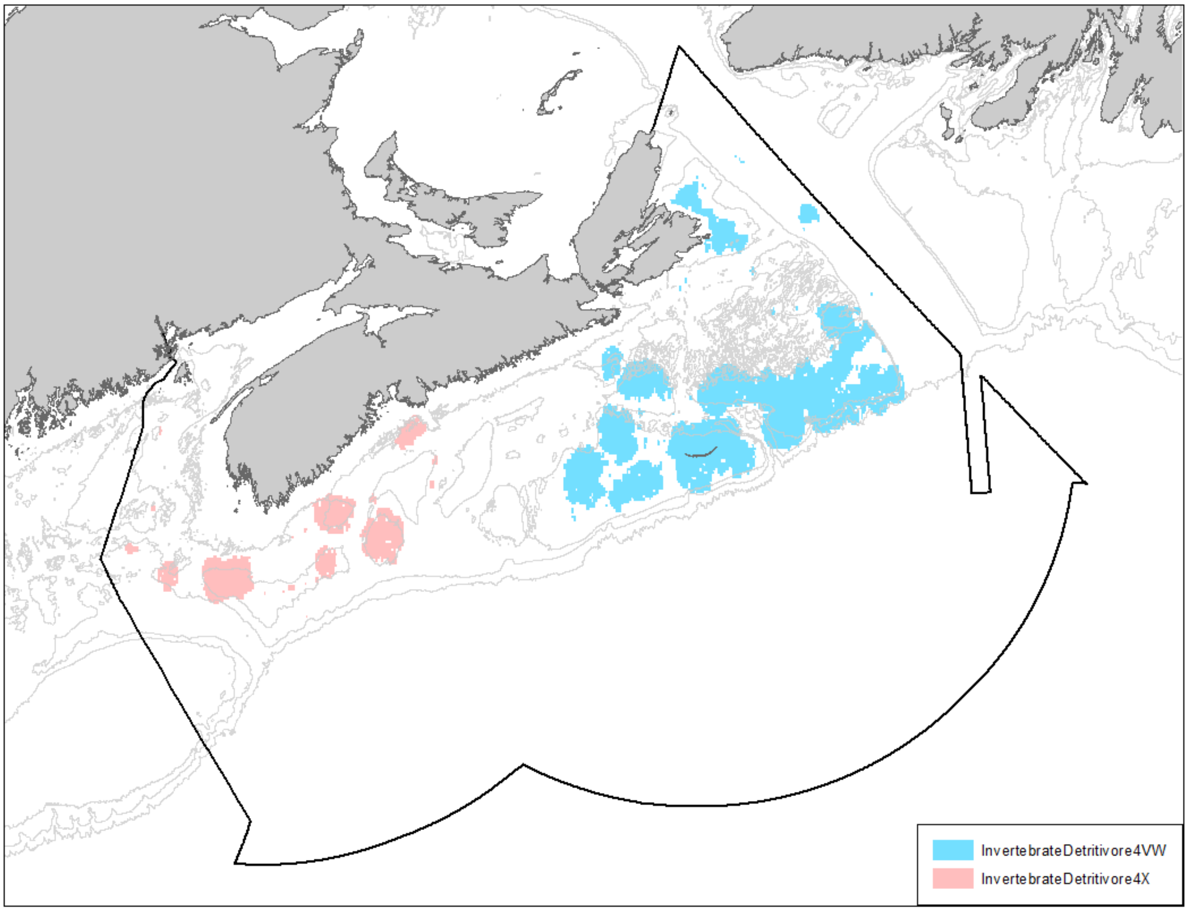

Figure 17. Invertebrate: Detritivore functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 3 in the Appendix.

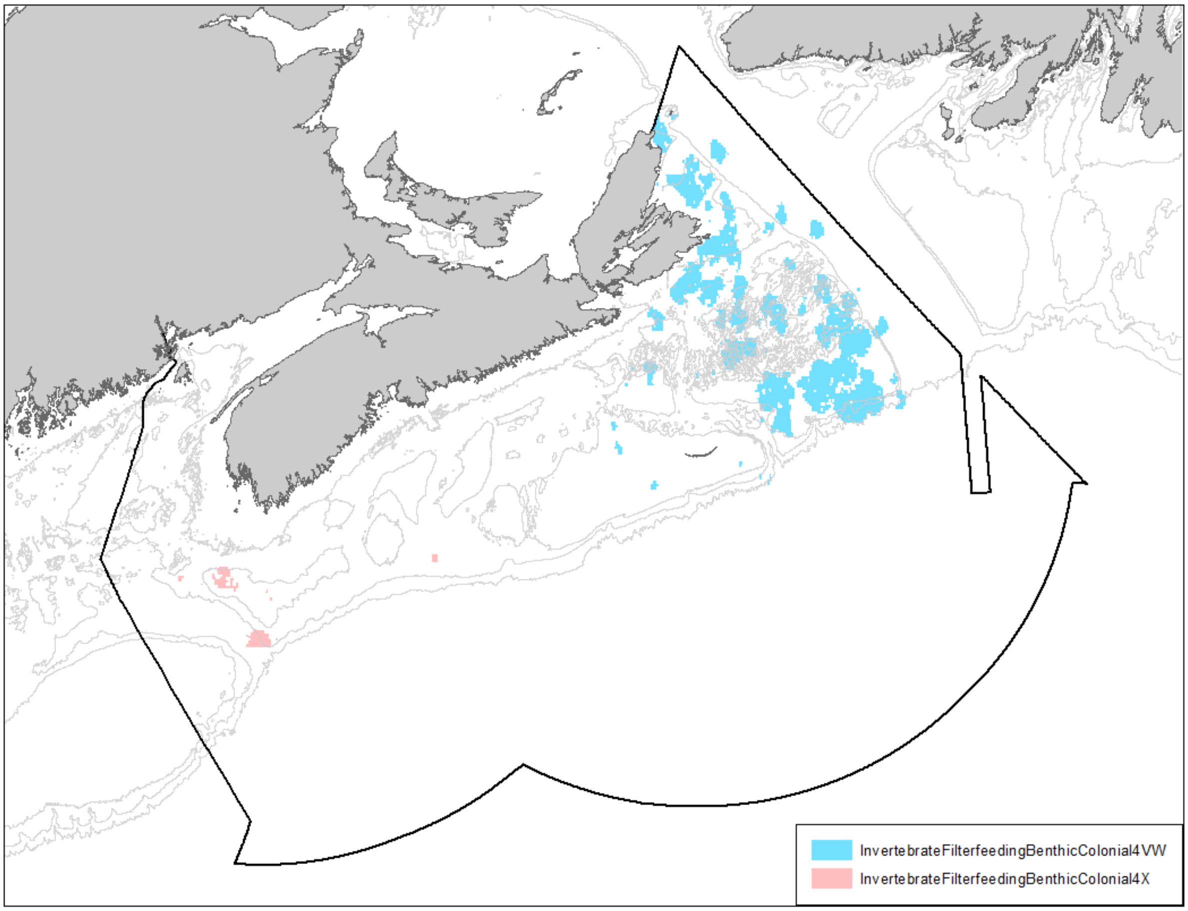

Figure 18. Invertebrate: Filter feeder, Benthic, Colonial functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 3 in the Appendix.

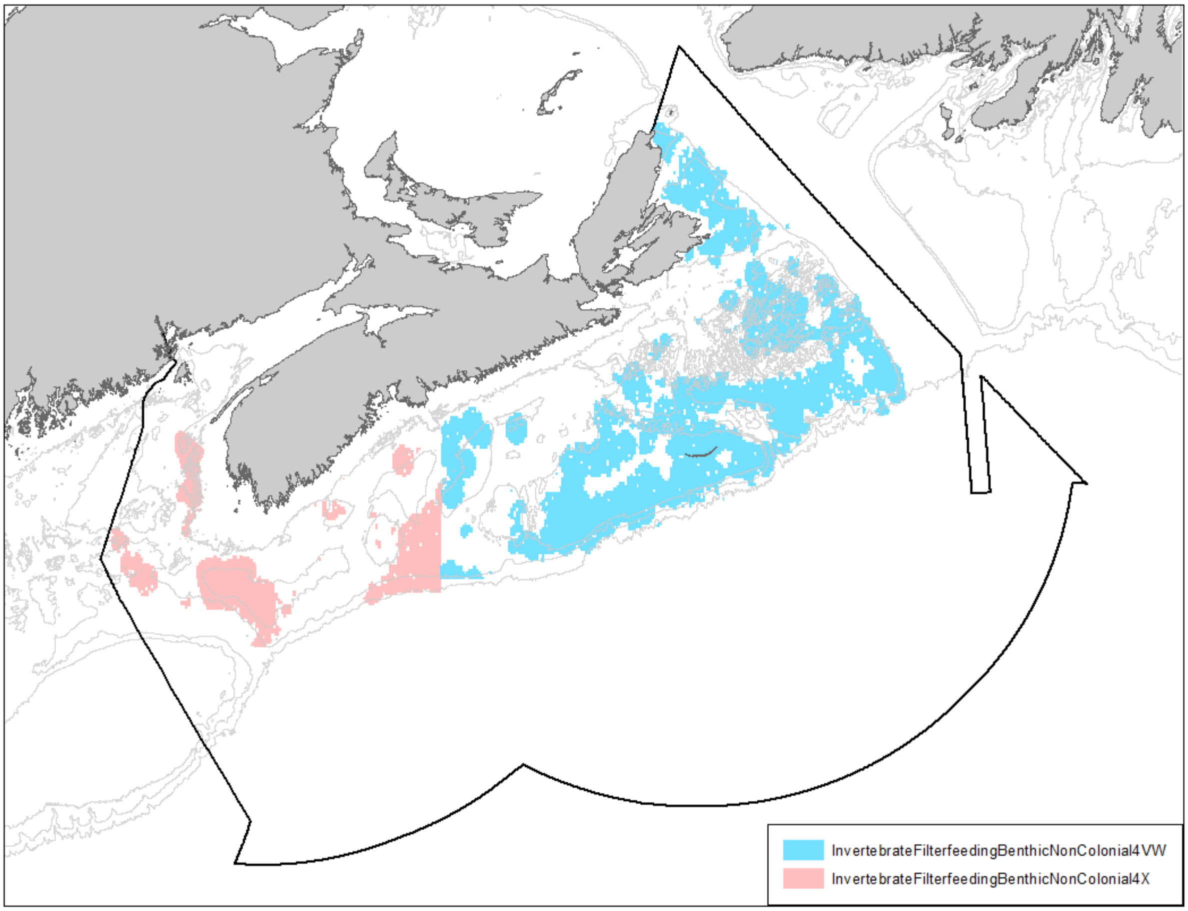

Figure 19. Invertebrate: Filter feeder, Benthic, Non-colonial functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 3 in the Appendix.

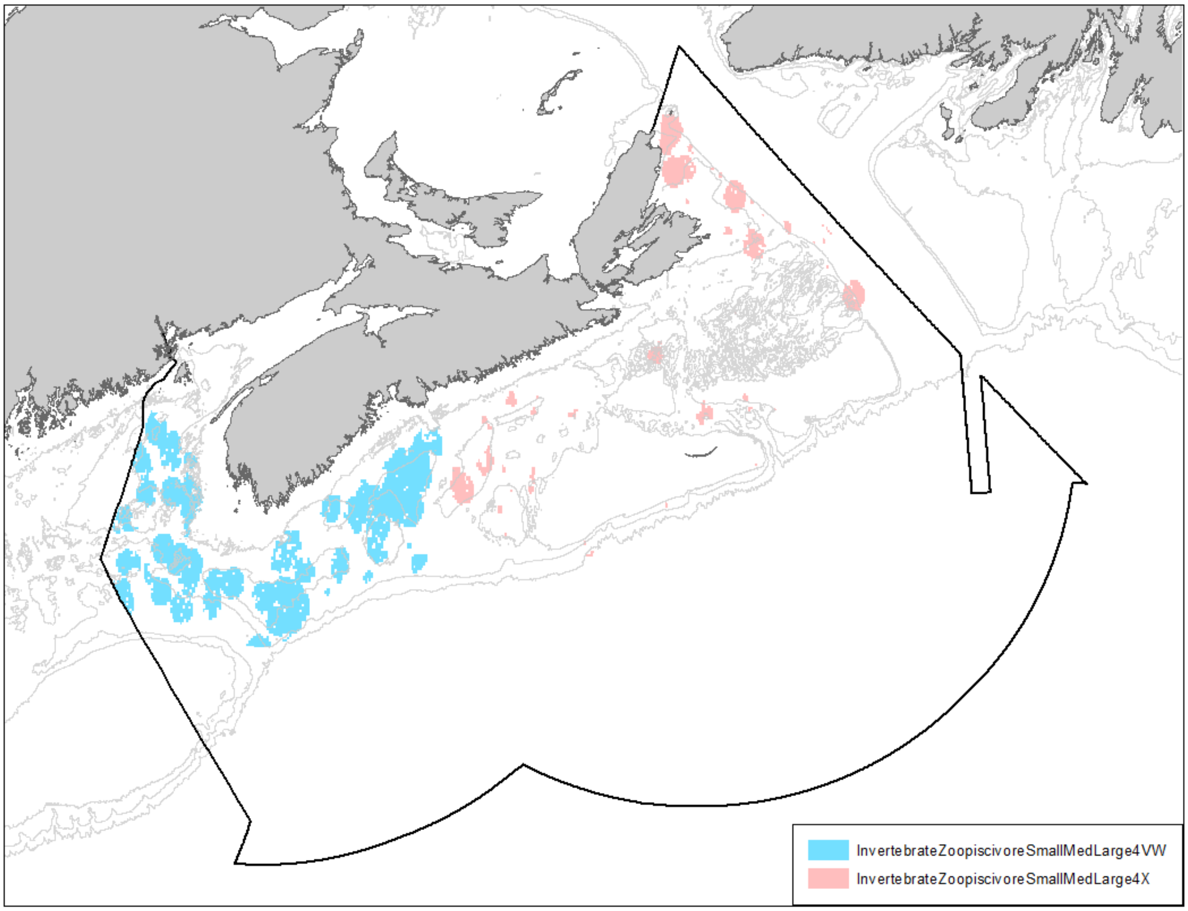

Figure 20. Invertebrate: Zoopiscivore, Small + Medium + Large functional group (split into Western Scotian Shelf and Eastern Scotian Shelf) from Bundy et al. (2017). The species represented in this functional group are listed in Table 3 in the Appendix.

2.1.3.3: Functional Groups: Seabirds

Description: Allard et al. (2014) used a hotspot analysis to identify important areas for seabird functional groups. They mapped areas of high relative abundance for eight seabird functional groups using data from Environment and Climate Change Canada (i.e., the Programme intégré de recherches sur les oiseaux pélagiques [PIROP] and Eastern Canada Seabirds at Sea [ECSAS] databases). Details on that program can be found in Gjerdrum et al. (2012). Only the top quintiles from Allard et al.'s (2014) analysis are shown in Figure 21 – Figure 28, as that is what was included in the network analysis.

Seabird functional groups were as follows:

- Plunge-diving piscivores
- Pursuit-diving piscivores
- Pursuit-diving planktivores
- Shallow pursuit generalists
- Ship-following generalists
- Surface-seizing planktivores
- Surface shallow-diving coastal piscivores

See Table 4 in Appendix for a list of species included in each functional group.

Rationale: The seabird functional group layers were used as representative layers, as with Bundy et al.'s (2017) fish and invertebrate functional groups. Functional groups are considered to perform a similar role in the ecosystem, so they were used to represent a number of different species, rather than using individual species layers.

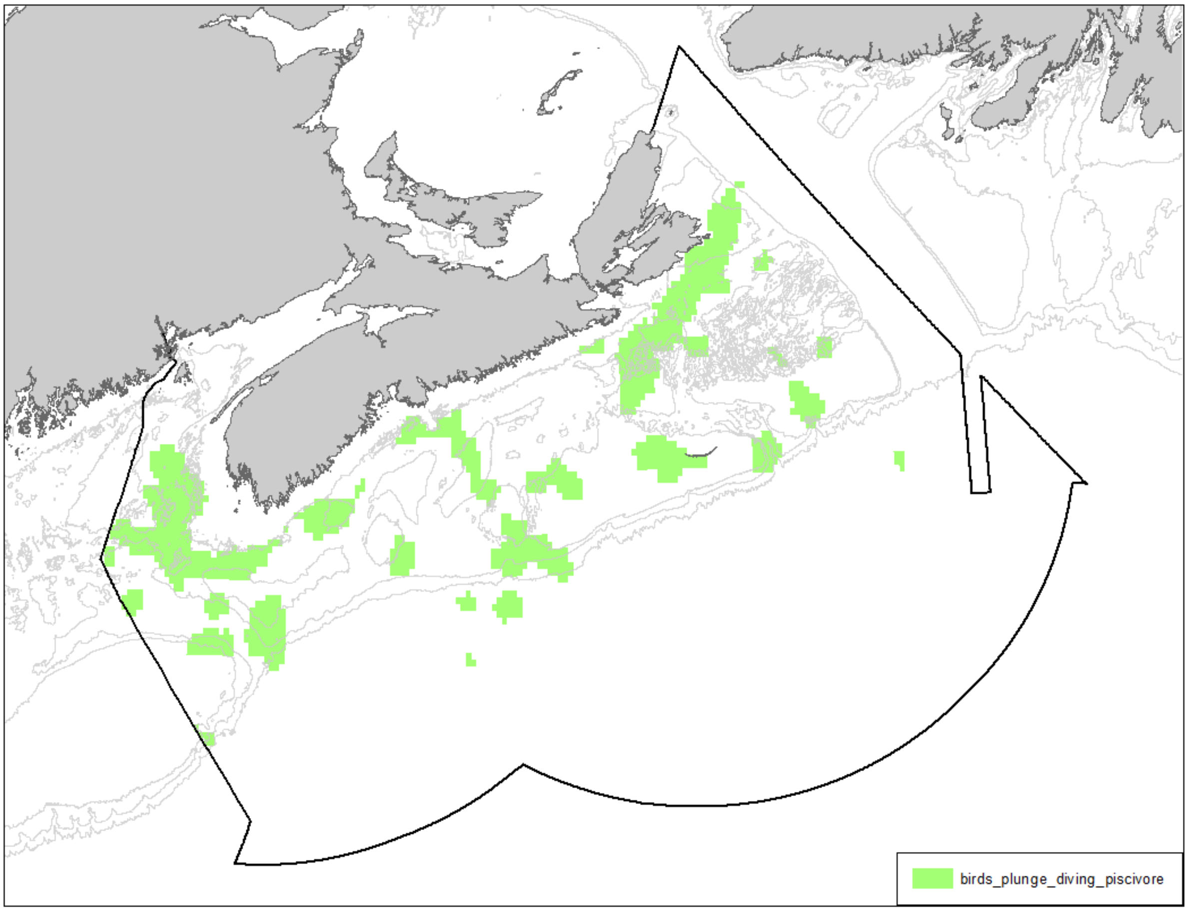

Figure 21. Seabird: Plunge-diving piscivore functional group from Allard et al. (2014). The species represented in this functional group are listed in Table 4 in the Appendix.

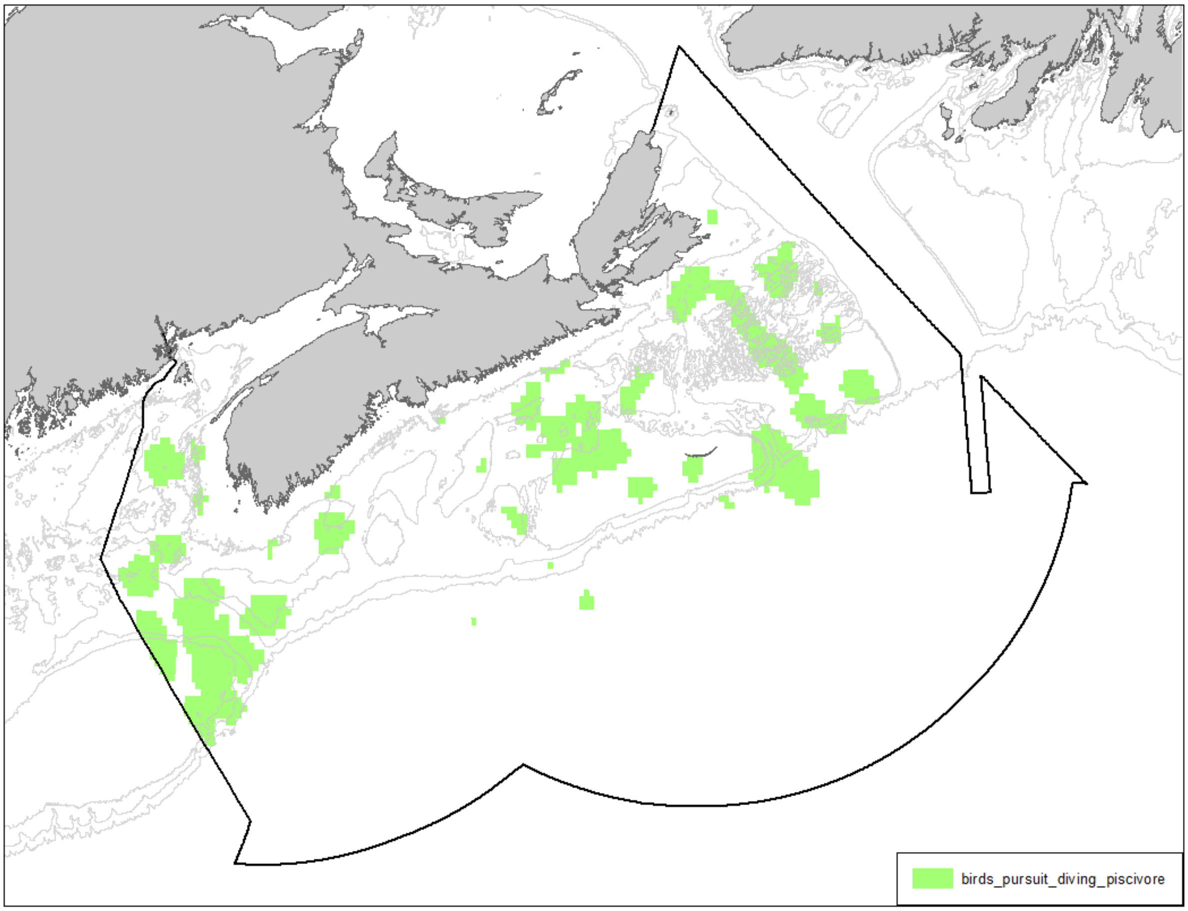

Figure 22. Seabird: Pursuit-diving piscivore functional group from Allard et al. (2014). The species represented in this functional group are listed in Table 4 in the Appendix.

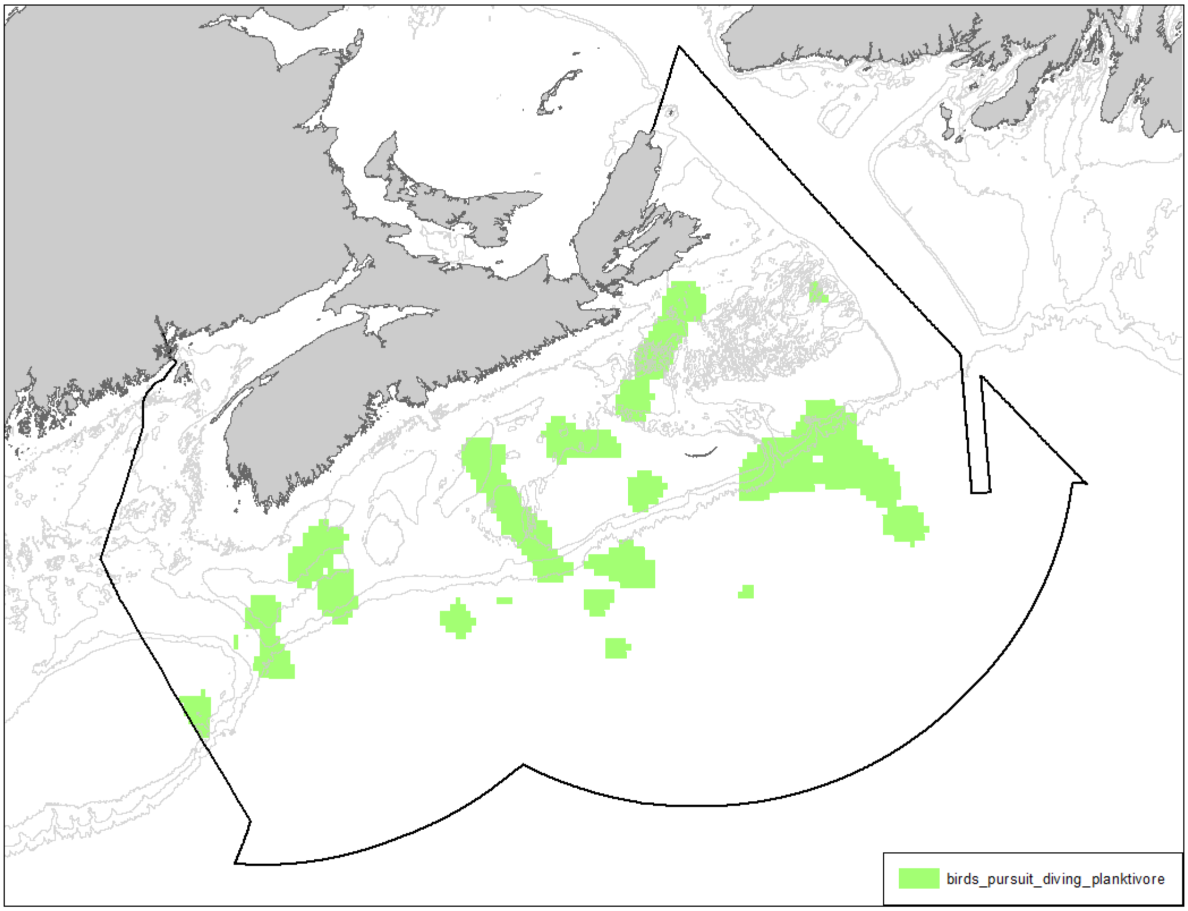

Figure 23. Seabird: Pursuit-diving planktivore functional group from Allard et al. (2014). The species represented in this functional group are listed in Table 4 in the Appendix.

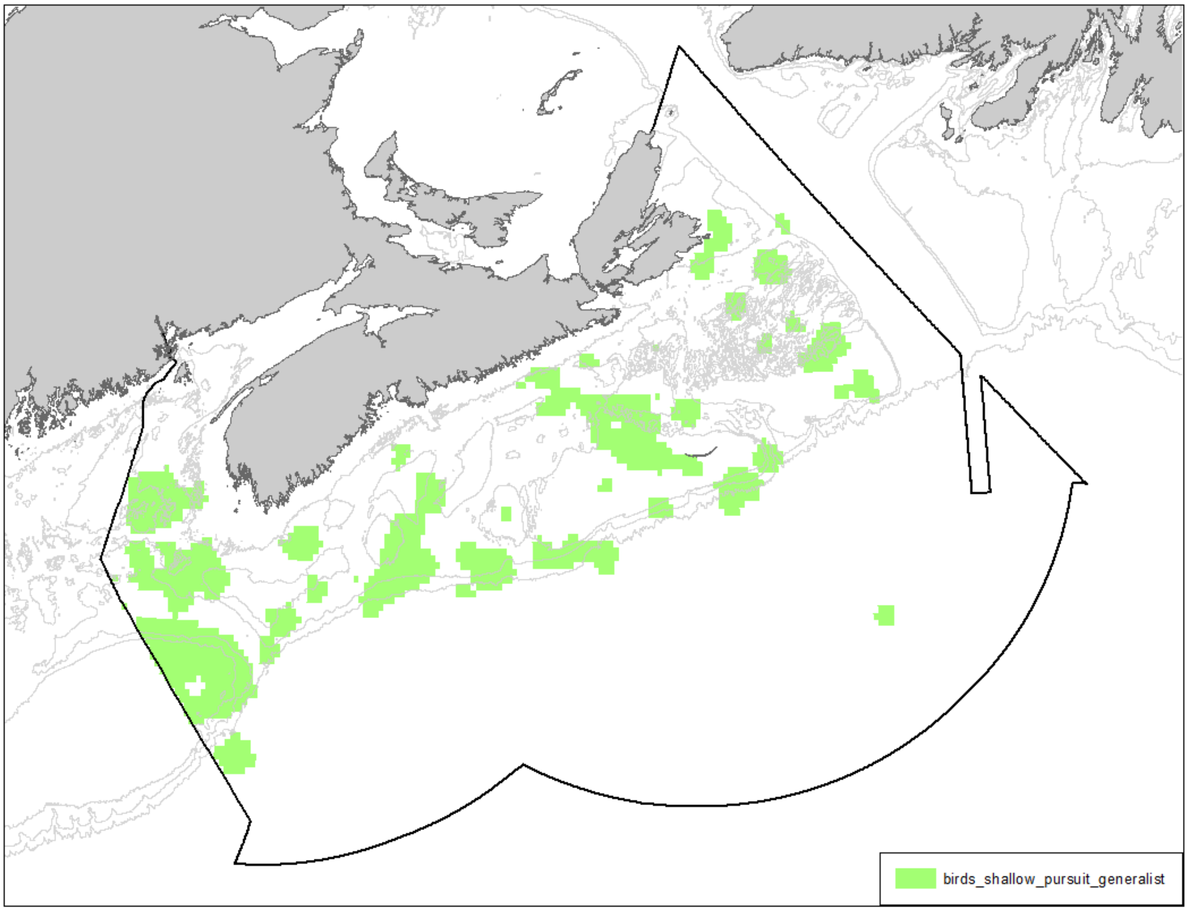

Figure 24. Seabird: Shallow pursuit generalist functional group from Allard et al. (2014). The species represented in this functional group are listed in Table 4 in the Appendix.

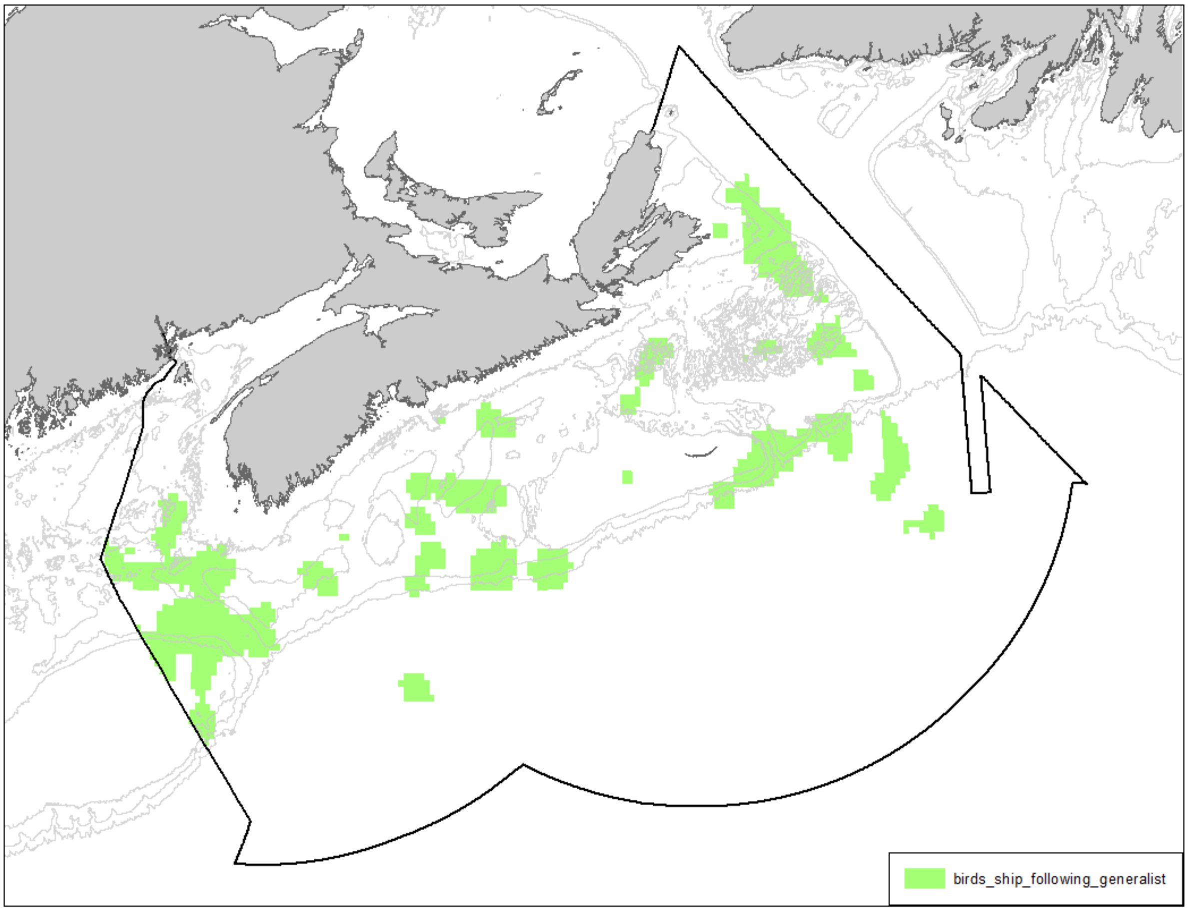

Figure 25. Seabird: Ship-following generalist functional group from Allard et al. (2014). The species represented in this functional group are listed in Table 4 in the Appendix.

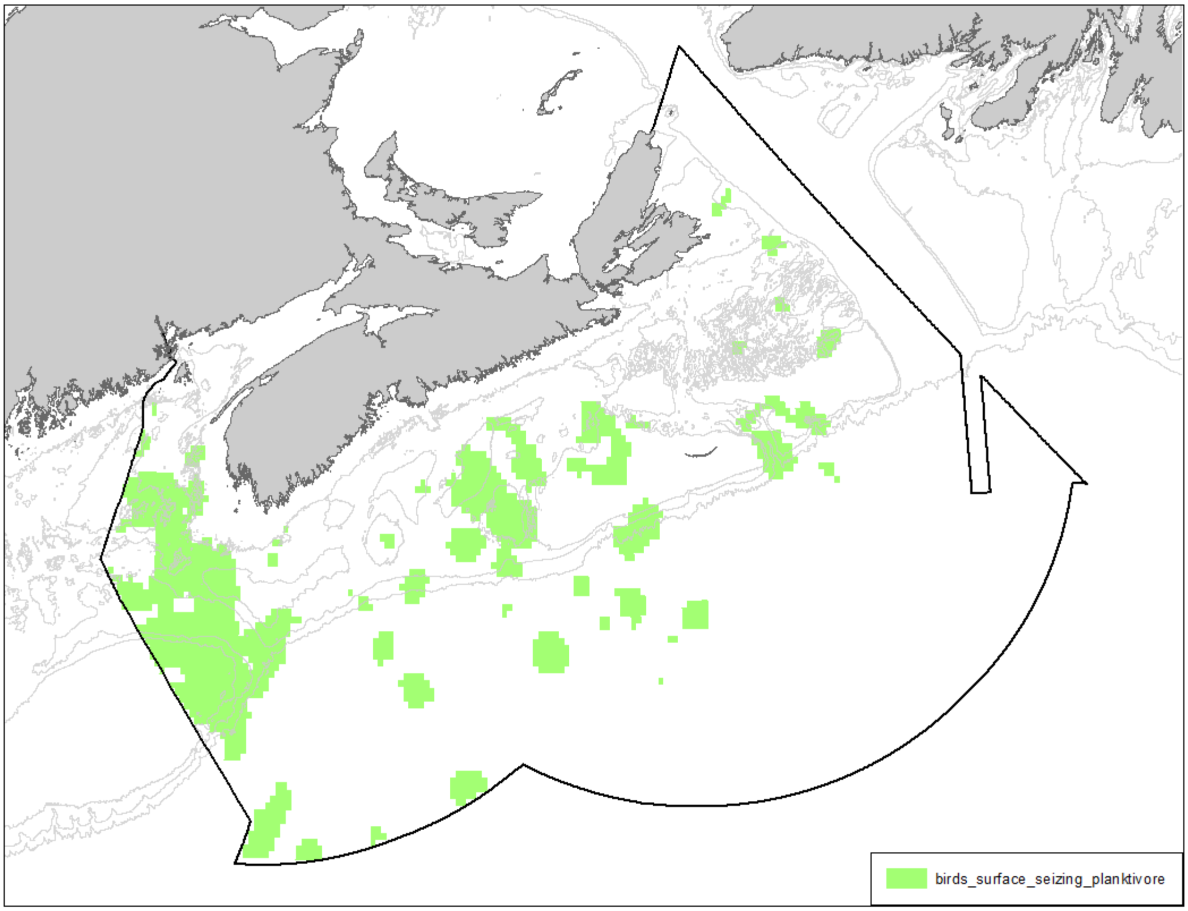

Figure 26. Seabird: Surface-seizing planktivore functional group from Allard et al. (2014). The species represented in this functional group are listed in Table 4 in the Appendix.

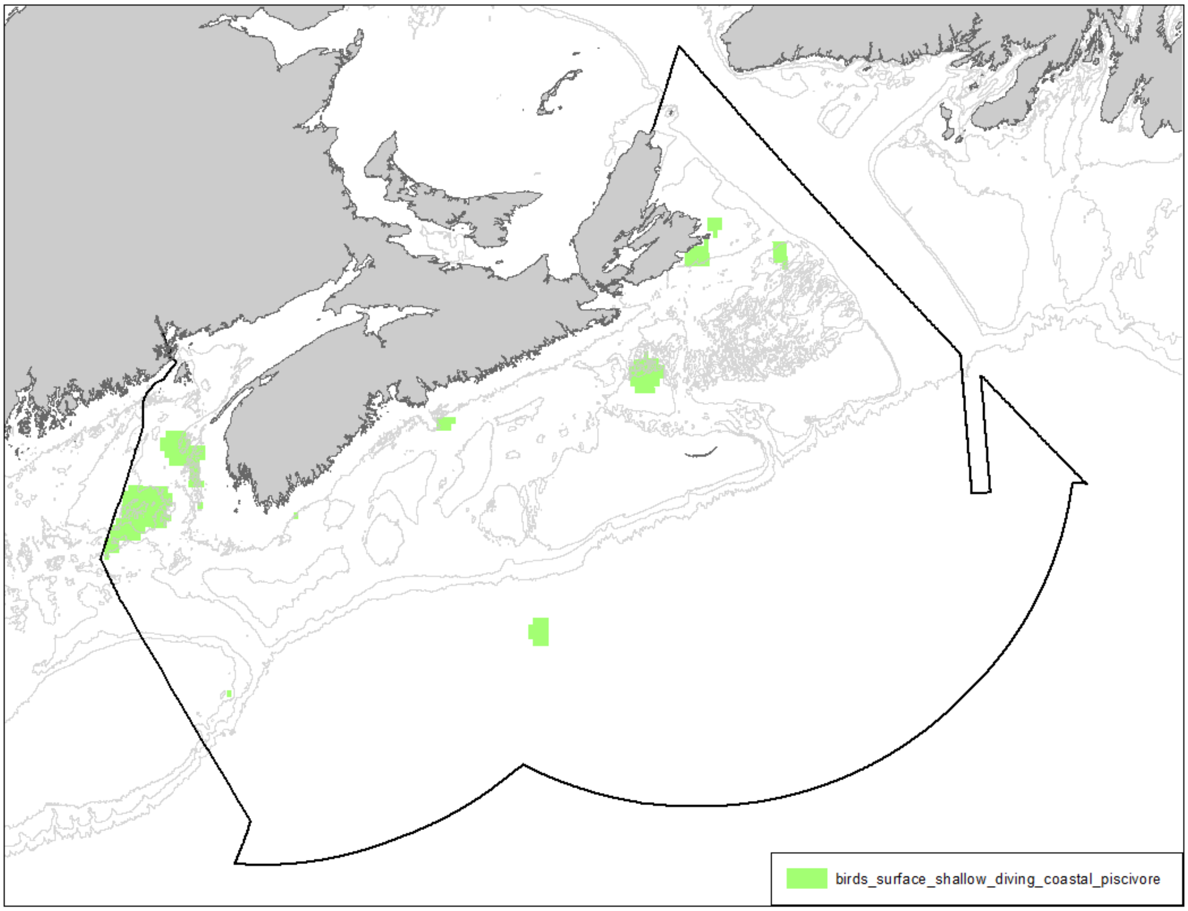

Figure 27. Seabird: Surface shallow-diving coastal piscivore functional group from Allard et al. (2014). The species represented in this functional group are listed in Table 4 in the Appendix.

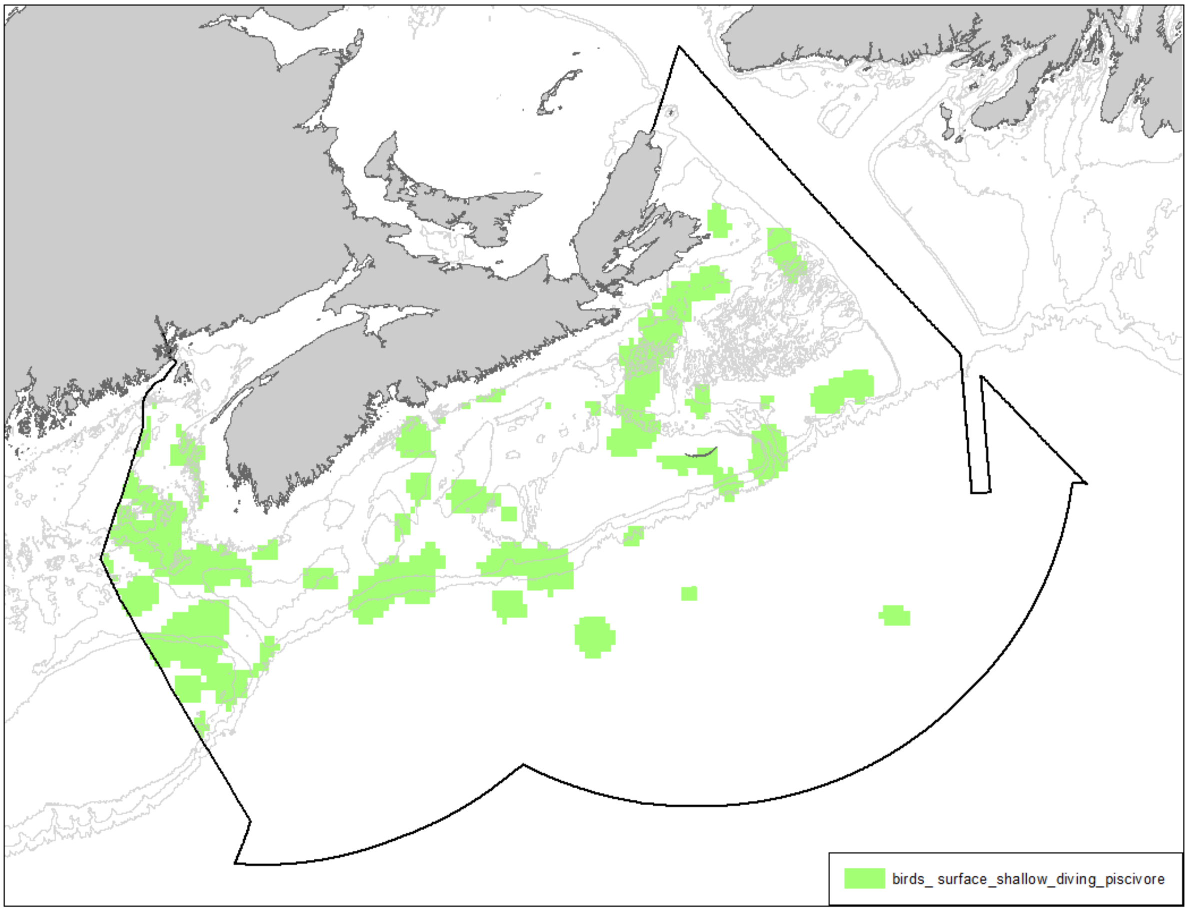

Figure 28. Seabird: Surface shallow-diving piscivore functional group from Allard et al. (2014). The species represented in this functional group are listed in Table 4 in the Appendix.

2.2 FINE-FILTER CONSERVATION PRIORITIES

Fine-filter conservation priorities are generally smaller scale ecological features, such as individual populations, species or habitats that often have very high conservation value. Examples of fine-filter conservation priorities include important habitats for depleted or endangered species, highly sensitive biogenic habitats that provide shelter for many other species (e.g. cold-water coral reefs), and distinct geological features (Lieberknecht et al. 2010).

2.2.1 Areas of High Species Richness

2.2.1.1 Areas of High Fish and Invertebrate Species Richness

Description: Ward-Paige and Bundy (2016) generated three biodiversity indices for the fishes and invertebrates of the Scotian Shelf Bioregion, using data from the annual DFO RV Survey. The indices generated were Species Richness, Heip's Evenness Index, and the exponential of Shannon-Weiner Index (ESW). Species richness was used in the MPA network analysis. Ward-Paige and Bundy (2016) calculated the number of species caught per tow for fishes and invertebrates separately to map species richness. Continuous surfaces were created using an Inverse Distance Weighted interpolation. The data layers were then classified into quintiles, and the areas within the top quintile (top 20%) were considered areas of high diversity/species richness. The top quintiles for each species are shown in Figure 29 – Figure 30, as that is what was included in the network analysis. Ward-Paige and Bundy's (2016) work was further split into an eastern and western component to account for the fact that Eastern Scotian Shelf is markedly different in species composition from the Western Scotian Shelf.

Rationale: The MPA Network Technical Working Group recommended that the Species Richness index be used in the MPA network design analysis because it was anticipated that species evenness would be captured by the fish and invertebrate functional groups (see sections 2.1.3.1 and 2.1.3.2).

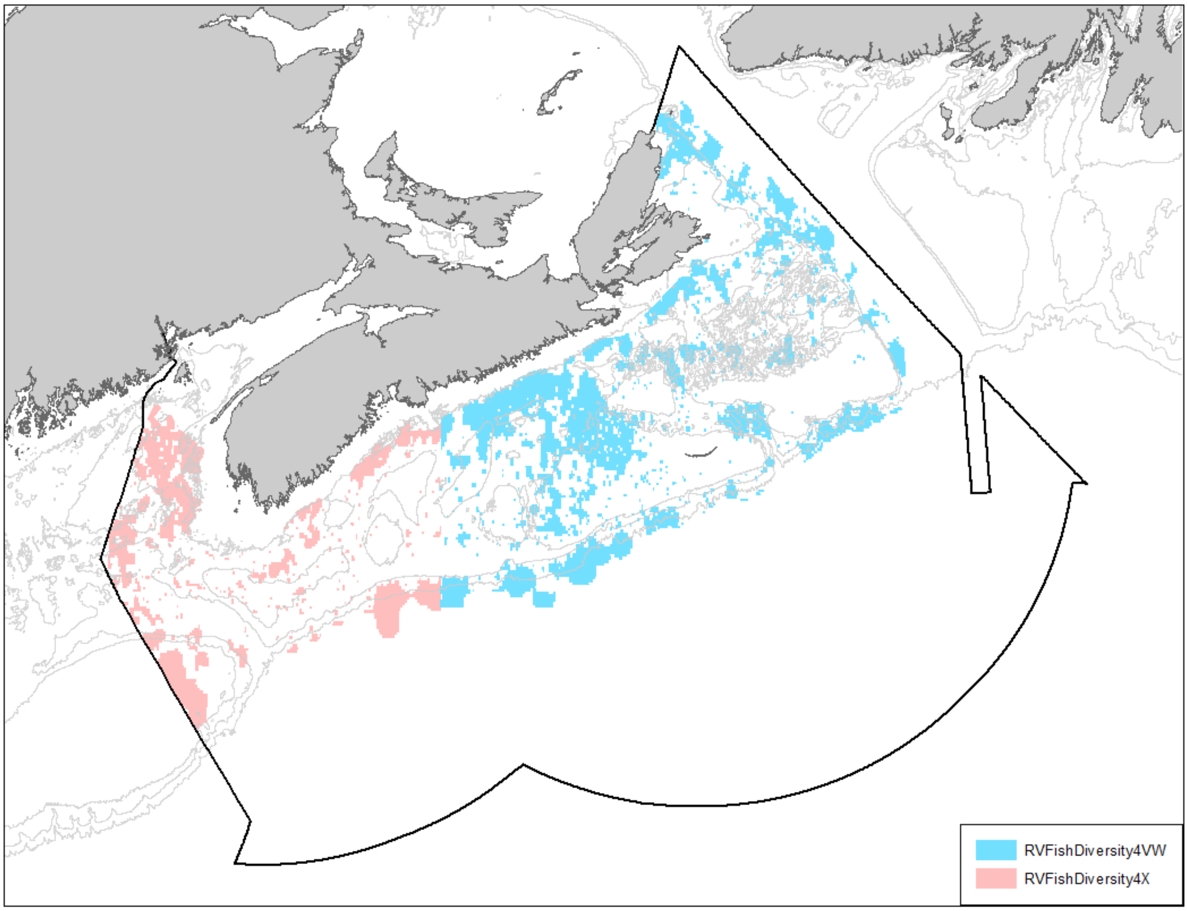

Figure 29. Areas of high fish species richness (Ward-Paige and Bundy 2016).

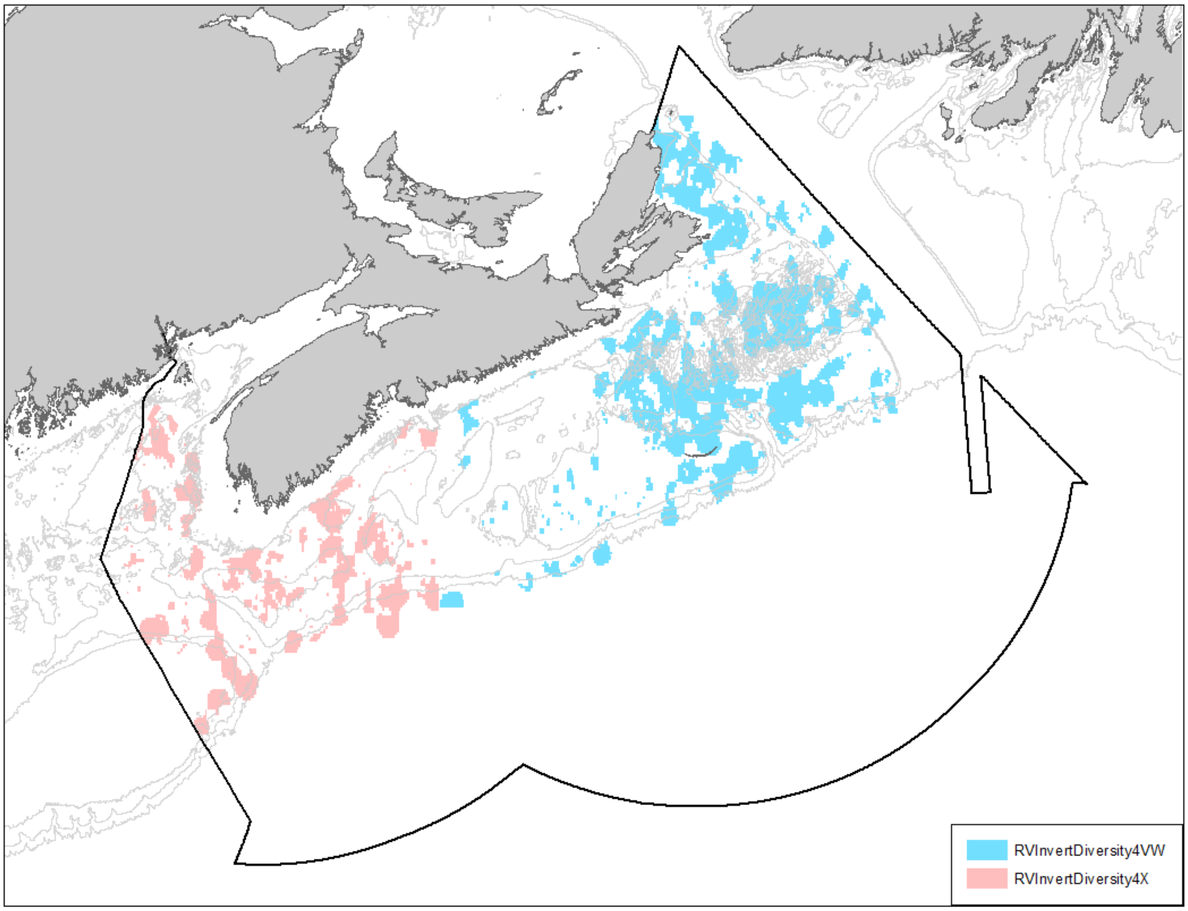

Figure 30. Areas of high invertebrate species richness (Ward-Paige and Bundy 2016).

2.2.1.2 Areas of High Small Fish and Small Invertebrate Species Richness

Description: Cook and Bundy (2012) mapped areas of high small fish and small invertebrate species richness based on an analysis of the stomach contents of fishes caught in the DFO RV survey. They used a 272 km^2 grid to map richness and counted the total number of species identified in each grid from both the RV trawl and stomach contents data. See Cook and Bundy (2012) for the specific statistics performed on the data. For use in the MPA network, their analysis was classified into quintiles, and only the top quintiles were used (shown in Figure 31 – Figure 32).

Rationale: These layers were used in addition to the layers described in section 2.2.1.1, as they represent smaller fish and invertebrate species not well caught by DFO's RV Survey.

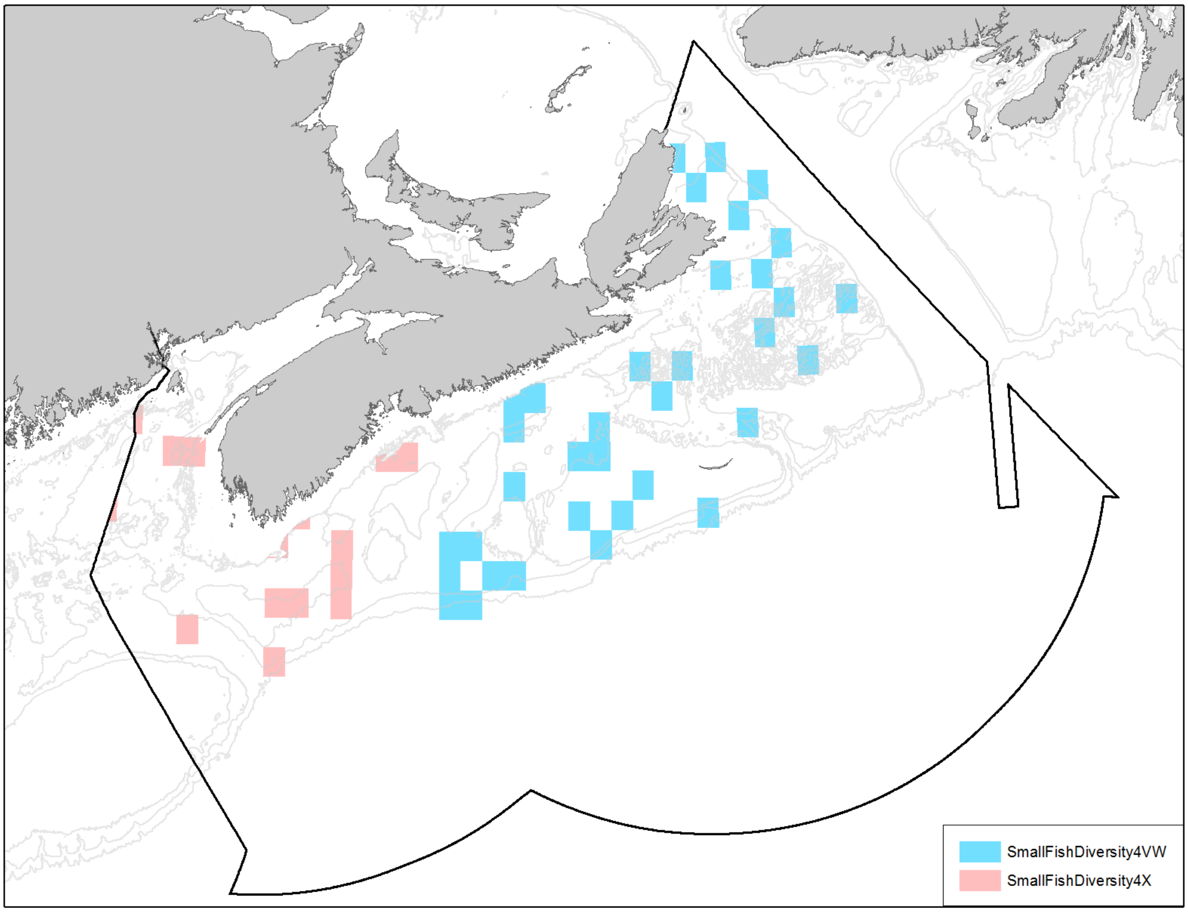

Figure 31. Areas of high small fish species richness (modified from Cook and Bundy [2012]).

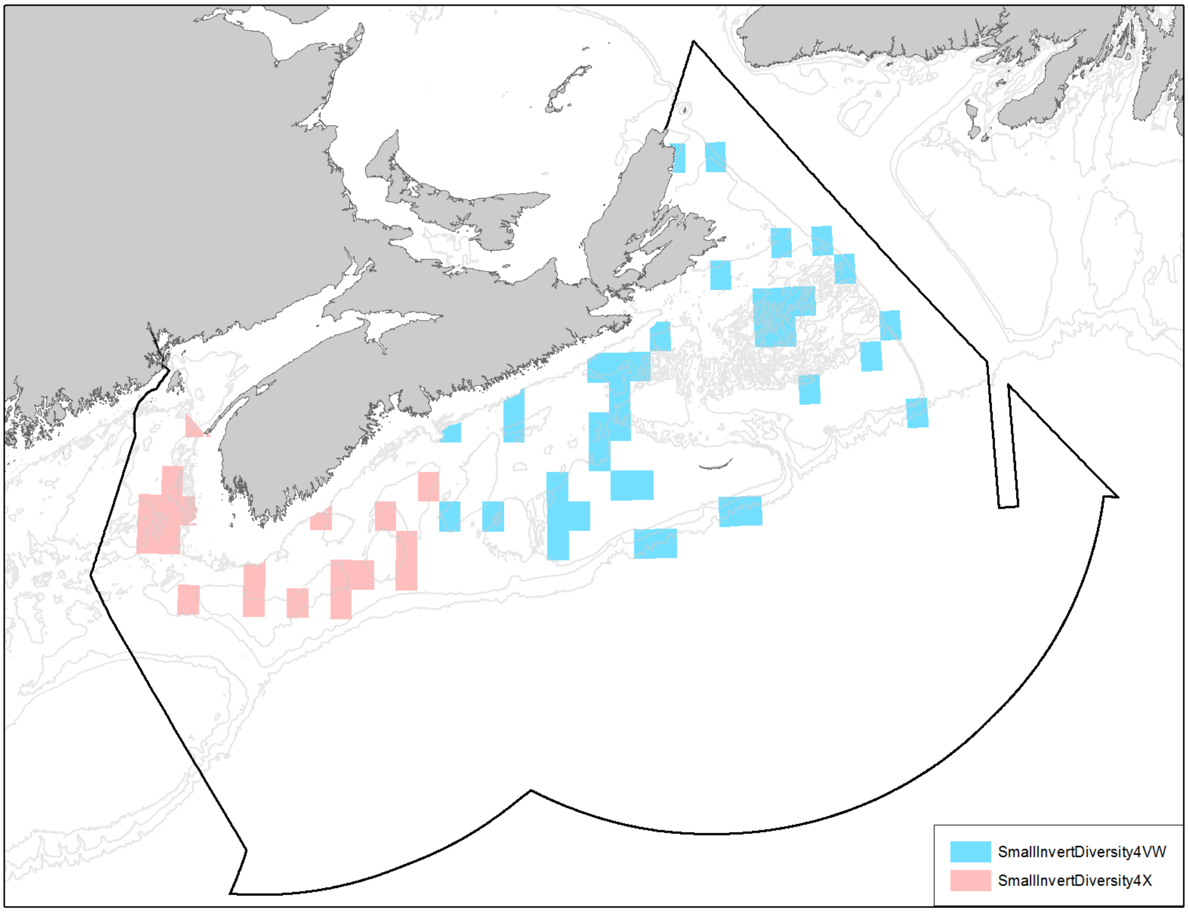

Figure 32. Areas of high small invertebrate species richness (modified from Cook and Bundy [2012]).

2.2.1.3 Areas of High Ichthyoplankton Genus Richness

Description: Shackell and Frank (2000) described areas of high larval fish genus richness using egg and larval data from the Scotian Shelf Icthyoplankton Program (SSIP; 1978-1982). This analysis was repeated for use in MPA network planning. Data were cleaned to exclude any records not identified to genus level. The number of genera per tow was calculated and interpolated using Inverse Distance Weighted and displayed using quintiles. The top quintile was considered an area of high larval genus richness, shown in Figure 33.

Rationale: The SSIP data are somewhat dated but remain the only shelf-wide larvae dataset available for the Scotian Shelf Bioregion.

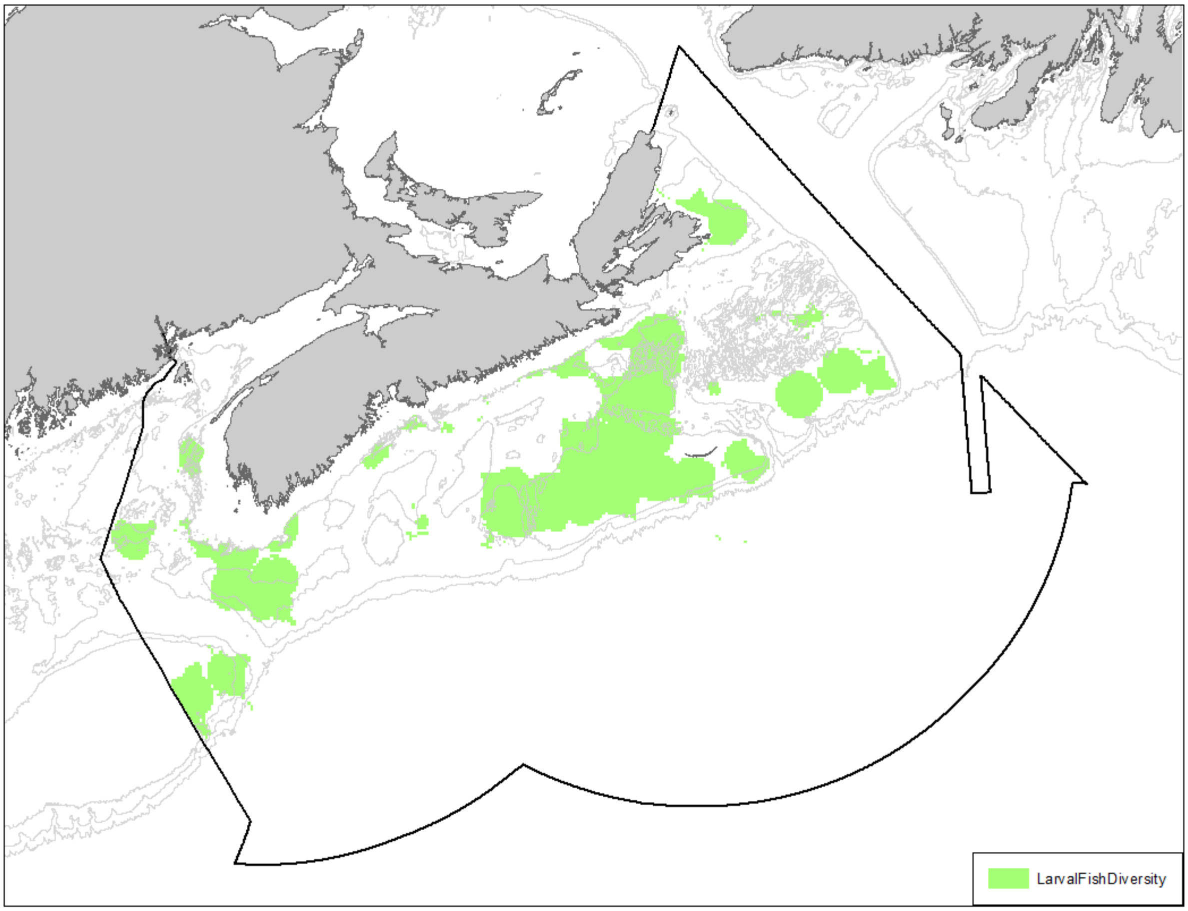

Figure 33. Areas of high larval fish genus richness (originally created by Shackell and Frank 2000).

2.2.2 Biogenic Habitats

Description: Two types of biogenic habitat data layers have been generated by the DFO Maritimes Region Benthic Ecology Lab. Kenchington et al. (2016) identified significant concentrations of a species or taxa through a Kernel Density Estimation (KDE) analysis of RV Survey (Figure 34 – Figure 37). These are known areas of relatively high concentrations. One limitation of the layers generated using the RV Survey data is limited distribution of the survey. For example, the RV Survey intentionally avoids areas that are known to contain dense concentrations of large gorgonian corals, which is why the layer generated for this group of species does not highlight several known areas of high coral density like the Gully or the Northeast Channel.

In addition, Beazley et al. (2016, 2017) generated species distribution models for certain species or taxa using a random forest model and a variety of environmental data (Figure 38 – Figure 43). These layers are predicted distributions for a species or taxa based on environmental variables.

Rationale: Biogenic habitats generally represent sessile and, in some cases, highly sensitive species, which provide habitat for other species. These types of species/taxa or features have high ecological value and represent important conservation priorities for an MPA network.

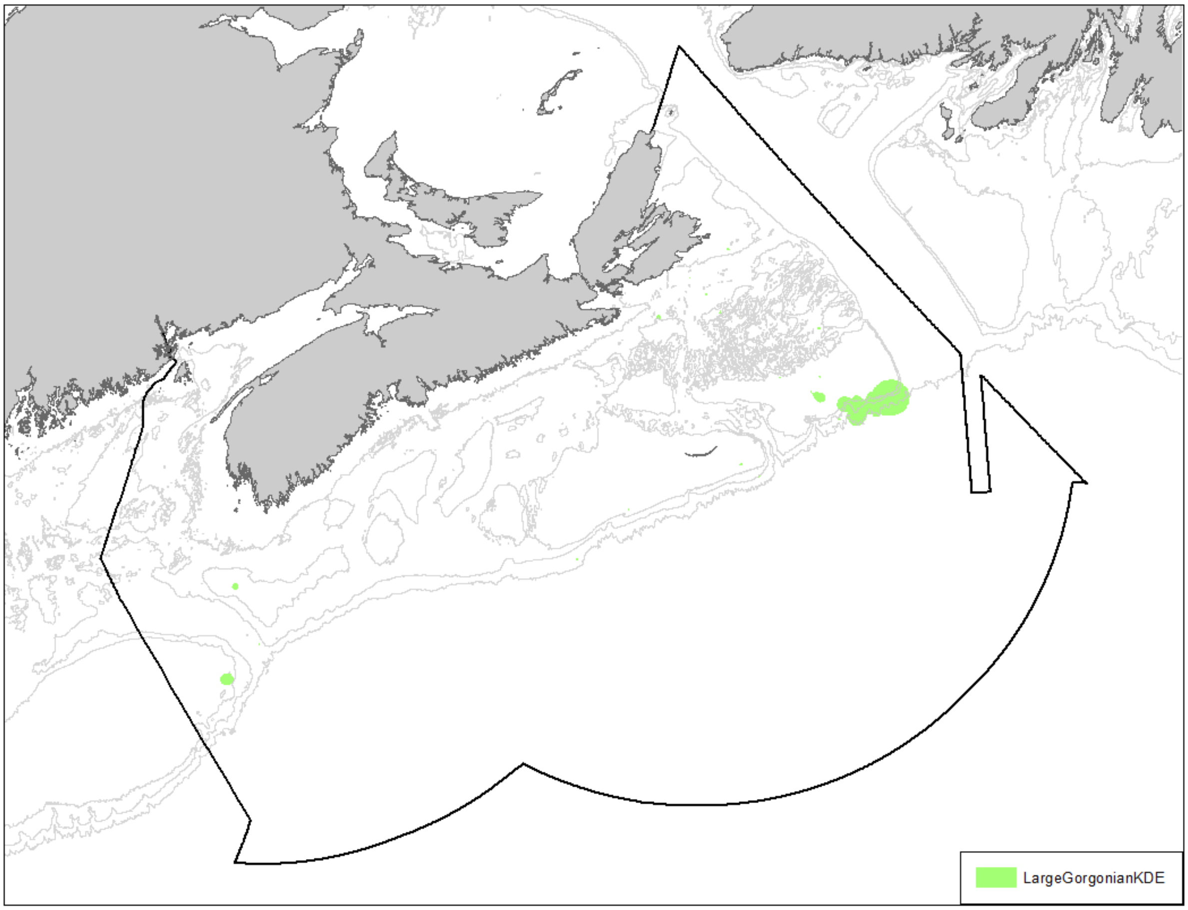

Figure 34. Significant concentrations of large gorgonian corals based on KDE analysis (Kenchington et al. 2016). The species represented in this map are *Acanthogorgia armata*, *Keratoisis ornate*, *Paragorgia arborea*, and *Primnoa resedaeformis.*

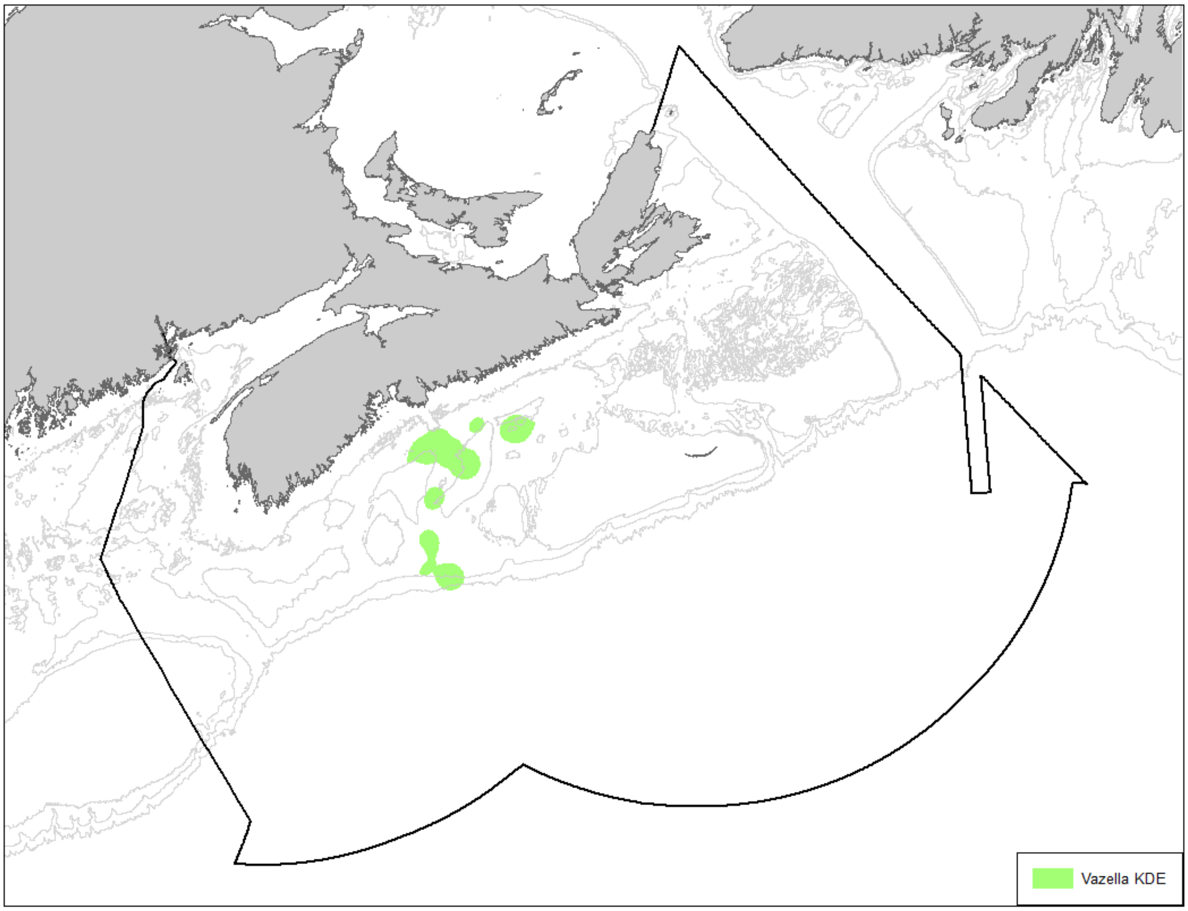

Figure 35. Significant concentrations of *Vazella pourtalesi* sponges based on KDE analysis (Kenchington et al. 2016).

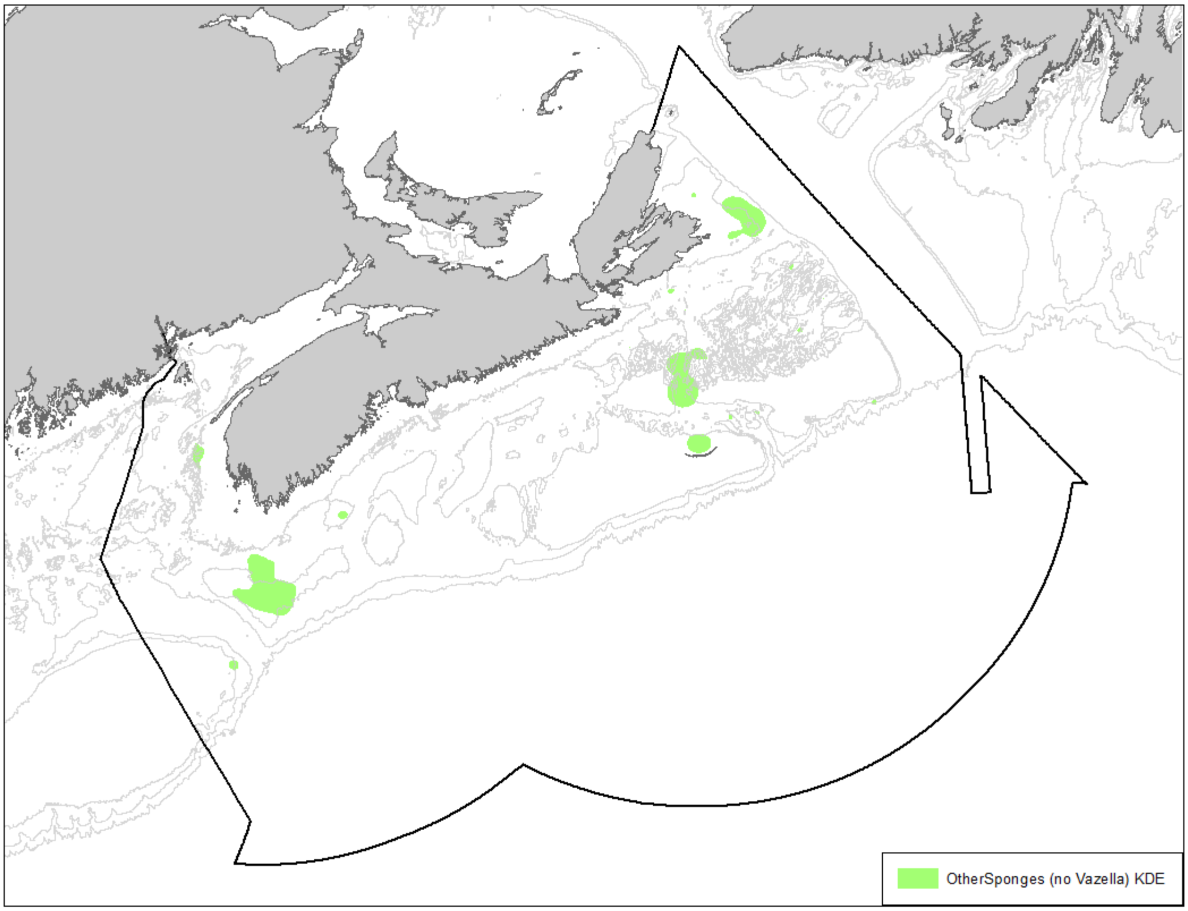

Figure 36. Significant concentrations of other sponges based on KDE analysis (Kenchington et al. 2016). The species/taxa represented in this map are *Geodia* spp., *Polymastia* sp., *Rhizaxinella* sp., and Phylum Porifera.

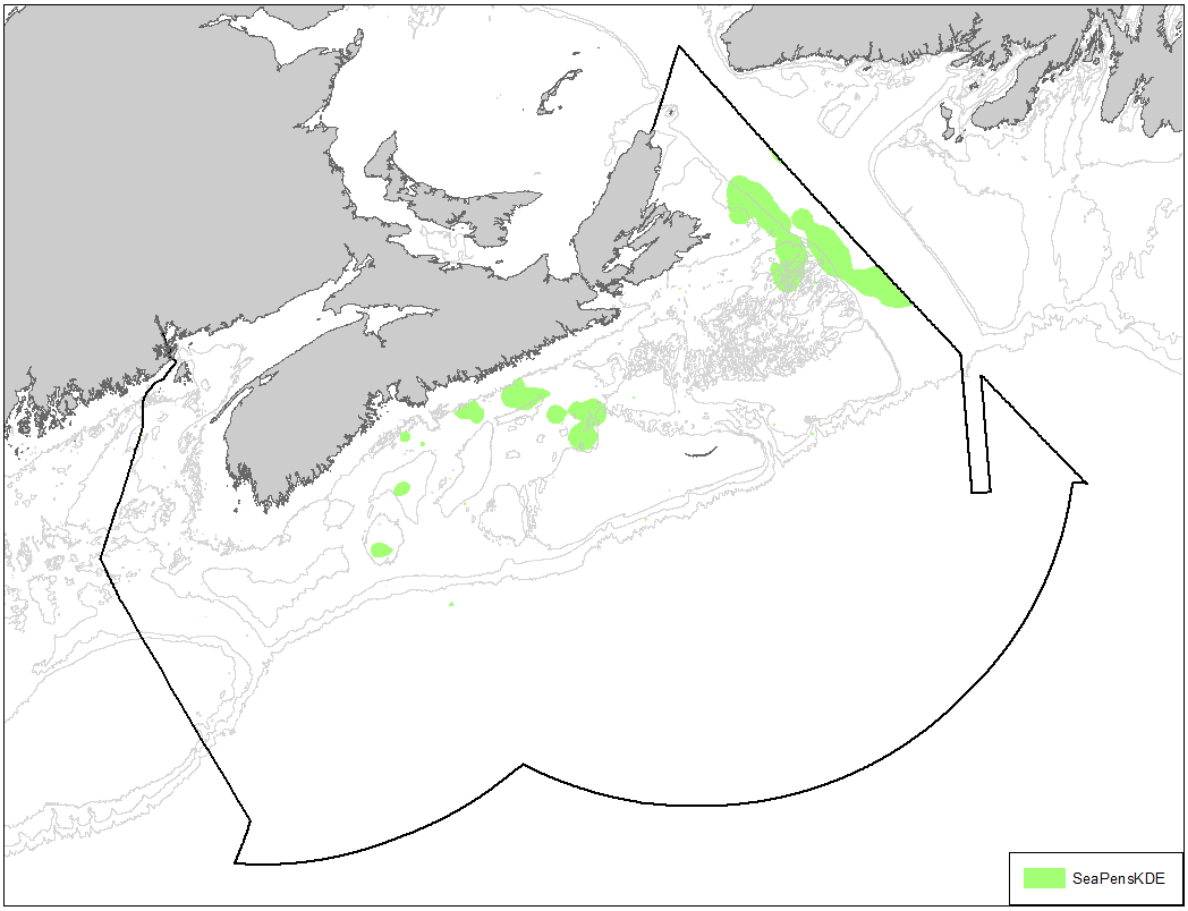

Figure 37. Significant concentrations of sea pens based on KDE analysis (Kenchington et al. 2016). The species/taxa represented in this map are *Anthoptilum grandiflorum*, *Funiculina quadrangularis*, *Halipteris* sp., *Pennatula borealis*, and Order Pennatulacea.

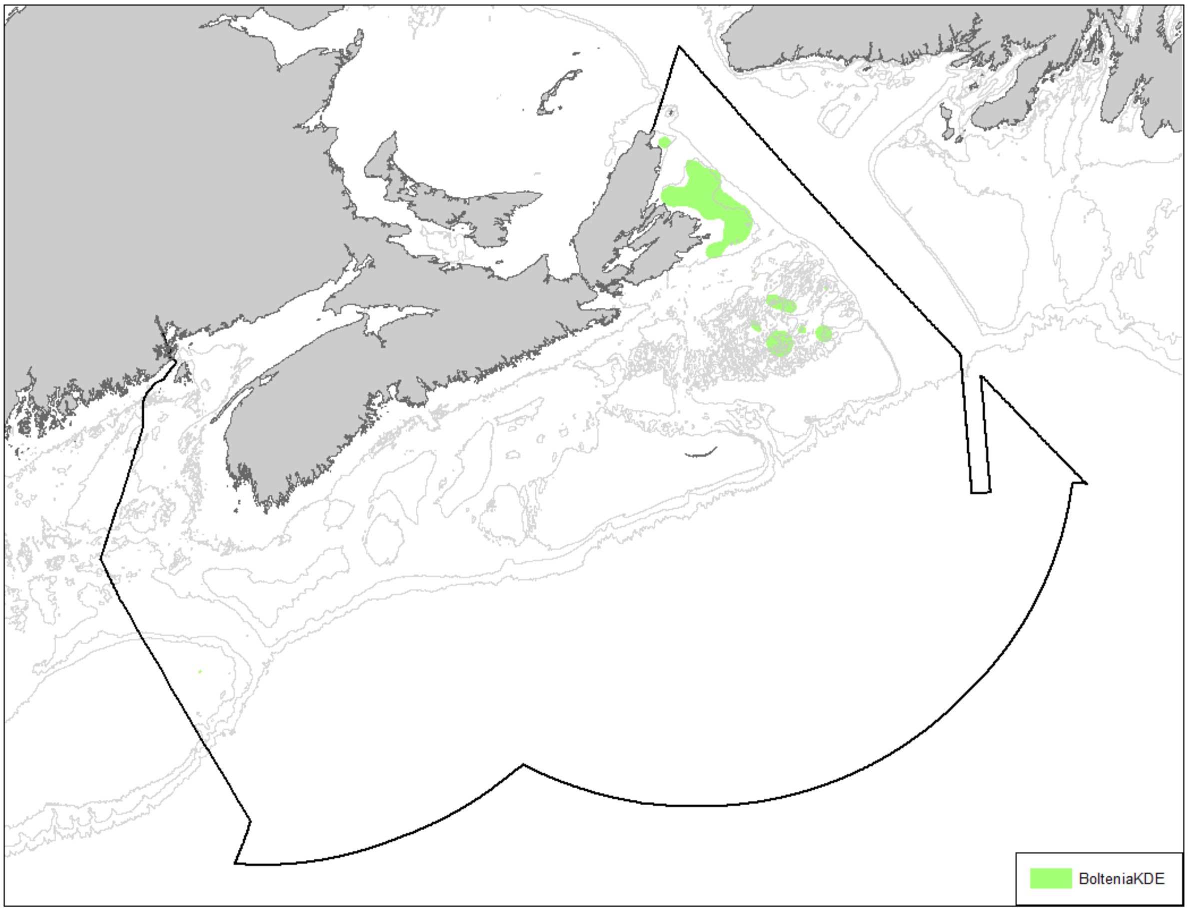

Figure 38. Significant concentrations of stalked tunicates (*Boltenia* sp.) based on KDE analysis (Beazley et al. 2017).

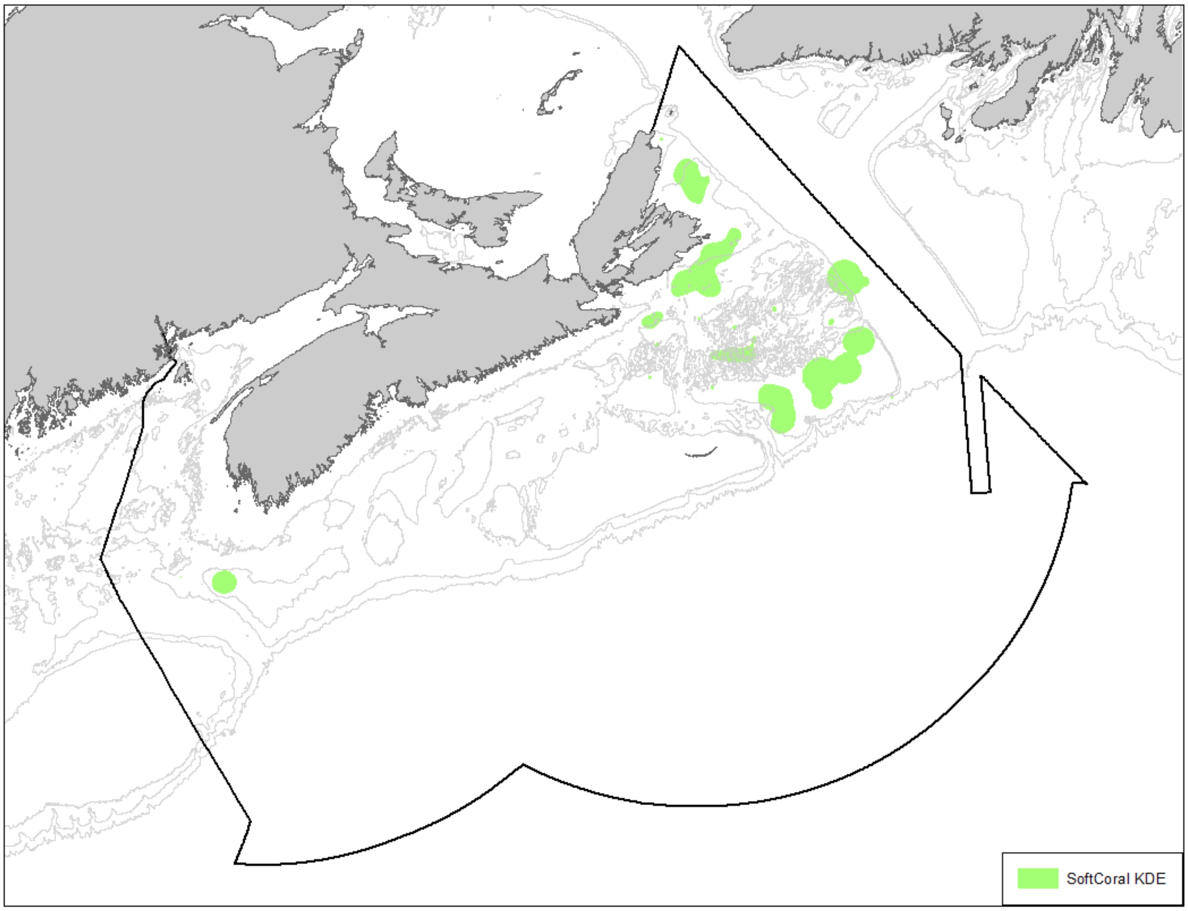

Figure 39. Significant concentrations of cup corals (*Flabellum* sp.) based on KDE analysis (Beazley et al. 2017).

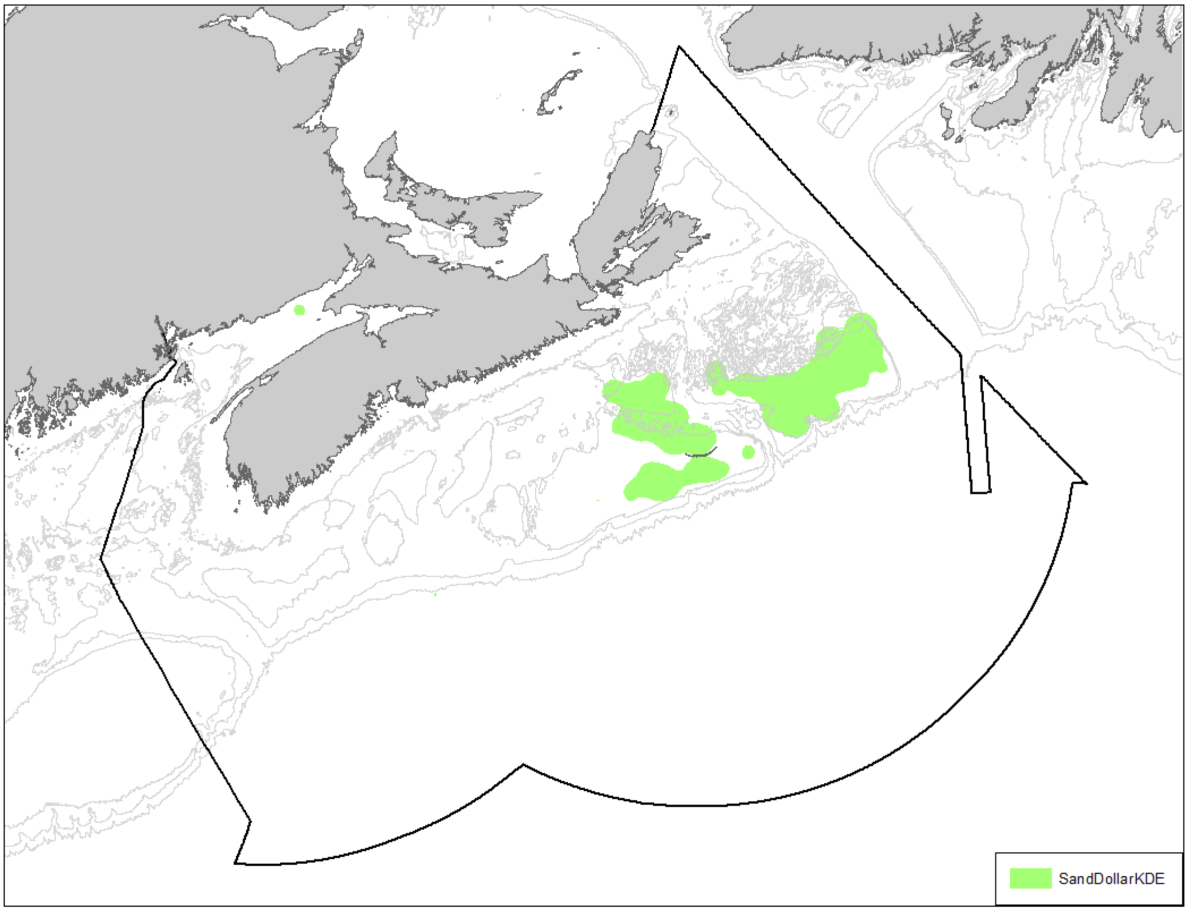

Figure 40. Significant concentrations of sand dollars based on KDE analysis (Beazley et al. 2017). The species/taxa represented in this map are *Echinarachnius parma*, and Order Clypeasteroida.

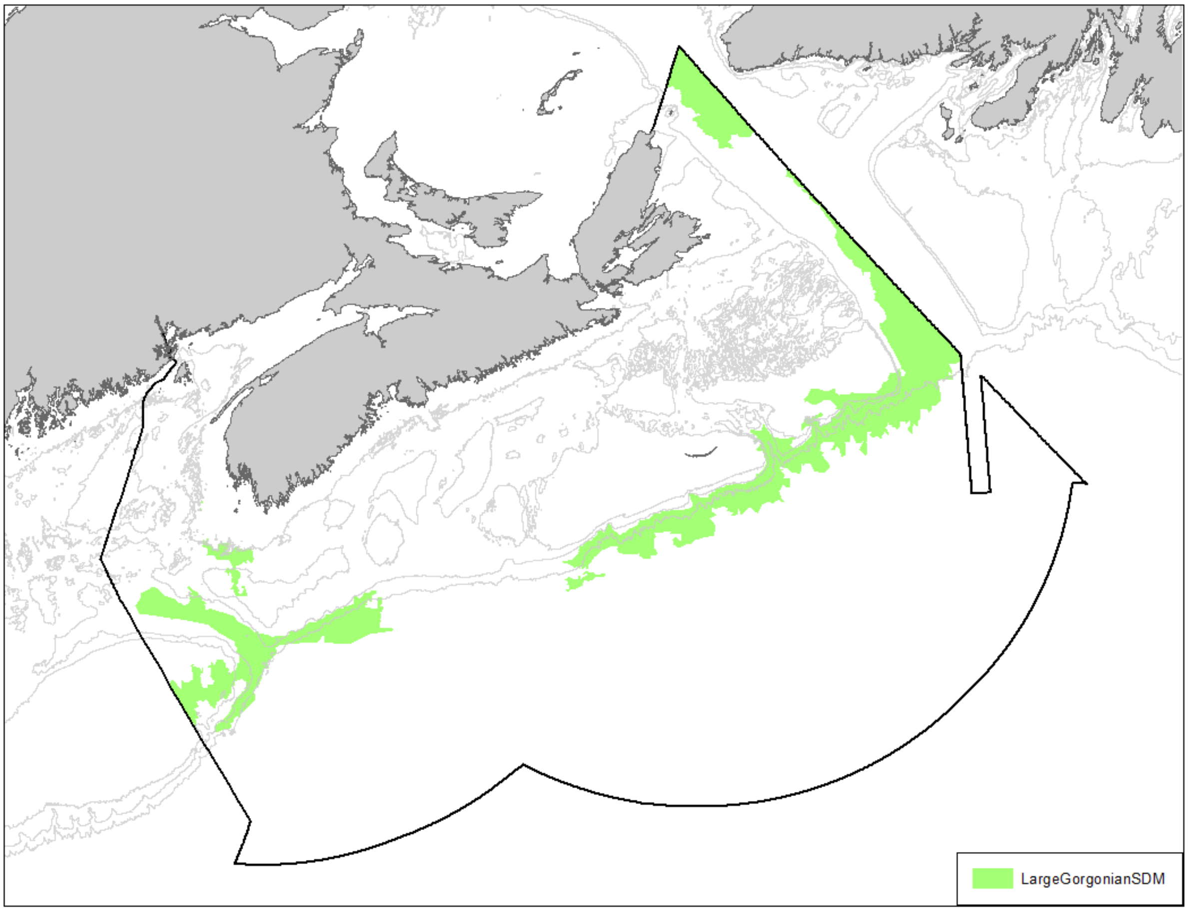

Figure 41. Predicted large gorgonian coral distribution based on species distribution model (Beazley et al. 2016). The species represented in this map are *Acanthogorgia armata*, *Keratoisis ornate*, *Paragorgia arborea*, and *Primnoa resedaeformis*.

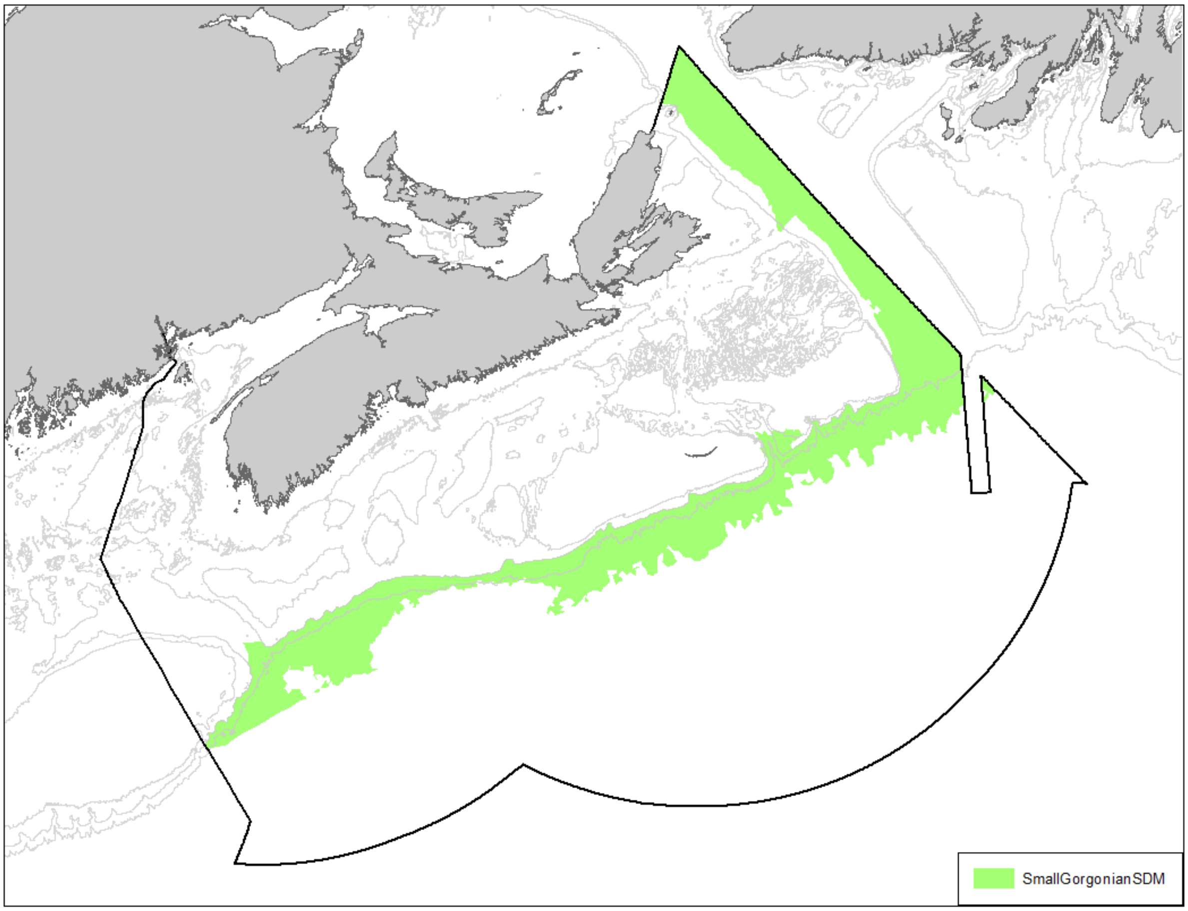

Figure 42. Predicted small gorgonian coral distribution based on species distribution model (Beazley et al. 2016). The species represented in this map are *Acanella arbuscula*, *Chrysogorgia agassizii*, and *Radicipes gracilis*.

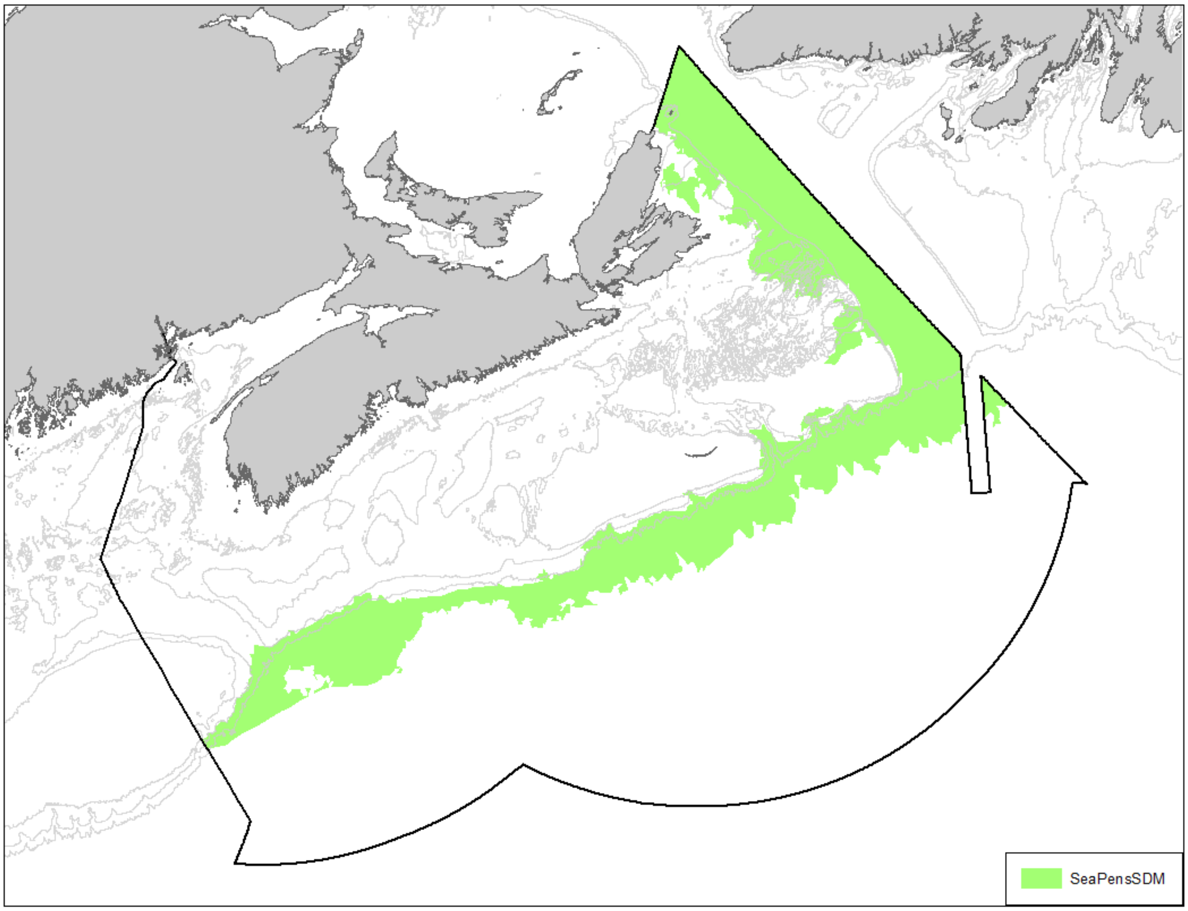

Figure 43. Predicted sea pen distribution based on species distribution model (Beazley et al. 2016). The species/taxa represented in this map are *Anthoptilum grandiflorum*, *Funiculina quadrangularis*, *Halipteris* sp., *Pennatula borealis*, and Order Pennatulacea.

2.2.3 Depleted Species

Description: Depleted species were defined for this process as species that have been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) or listed under the *Species at Risk Act* as Threatened or Endangered, are below the limit reference point in the DFO Precautionary Approach Framework (DFO 2006a, 2006b), or have been documented as being at abundance levels less than 40% of the long-term mean. There are multiple cetacean, turtle, shark and fish species that meet these criteria in the Scotian Shelf Bioregion (DFO 2018).

However, reliable spatial distribution data do not exist for all of these species so certain species could not be considered in the MPA network design process. The DFO RV survey can be used to map the distribution of most depleted groundfish species (Horsman and Shackell 2009), but there are no long-term, systematic surveys for the wide-ranging pelagic cetaceans, turtles and sharks. Satellite telemetry data have been used to identify broad areas of important habitat for leatherback turtles (DFO 2011) and habitat suitability models have been developed for certain cetaceans (Gomez et al. 2017, Gomez and Moors-Murphy 2014). The only two cetaceans considered in the offshore network design analysis were the endangered North Atlantic Right Whale (*Eubalaena glacialis*) and Northern Bottlenose Whale (*Hyperoodon ampullatus*) because Critical Habitat areas have been delineated for both of these species under the *Species at Risk Act* (Figure 44). Highly migratory species with very large habitat requirements are less suitable to protection through MPAs or MPA networks unless they consistently aggregate in the same discrete areas each year.

For depleted groundfish species, important habitat data layers were generated using DFO RV survey data. The summer RV survey has taken place annually since 1970, so this large time series was divided into five periods (1970-1977, 1978-1985, 1986-1993, 1994-2005, and 2007-2016) based on the approach used by Horsman and Shackell (2009). A composite layer was created for each species by combining the layers for each of the five periods. Areas of high biomass were identified by calculating the total biomass per tow and then creating a continuous surface using an Inverse Distance Weighted interpolation. The data layers were then classified into quintiles and the areas within the top quintile (i.e., top 20%) in all five periods were considered areas of high biomass and important habitat. The top quintiles for each species are shown in Figure 45 – Figure 57, as that is what was included in the network analysis.

Where separate populations have been described for a depleted species, a separate layer was generated for each population (see Atlantic Cod as an example). In these cases each population was assigned a target in the network design analysis to ensure some of the genetic diversity within these species was captured within the network. The depleted species and populations (if applicable) considered in the network design process are listed below. It should be noted that these species were considered depleted as of 2017, and thus included, but they may not currently be depleted.

- Atlantic Cod (*Gadus morhua*): 4Vn, 4VsW, 4X
- Redfish (*Sebastes sp*.): Unit 2
- Winter Skate (*Leucoraja ocellata*): 4VsW
- American Plaice (*Hippoglossus platessoides*): 4VW, 4X
- Cusk[5] (*Brosme brosme*)
- White Hake (*Urophycis tenuis*): 4VW, 4X
- Smooth Skate (*Malacoraja senta*): 4VsW, 4X
- Atlantic Wolffish (*Anarhichas lupus*)
- Thorny Skate (*Amblyraja radiata*): 4VsW, 4X
- Spiny Dogfish (*Squalus acanthias*)
- Ocean Pout (*Zoarces americanus*)
- Roughhead Grenadier (*Macrourus berglax*)

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[5] The cusk layer used was based on a Species Distribution Model (SDM) created by DFO (2014b), as the RV Survey does not catch cusk well, and therefore does not provide an accurate distribution layer.

- Roundnose Grenadier (*Coryphaenoides rupestris*)

Rationale: A number of commercial and non-commercial groundfish species that occur in the Scotian Shelf Bioregion are considered depleted. The abundance and conservation status of these species will fluctuate over time. MPAs can contribute to the recovery of these species by protecting their habitat, including locations needed for important life history processes (e.g., spawning), and by providing a safe haven from fishing activities.

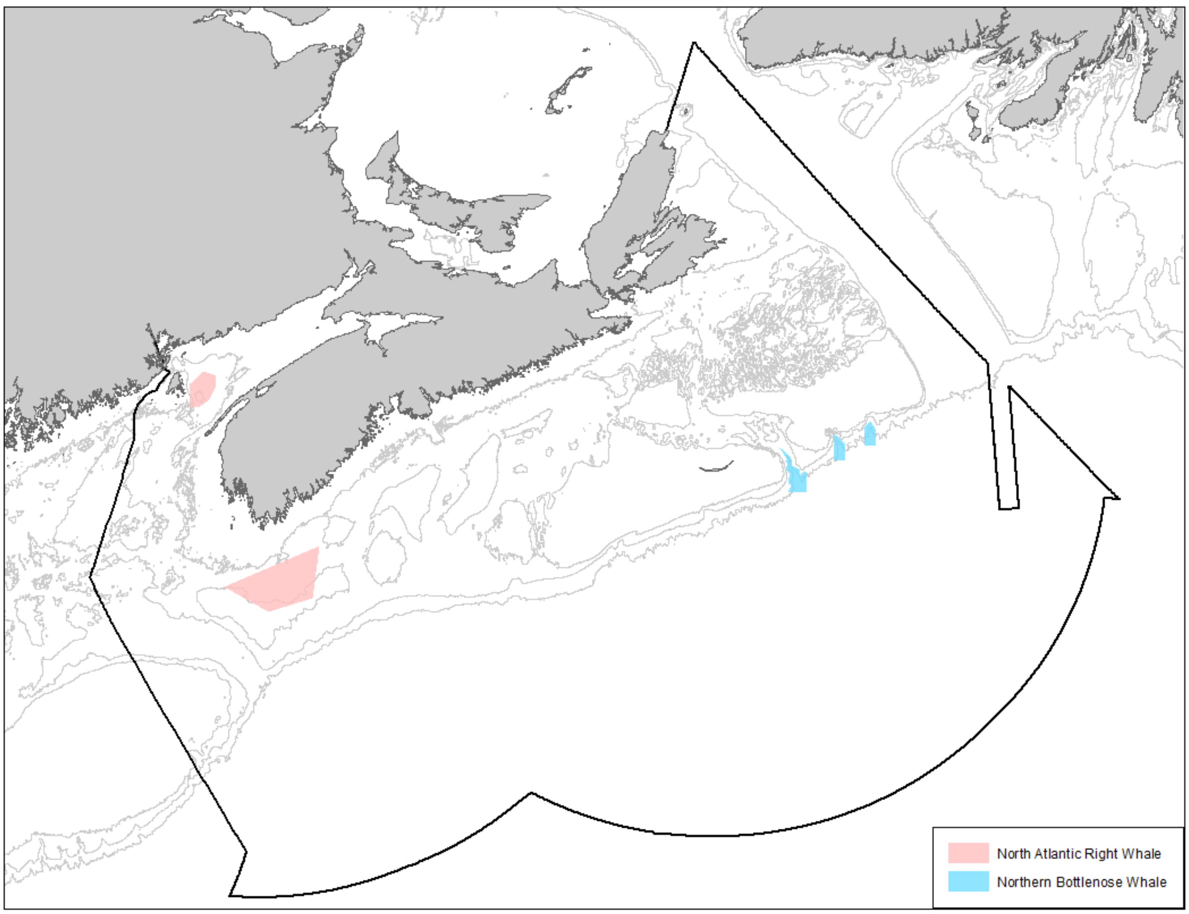

Figure 44. Identified Critical Habitat for North Atlantic Right Whale (*Eubalaena glacialis*; Brown et al. 2009) and Northern Bottlenose Whale (*Hyperoodon ampullatus*), Scotian Shelf population (DFO 2016b).

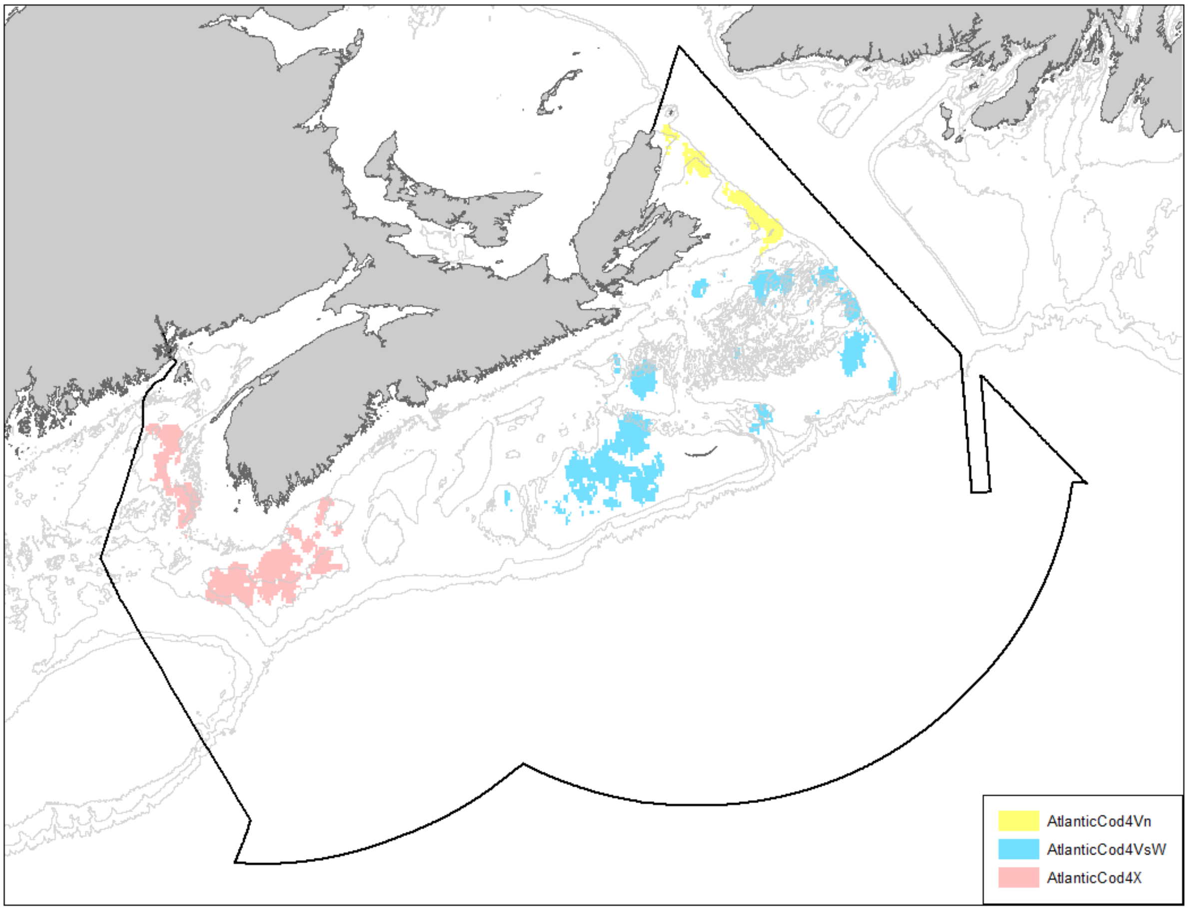

Figure 45. Important habitats for three Atlantic Cod (*Gadus morhua*) populations (4X, 4VsW, 4Vn) in the Scotian Shelf Bioregion.

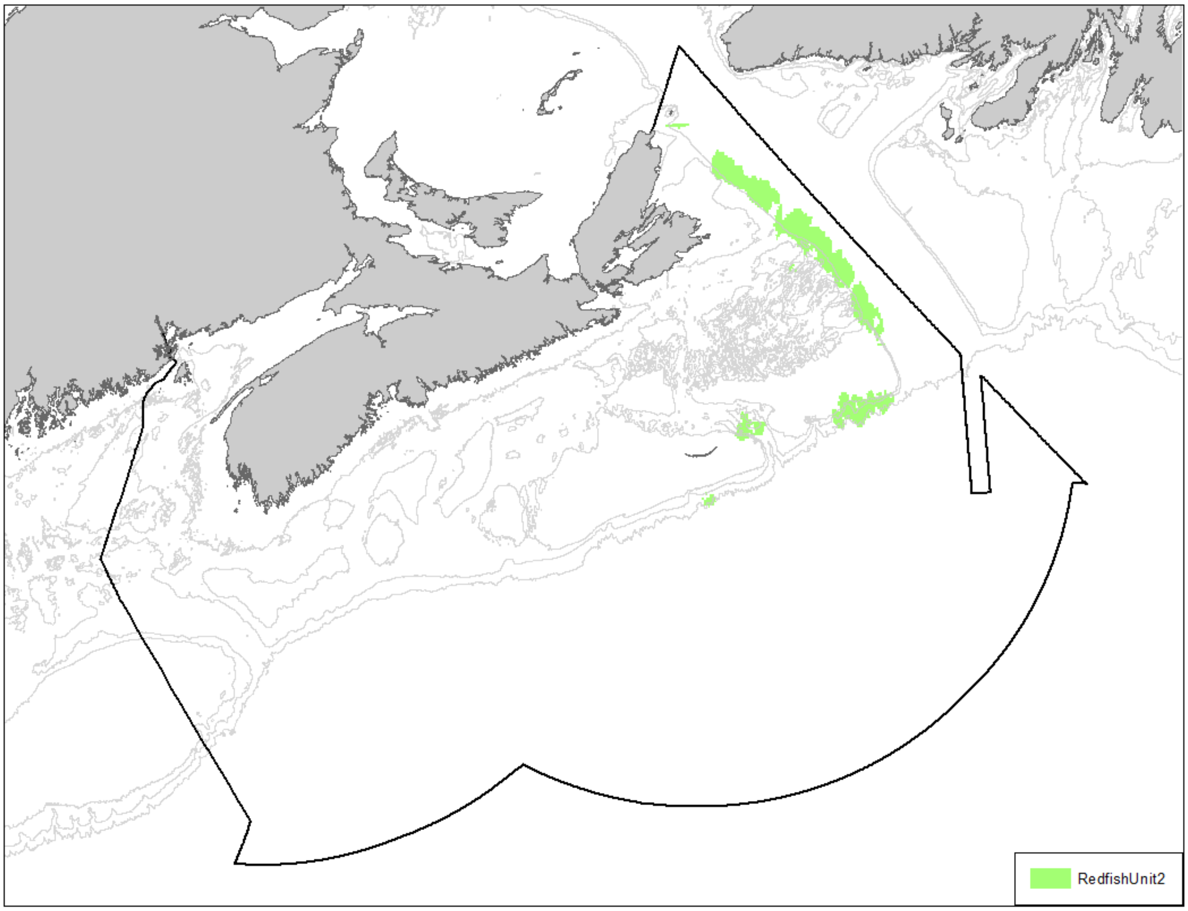

Figure 46. Important habitats for Unit 2 Redfish (*Sebastes sp*.) in the Scotian Shelf Bioregion

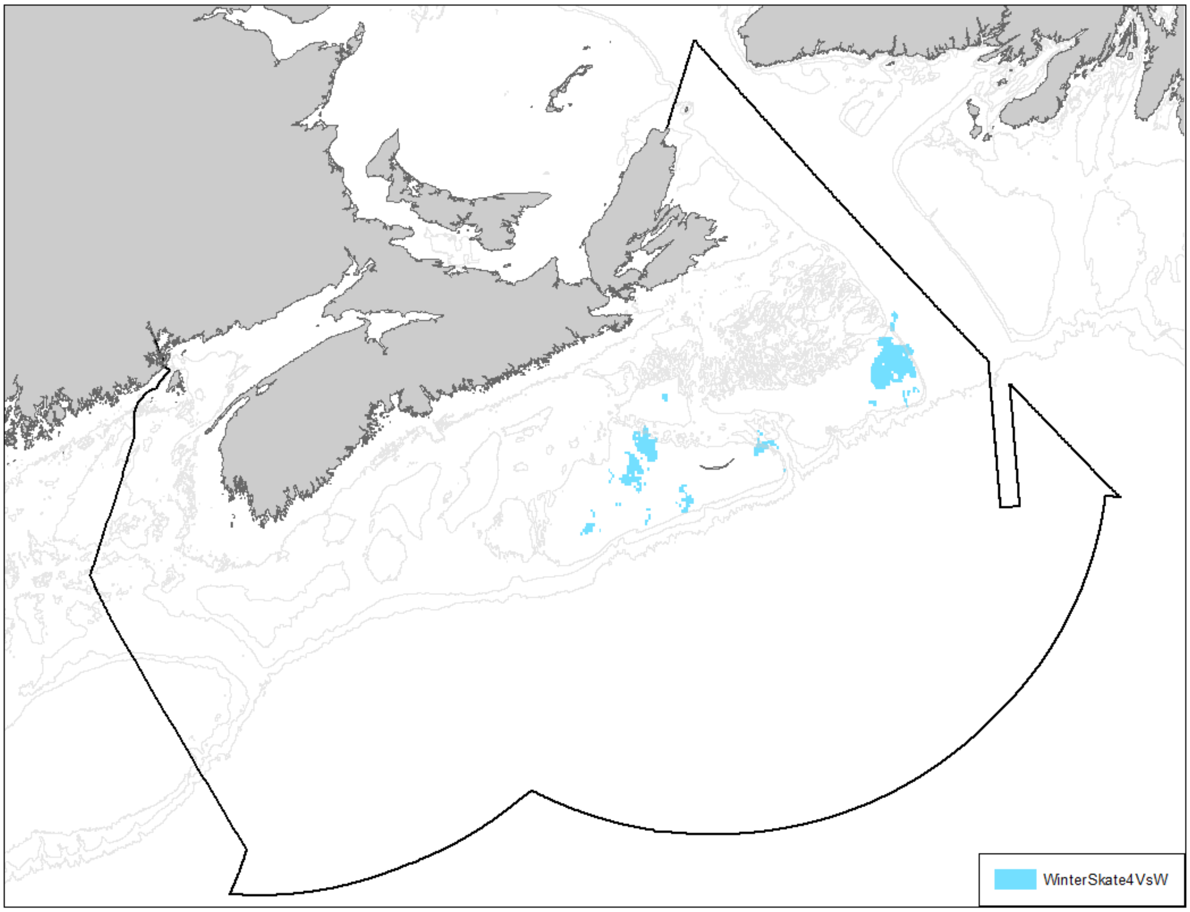

Figure 47. Important habitats for the 4VsW Winter Skate (*Leucoraja ocellata*) population in the Scotian Shelf Bioregion.

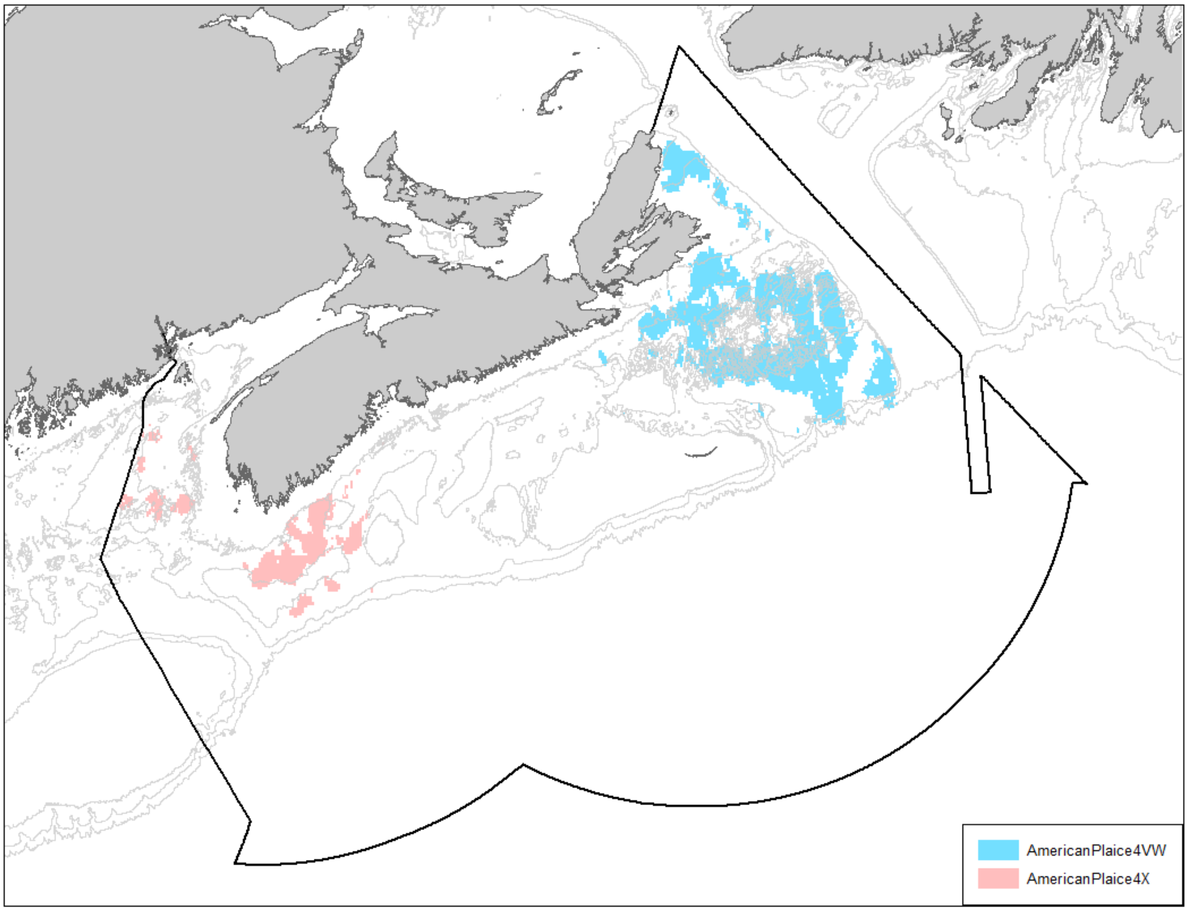

Figure 48. Important habitats for two American Plaice (*Hippoglossus platessoides*) populations (4X, 4VsW) in the Scotian Shelf Bioregion.

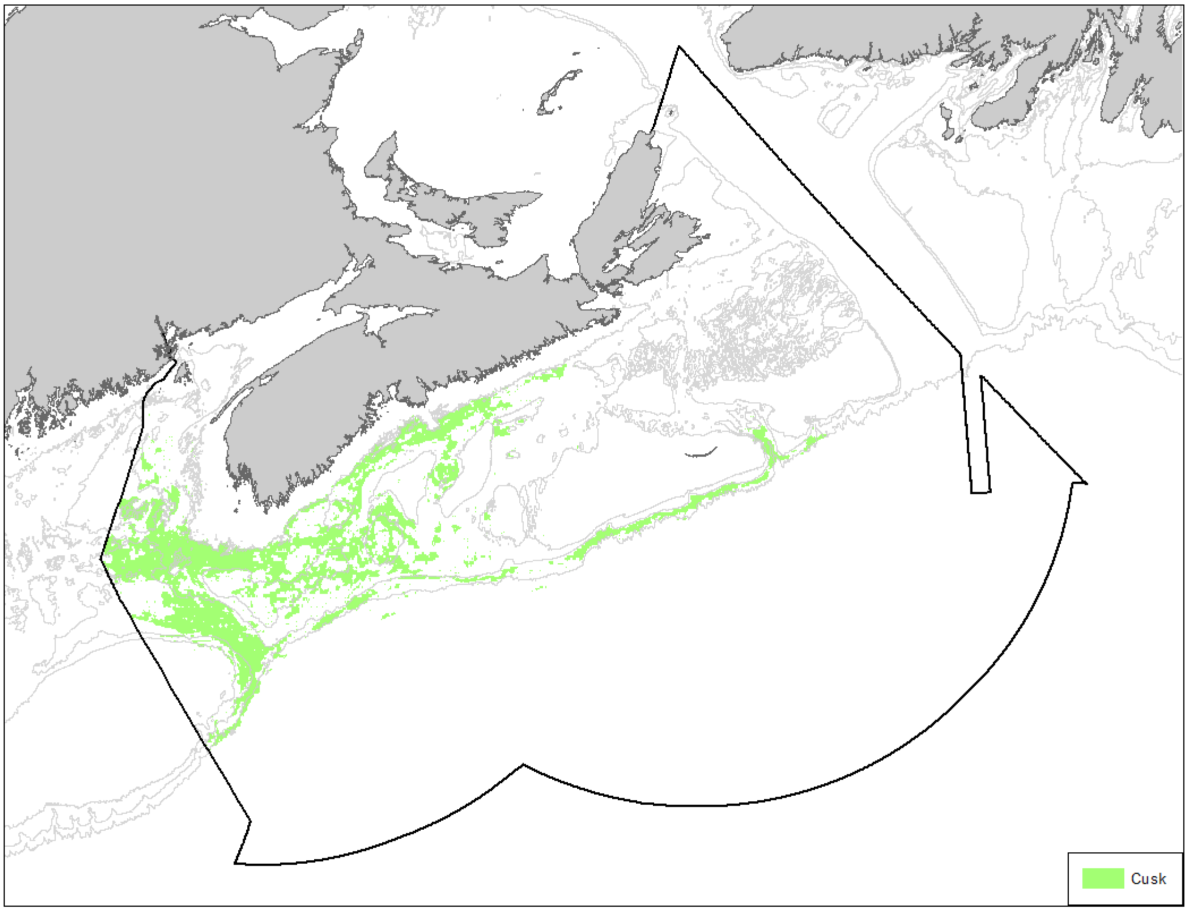

Figure 49. Important habitat for Cusk (*Brosme brosme*) in the Scotian Shelf Bioregion (modified from DFO, 2014b).

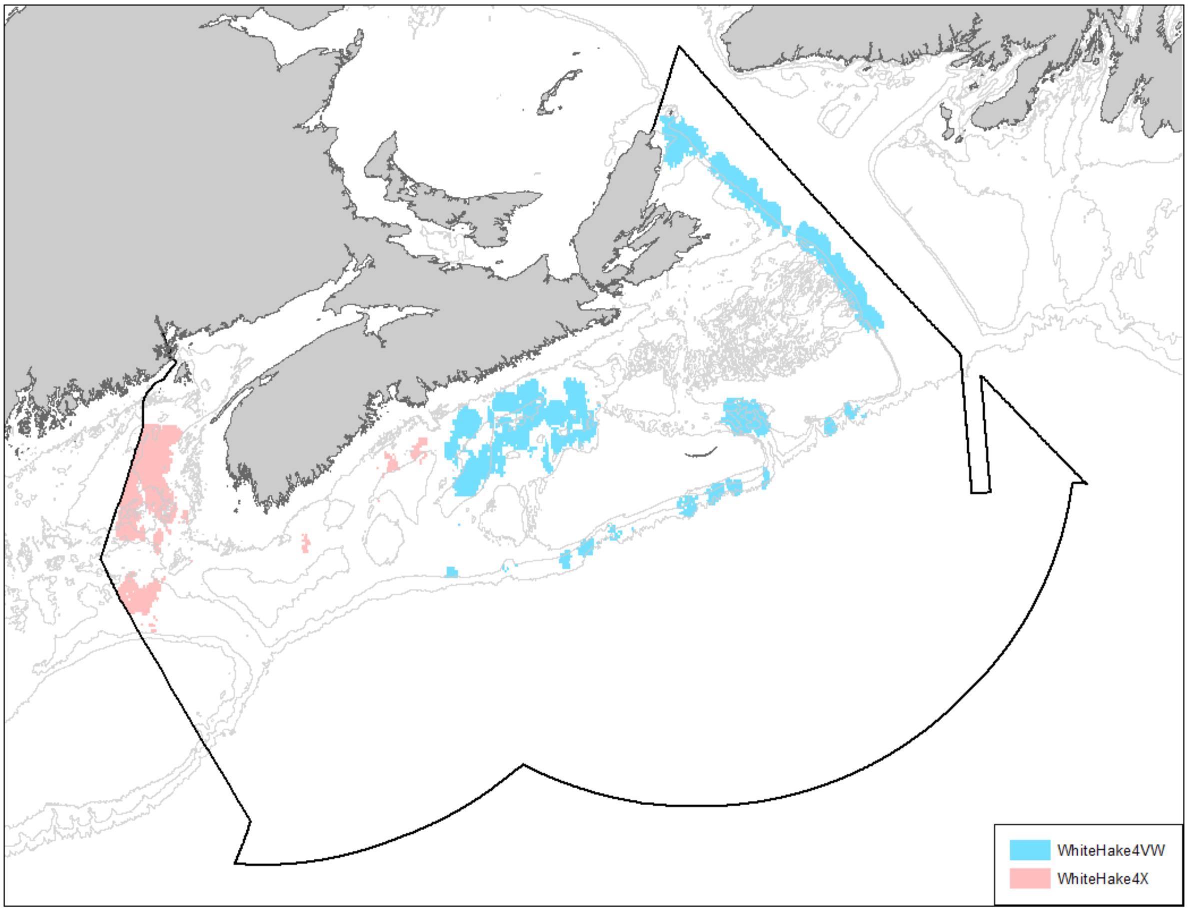

Figure 50. Important habitats for two White Hake (*Urophycis tenuis*) populations (4X, 4VW) in the Scotian Shelf Bioregion.

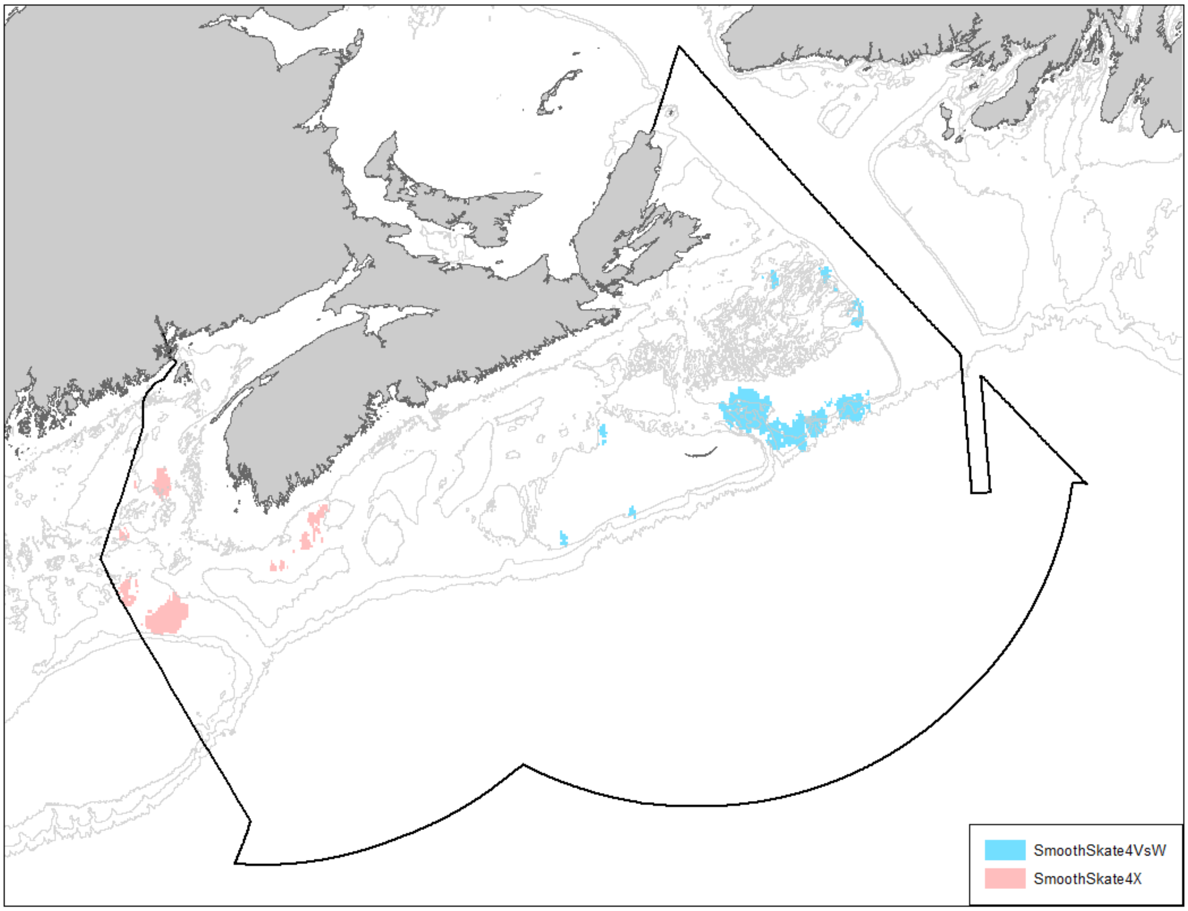

Figure 51. Important habitats for two Smooth Skate (*Malacoraja senta*) populations (4X, 4VsW) in the Scotian Shelf Bioregion.

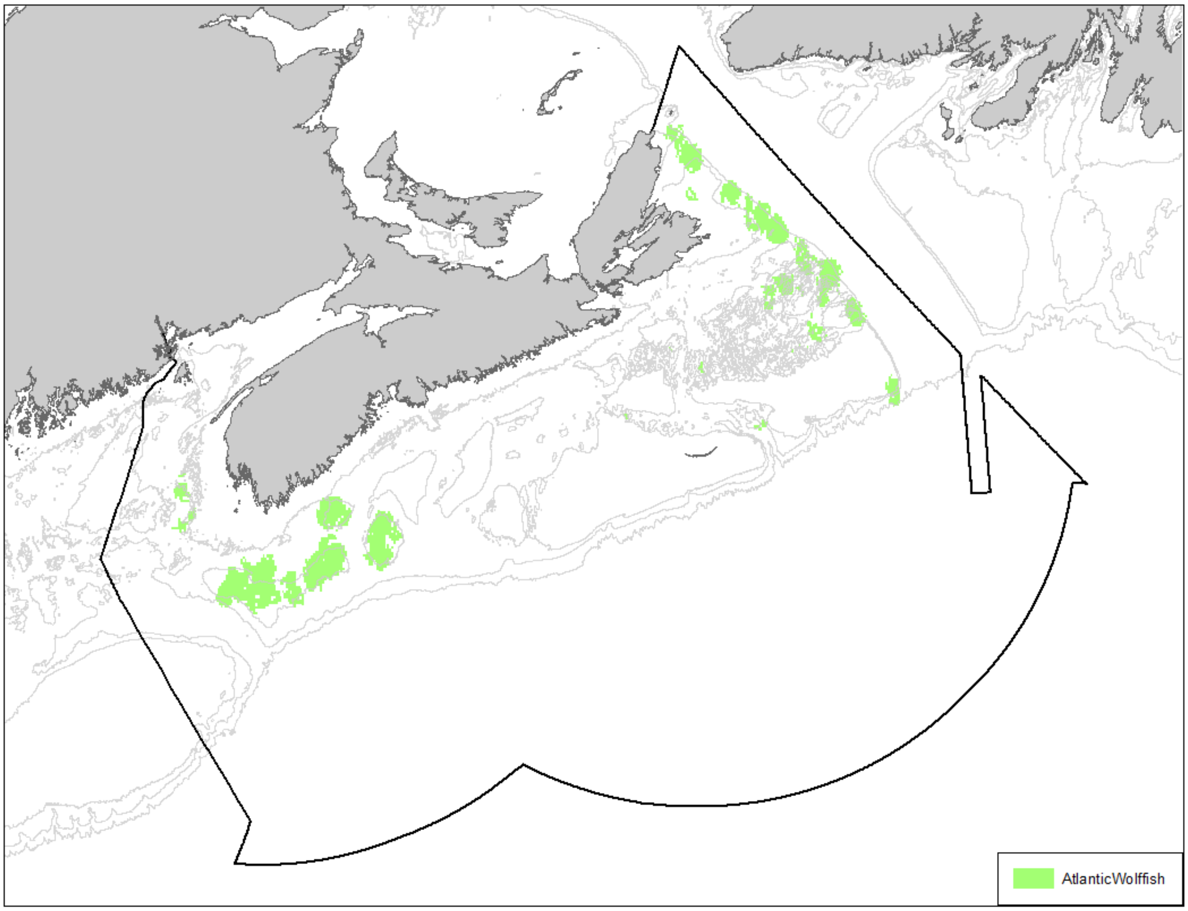

Figure 52. Important habitat for Atlantic Wolffish (*Anarhichas lupus*) in the Scotian Shelf Bioregion.

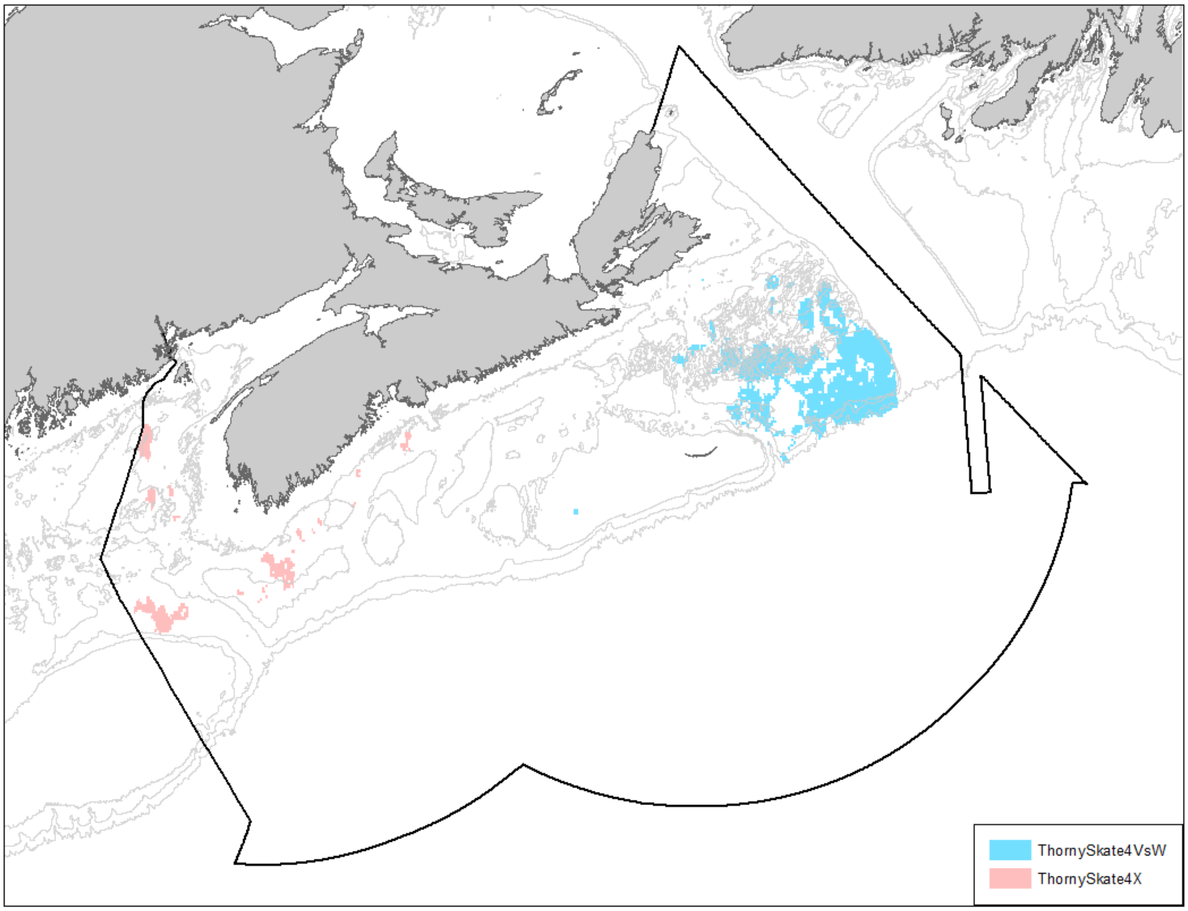

Figure 53. Important habitat for two Thorny Skate (*Amblyraja radiata*) populations (4X, 4VsW) in the Scotian Shelf Bioregion.

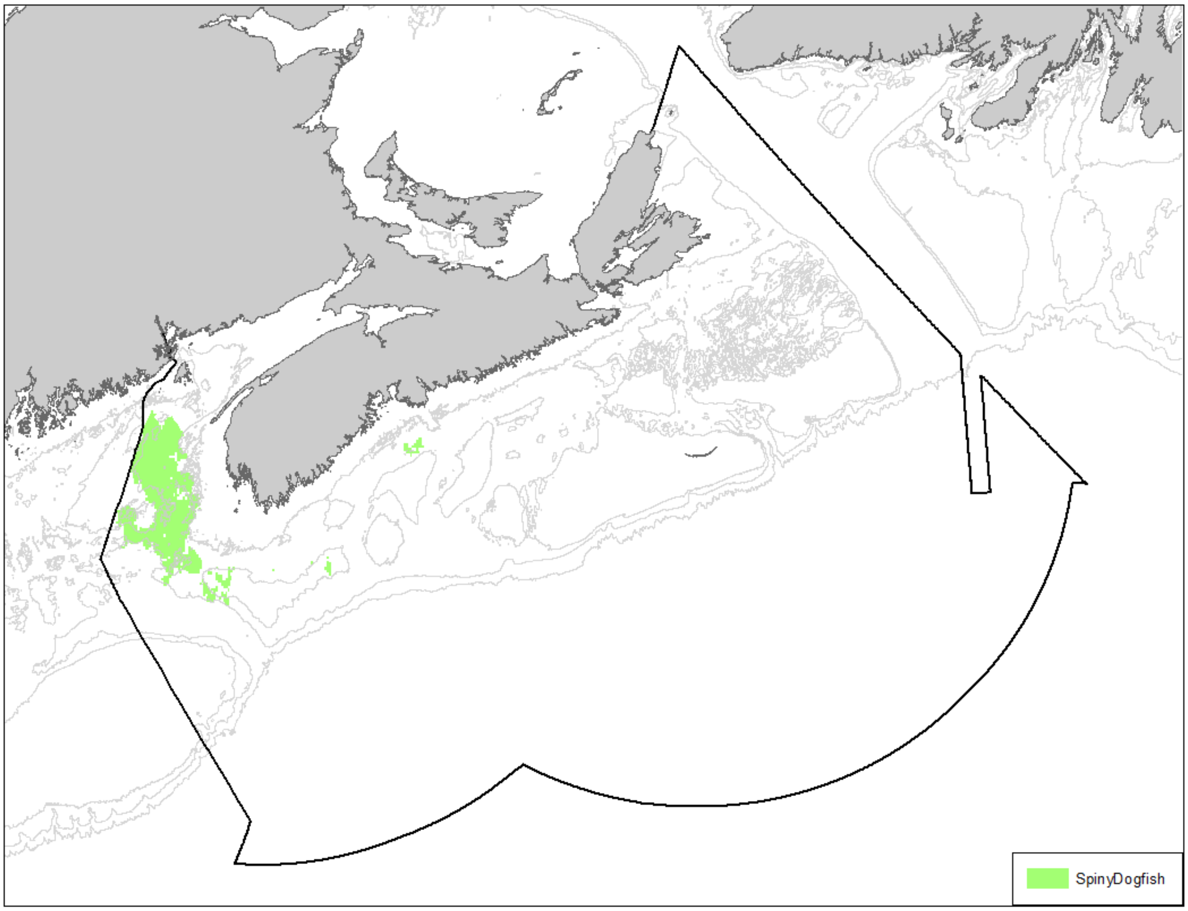

Figure 54. Important habitat for Spiny Dogfish (*Squalus acanthias*) in the Scotian Shelf Bioregion.

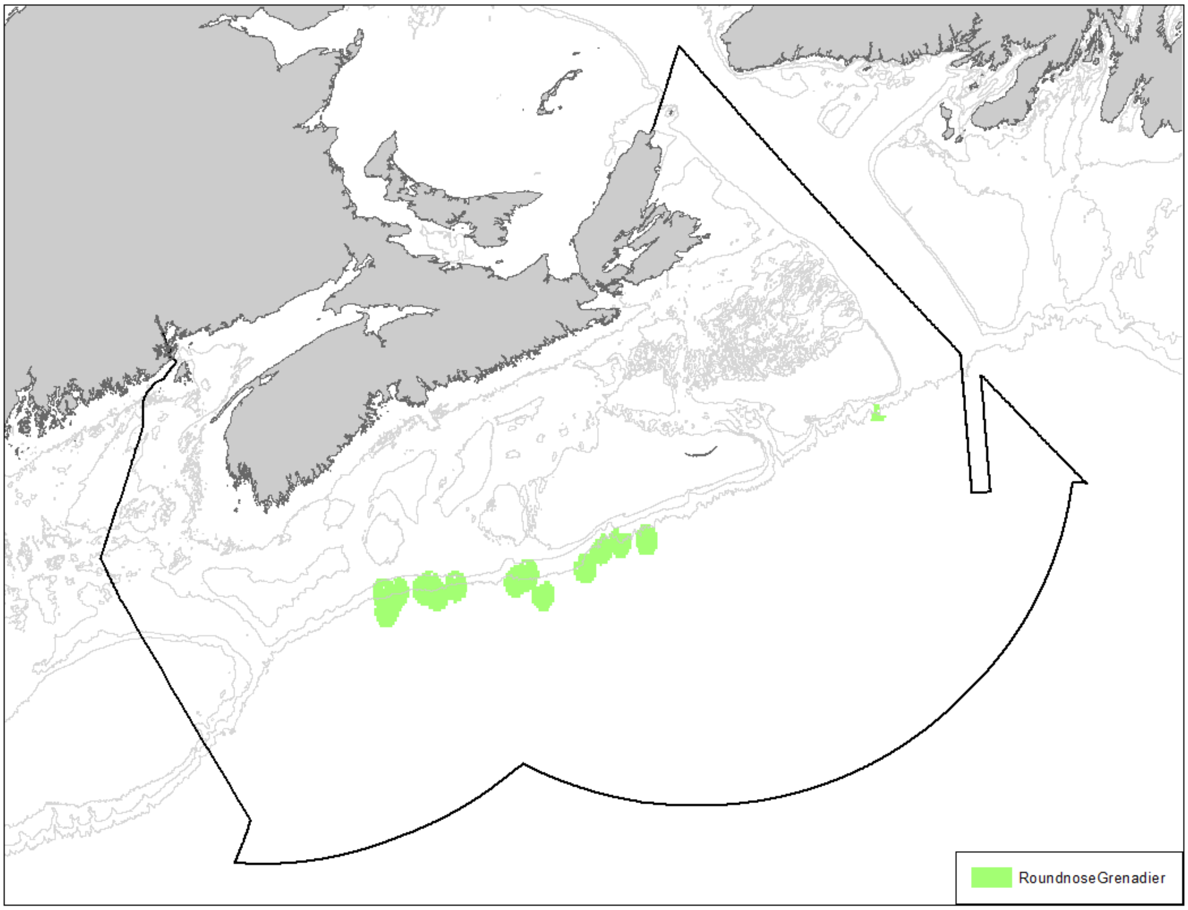

Figure 55. Important habitat for Roundnose Grenadier (*Coryphaenoides rupestris*) in the Scotian Shelf Bioregion.

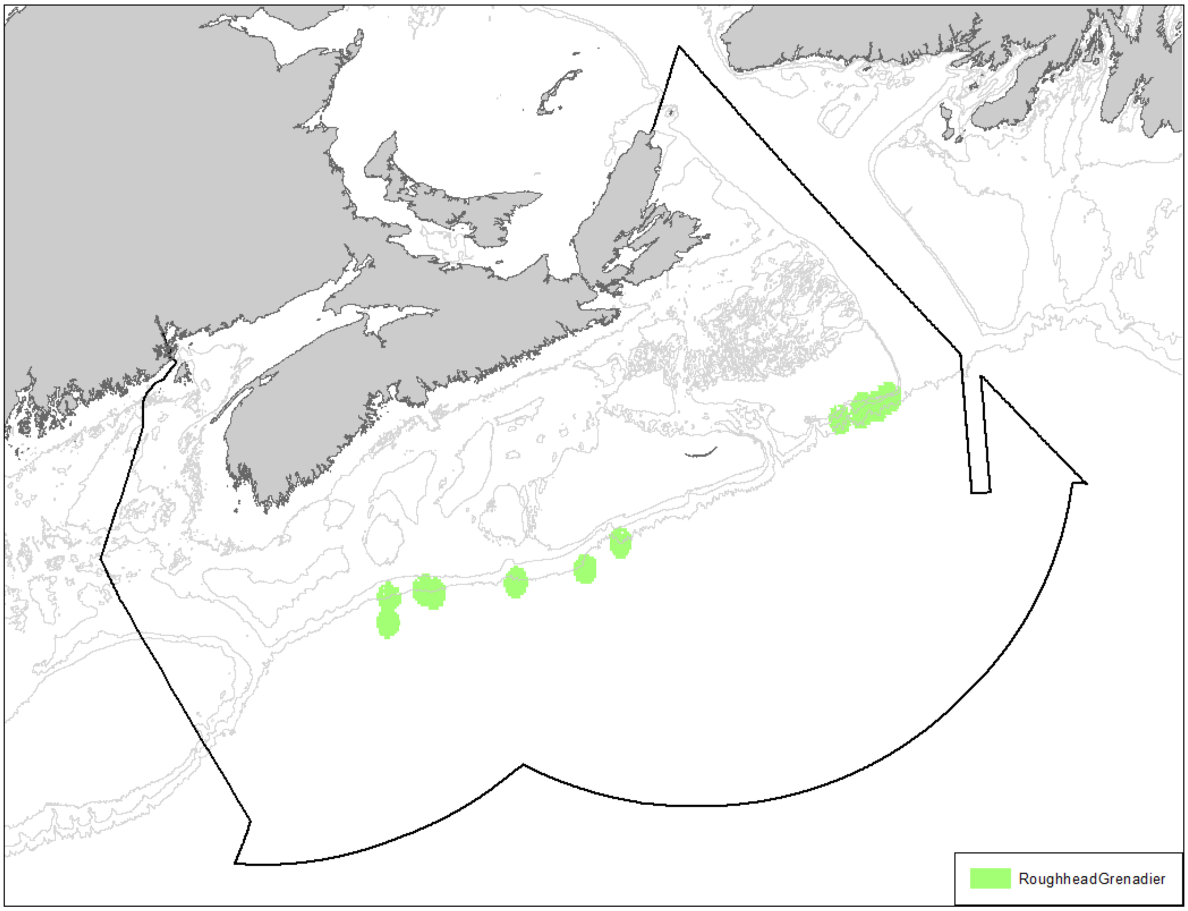

Figure 56. Important habitat for Roughhead Grenadier (*Macrourus berglax*) in the Scotian Shelf Bioregion.

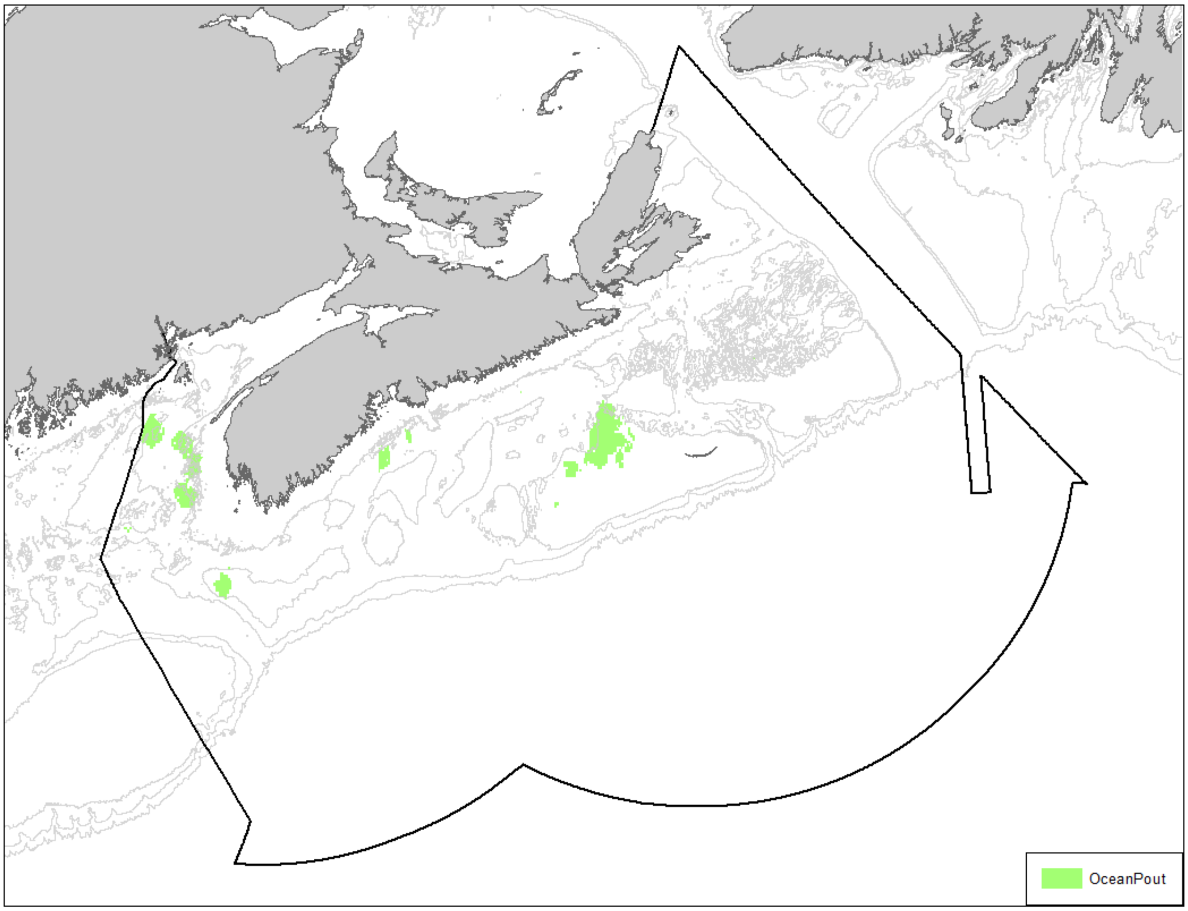

Figure 57. Important habitat for Ocean Pout (*Zoarces americanus*) in the Scotian Shelf Bioregion.

2.3 ECOLOGICALLY AND BIOLOGICALLY SIGNIFICANT AREAS

Ecologically and Biologically Significant Areas (EBSAs) were identified for the offshore Scotian Shelf by a DFO Science process (King et al. 2016). This process built on previous work by Doherty and Horsman (2007) and was informed by both data and expert opinion. Many of the fine-filter conservation priority data layers presented in this report were used by King et al. (2016) to identify and refine EBSAs in the offshore component of the bioregion. This is the first of two ways EBSAs were considered in the MPA network design process. The second way was to simply overlay the EBSAs with the results of the data-driven network design analysis to ensure no important areas were missed and ultimately inform the selection and delineation of proposed network sites.

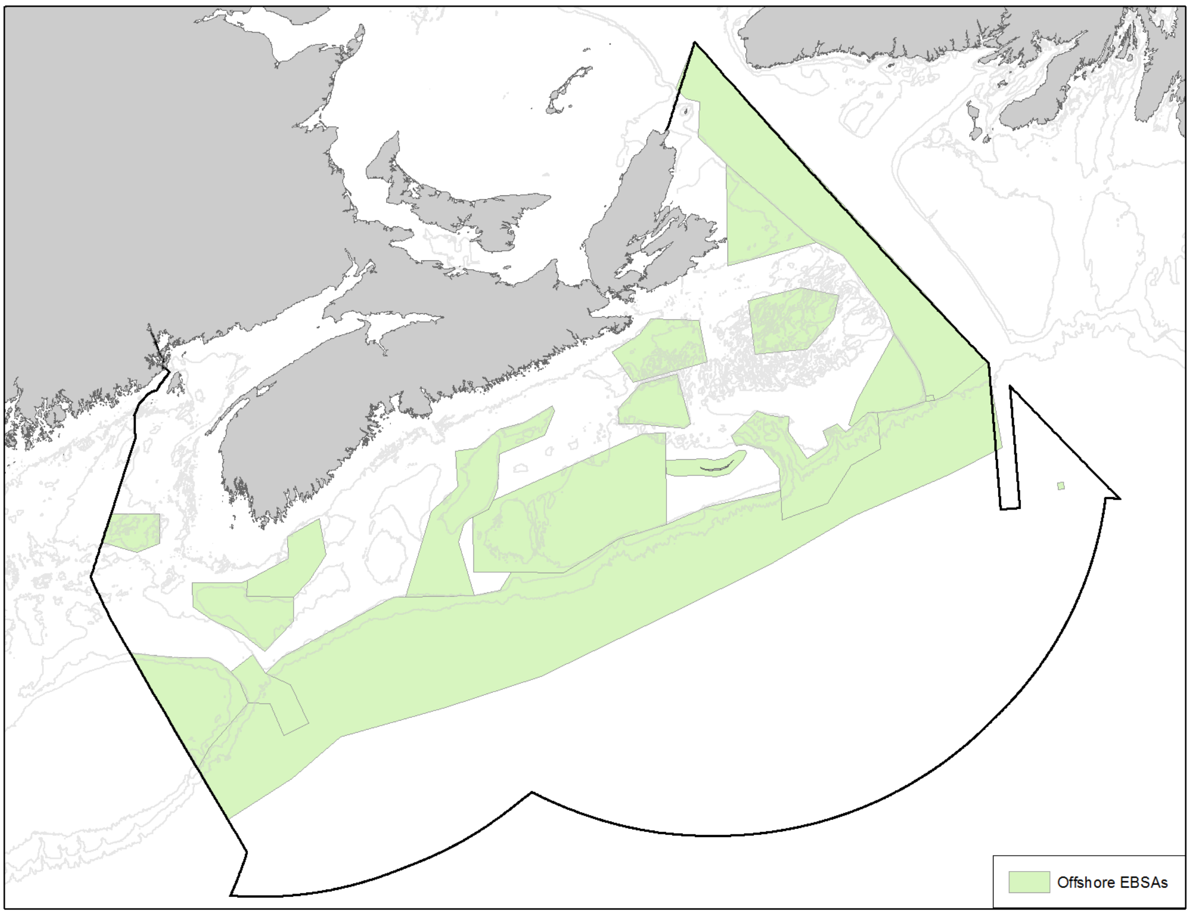

Figure 58. Offshore Ecologically and Biologically Significant Areas on the Scotian Shelf. (King et al. 2016).

3.0 HUMAN USE DATA INPUTS

In an effort to develop an MPA network design that reflects a balance between conservation and socioeconomics, available spatial information on commercial fisheries, oil and gas exploration and development, and shipping was considered in the design process. The intent is to develop a network design that meets all ecological targets with the lowest potential socioeconomic impacts. To do this, important areas for fishing, oil and gas and shipping were identified and, wherever possible, avoided when identifying potential MPA network configurations.

3.1 FISHERIES DATA

Logbook data from DFO's Policy and Economics Branch (Commercial Data Division) were used as fisheries data inputs in the MPA network design process. Landings data for 2005-2014 were summed on a two-minute grid, and split into fisheries management units where applicable. See Butler and Coffen-Smout (2017) for more details on mapping fisheries landings. Landings maps for the fisheries considered in this analysis are shown below in Figure 59 – Figure 77.[6]

Note that any grid cells with values less than 0.5 kg were excluded from the maps. Blank log records in the Maritimes Region's MARFIS database are assigned a value of 0.001 kg by DFO's Commercial Data Division to avoid calculation errors that would result from zero values. As such, these values do not significantly affect the data aggregation, except where a single grid cell has a very low binned weight value resulting in spurious map symbolization. Therefore, all grid cells with a total binned weight of < 0.5 kg were excluded from the maps (i.e., the smallest approximate weight of a single fish).

[6] Landings maps for several fisheries (offshore clam, offshore lobster, sea cucumber, and fixed gear shrimp) were considered for this analysis, but cannot be shown due to privacy considerations.

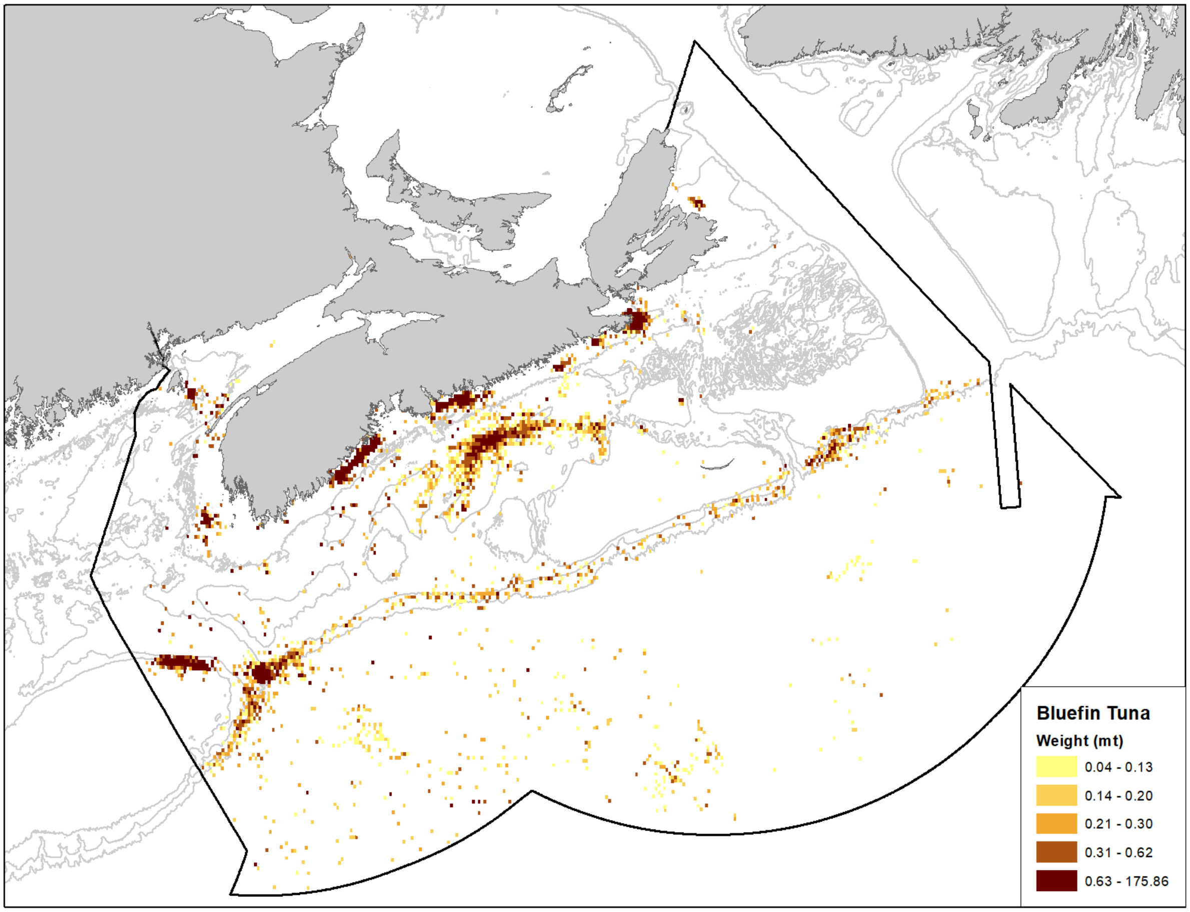

Figure 59. Bluefin tuna landings (metric tonnes) for the Scotian Shelf bioregion for 2005-2014. Grid cells with very low landed weights (< 0.5 kg / 0.0005 mt) are not shown.

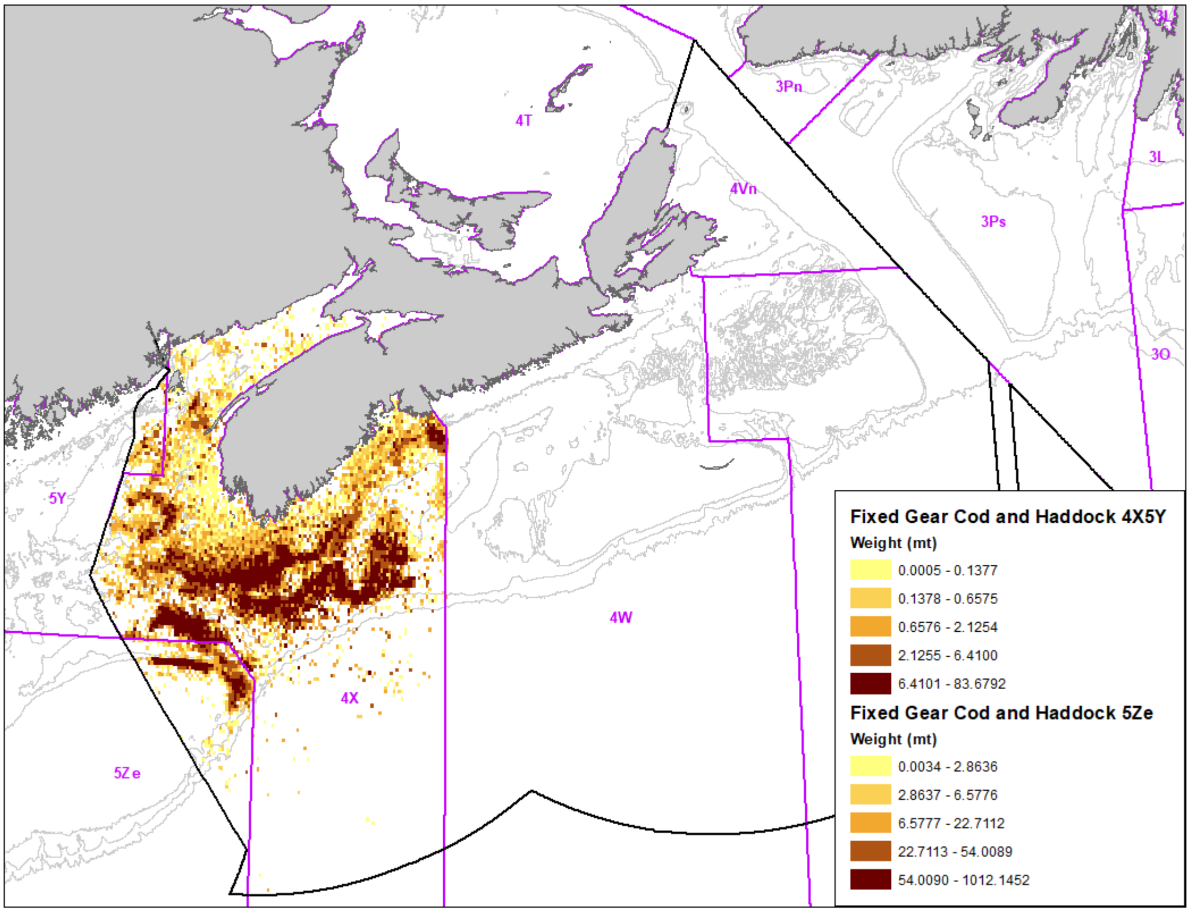

Figure 60. Fixed Gear Cod and Haddock landings (metric tonnes) for NAFO units 4X5Y and 5Ze for 2005-2014.

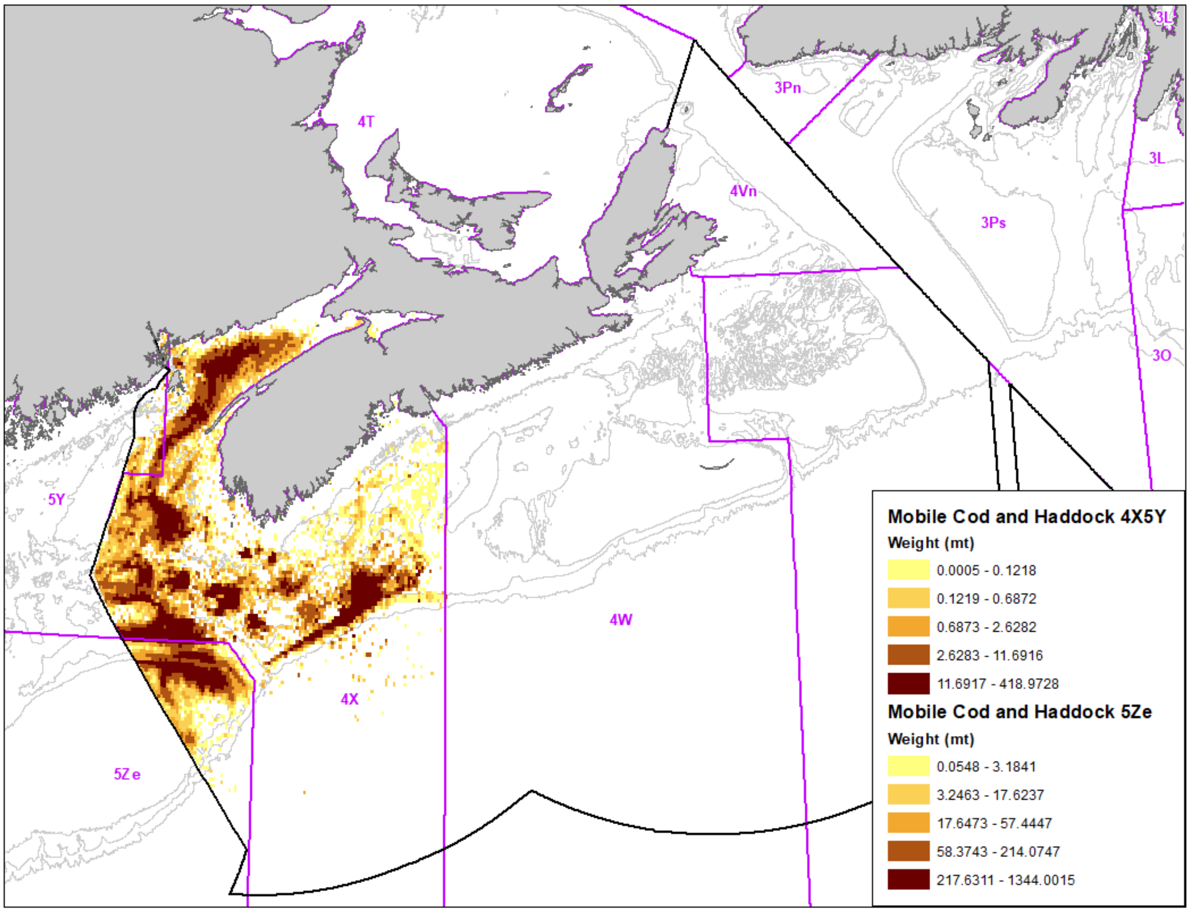

Figure 61. Mobile Gear Cod and Haddock landings (metric tonnes) for NAFO units 4X5Y and 5Ze for 2005-2014.

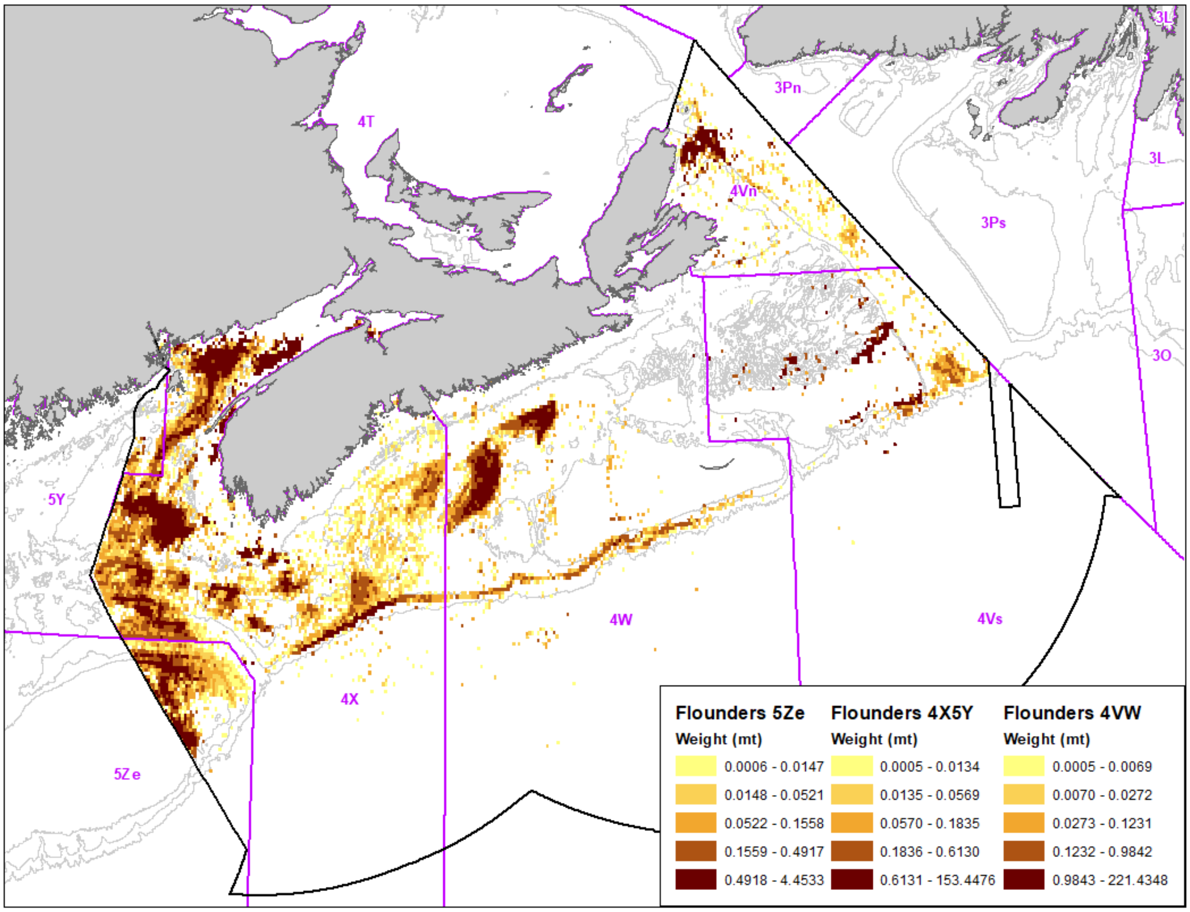

Figure 62. Flounder landings (metric tonnes) for NAFO units 4VW, 4X5Y and 5Ze for 2005-2014.

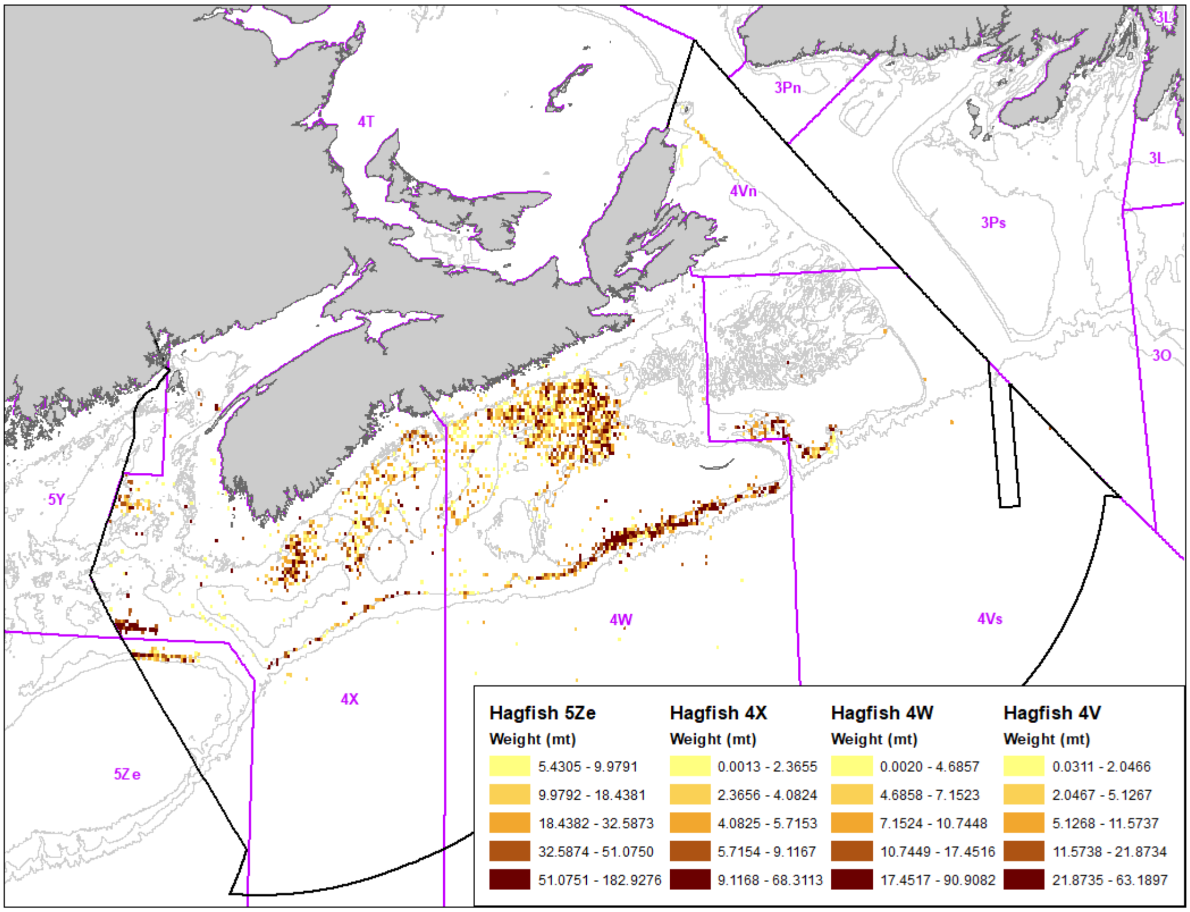

Figure 63. Hagfish landings (metric tonnes) for NAFO units 4V, 4W, 4X and 5Ze for 2005-2014.

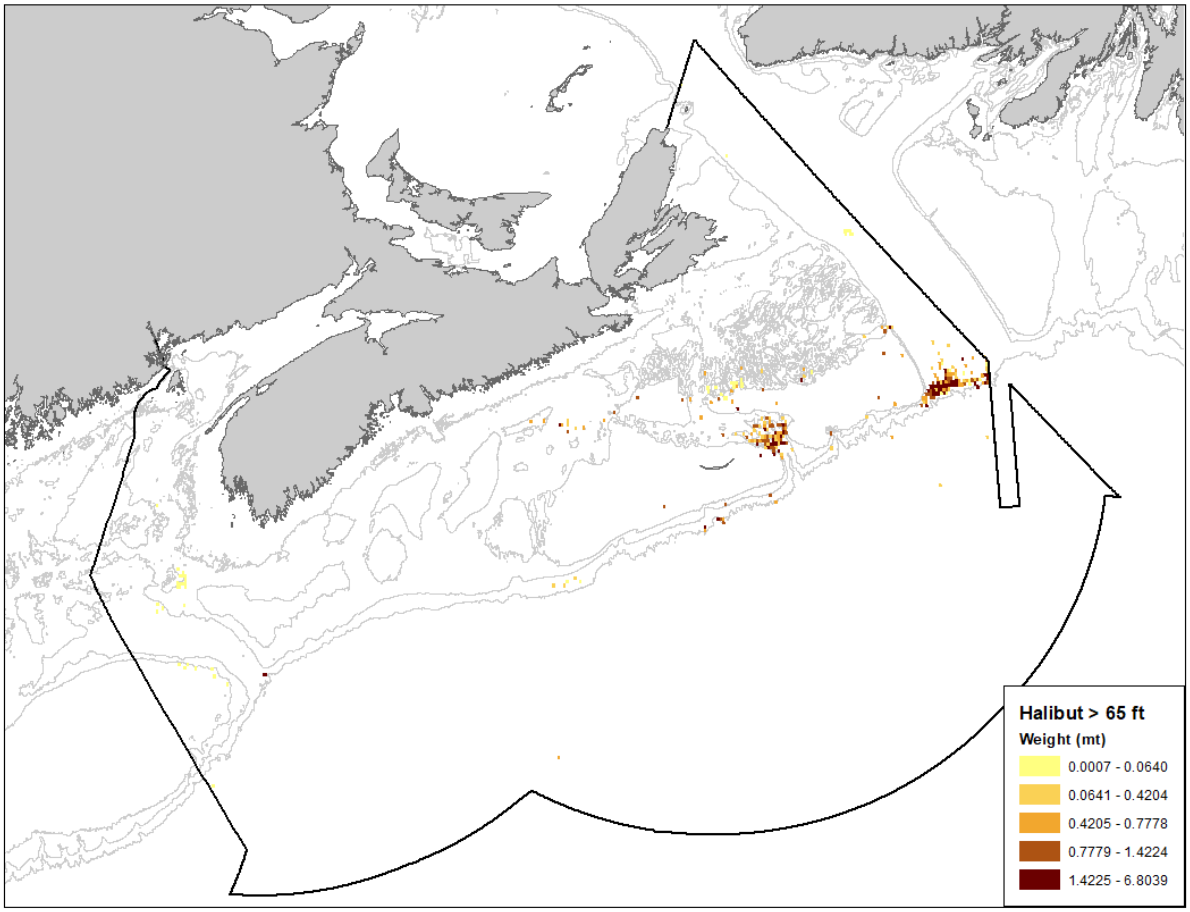

Figure 64. Halibut landings (metric tonnes) for vessels greater than 65 ft (2005-2014).

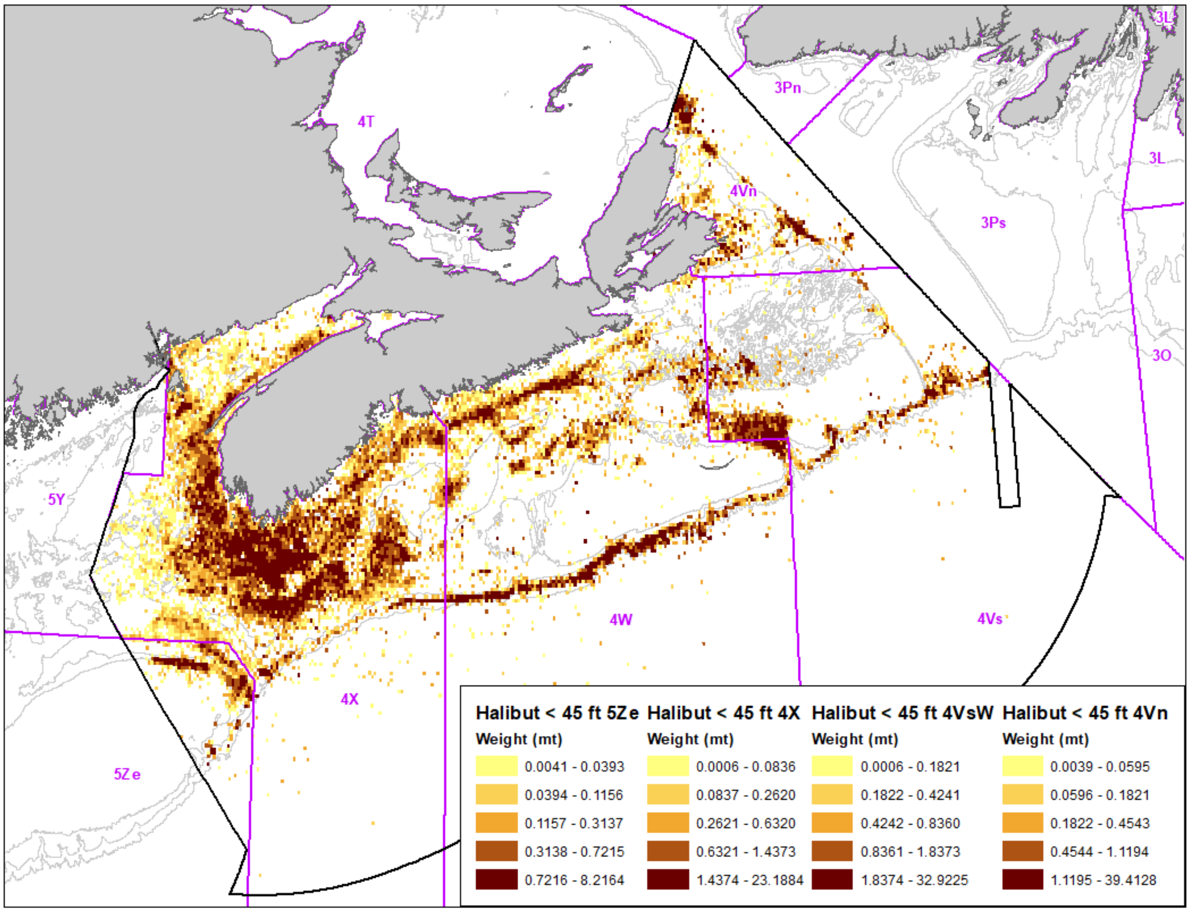

Figure 65. Halibut landings (metric tonnes) for vessels less than 45 ft, for NAFO units 4Vn, 4VsW, 4X and 5Ze (2005-2014).

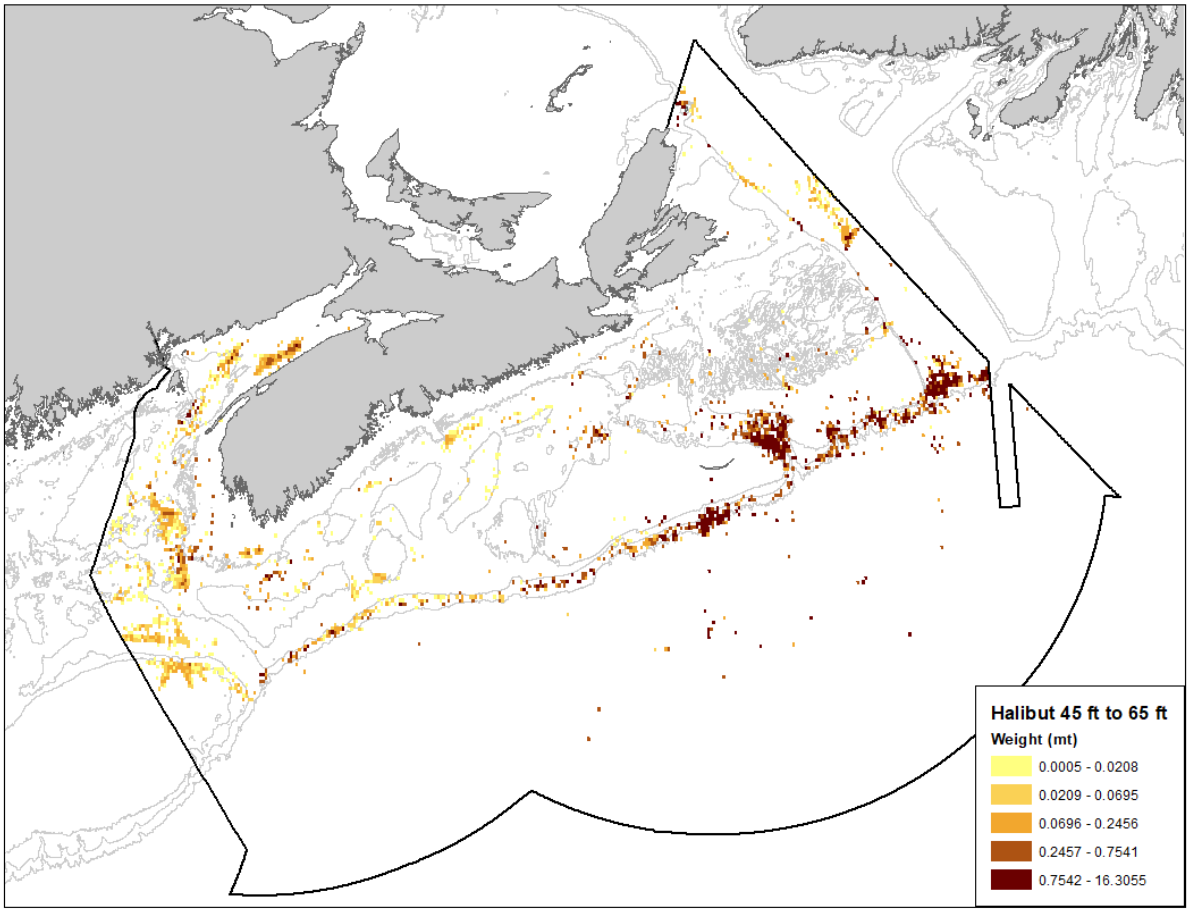

Figure 66. Halibut landings (metric tonnes) for vessels 45 to 65 ft, for the Scotian Shelf Bioregion (2005-2014).

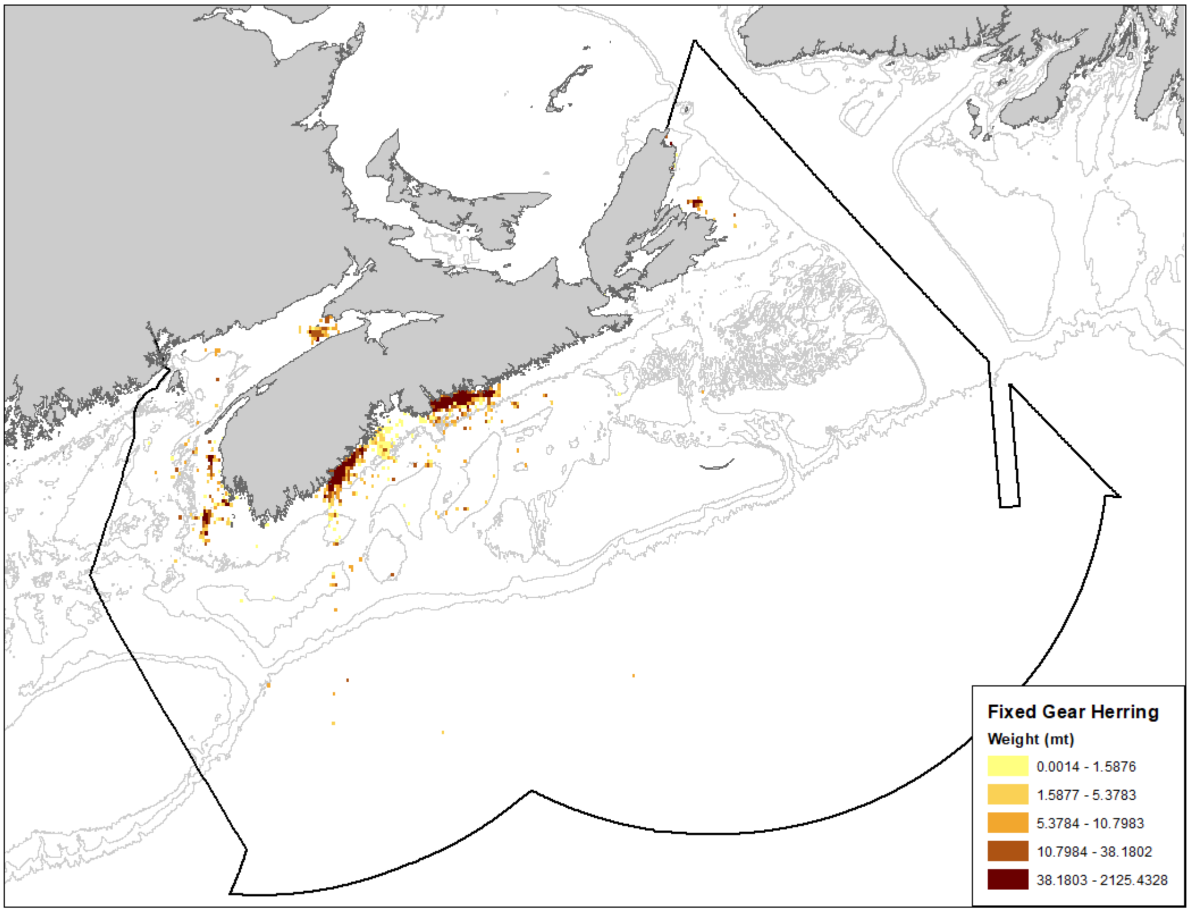

Figure 67. Fixed Gear Herring landings (metric tonnes) for the Scotian Shelf bioregion (2005-2014).

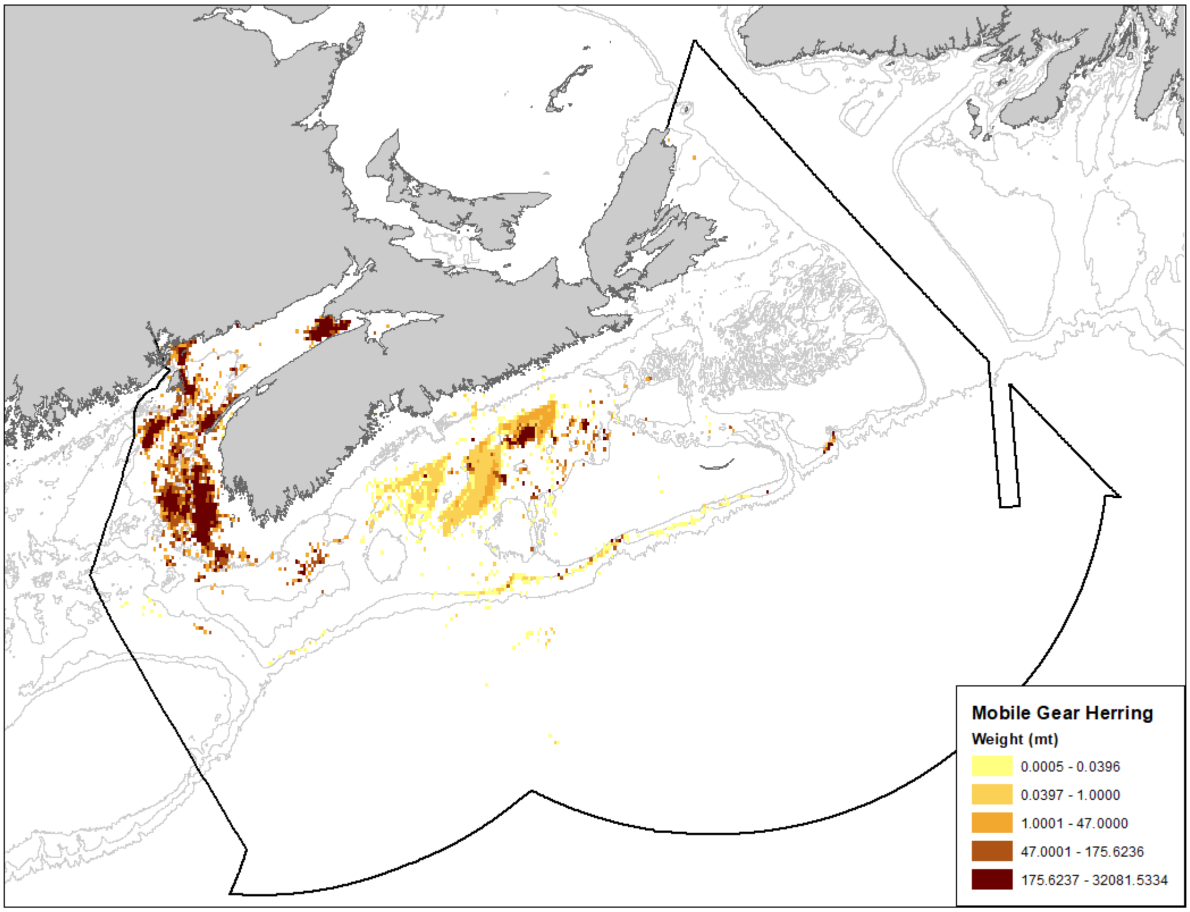

Figure 68. Mobile Gear Herring landings (metric tonnes) for the Scotian Shelf bioregion (2005-2014).

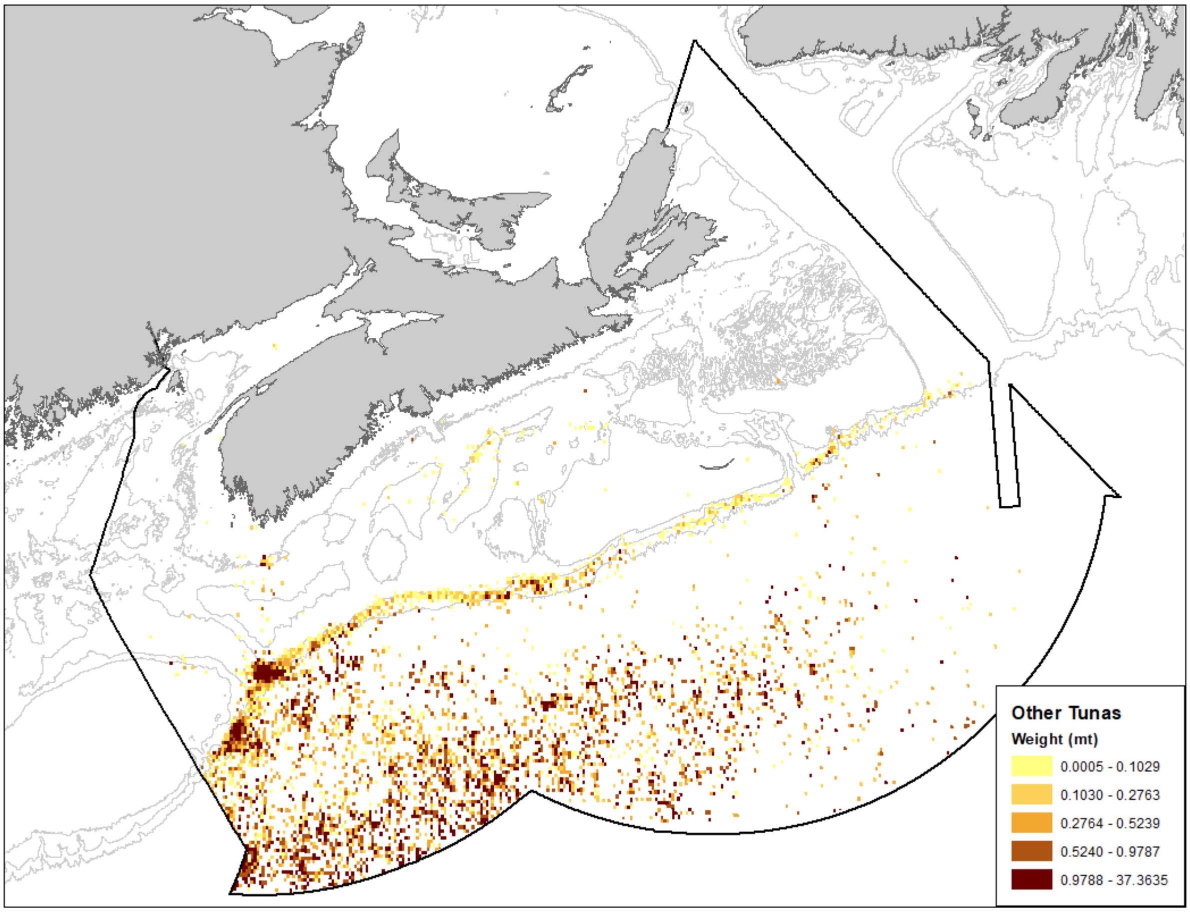

Figure 69. Other Tuna landings (metric tonnes) for the Scotian Shelf bioregion (2005-2014).

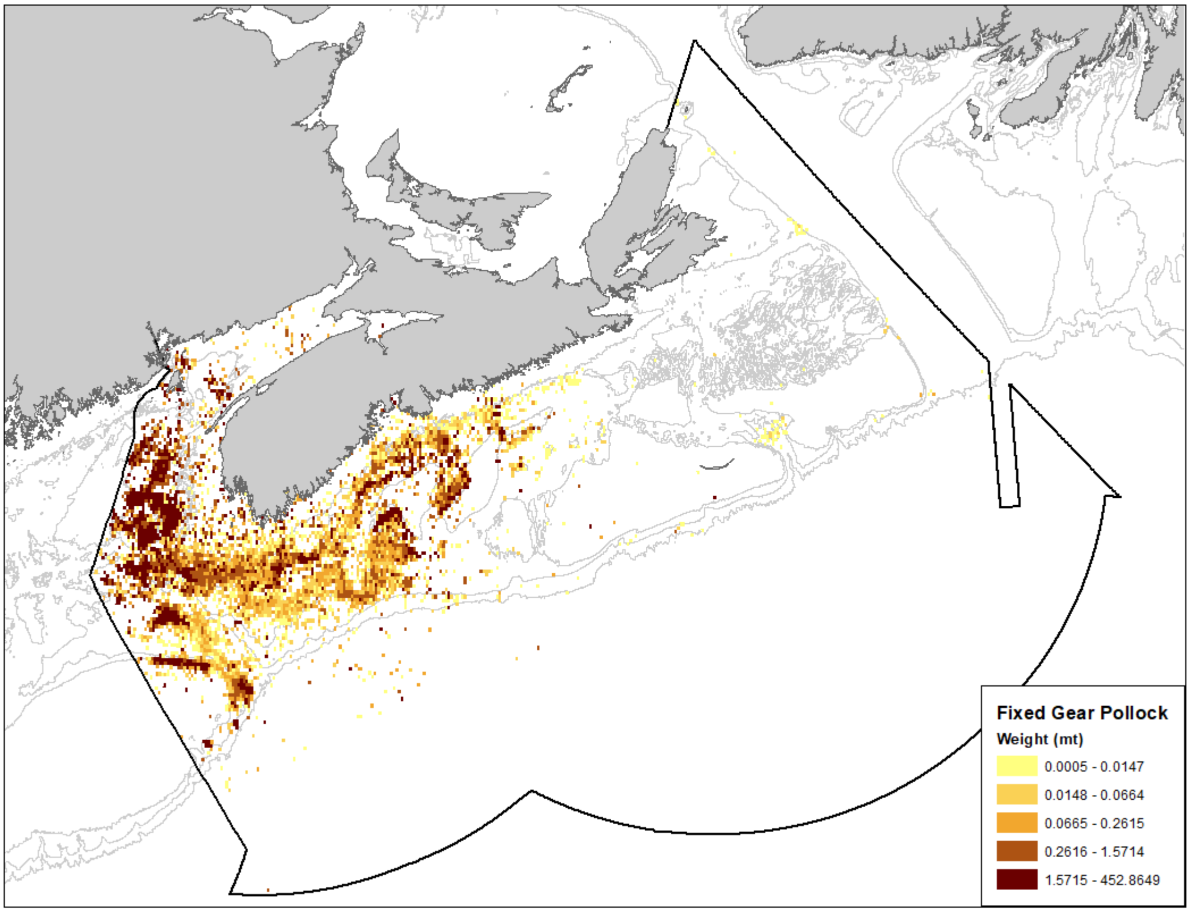

Figure 70. Fixed Gear Pollock landings (metric tonnes) for the Scotian Shelf bioregion (2005-2014).

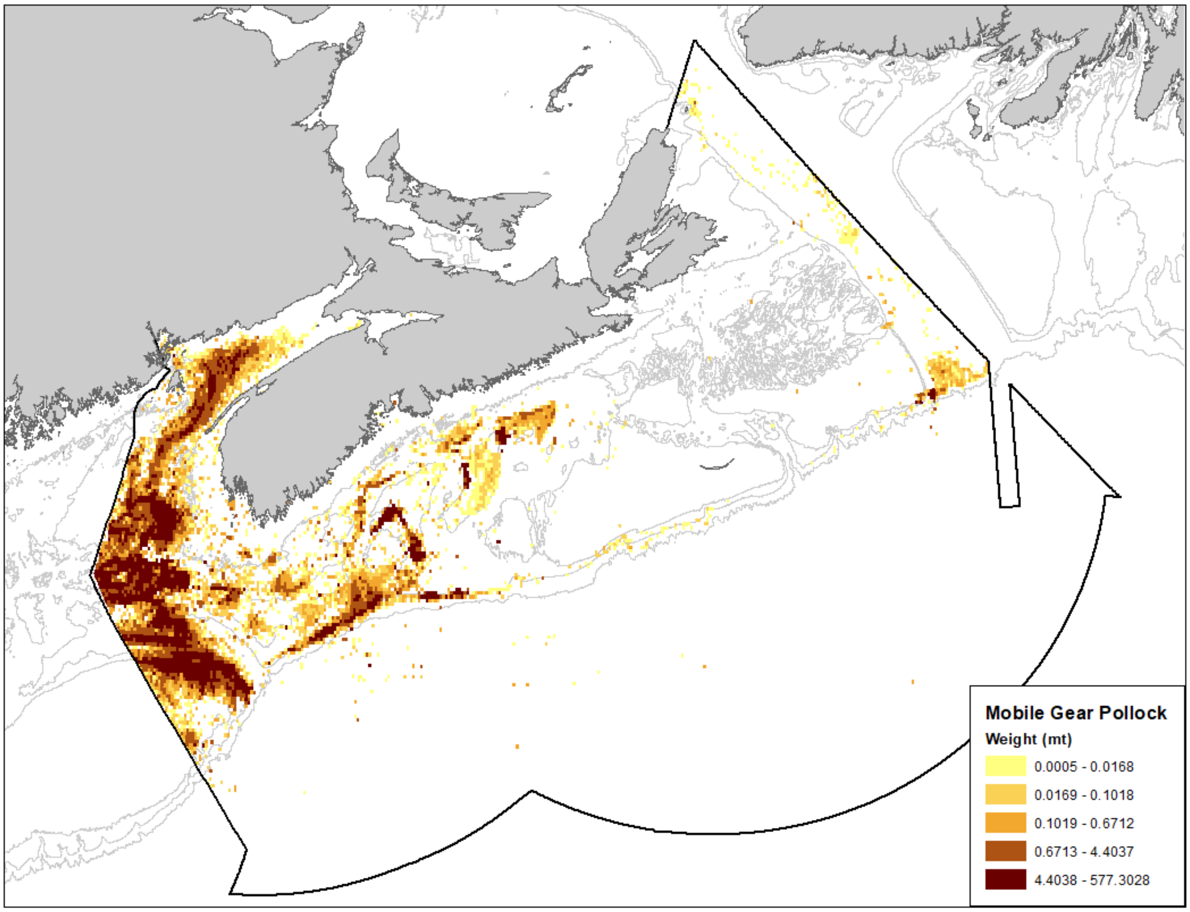

Figure 71. Mobile Gear Pollock landings (metric tonnes) for the Scotian Shelf bioregion (2005-2014).

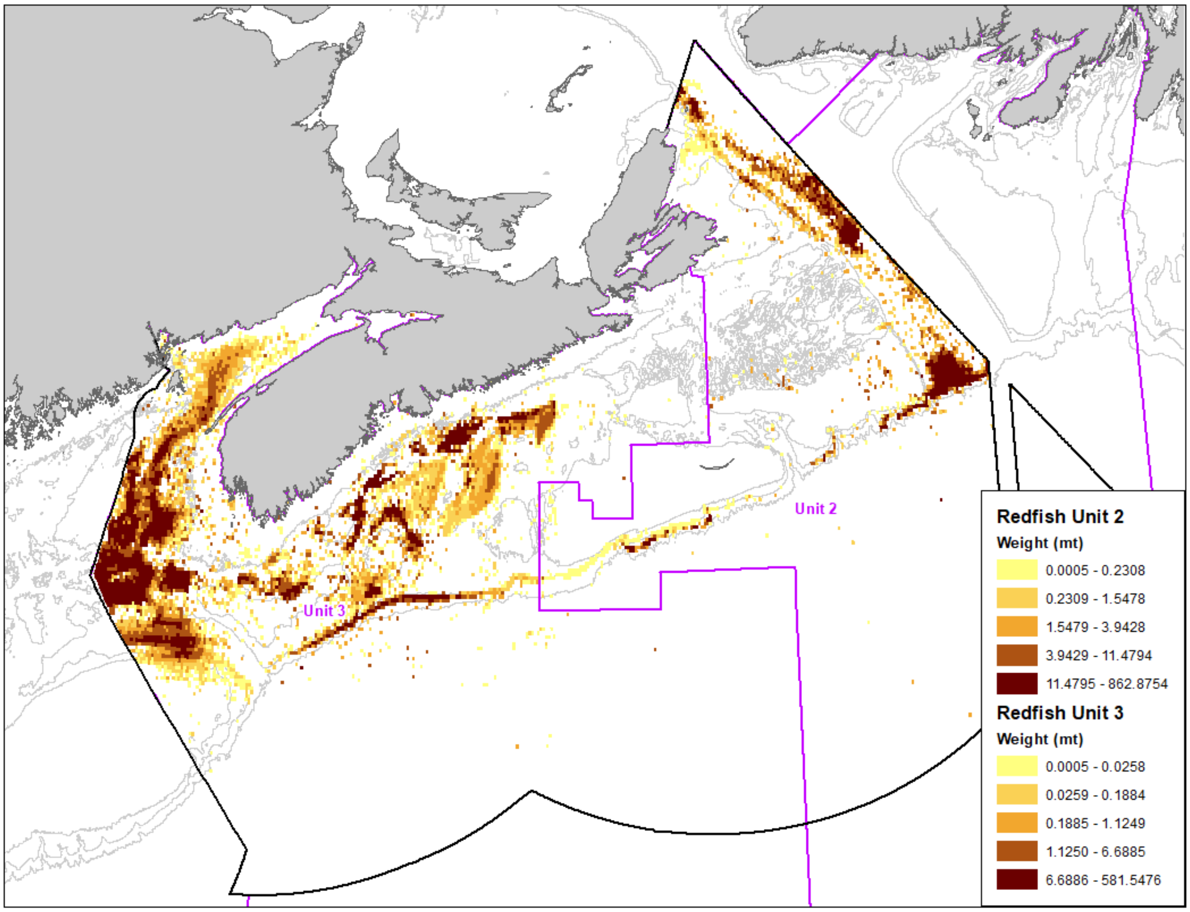

Figure 72. Redfish landings (metric tonnes) for Units 2 and 3 (2005-2014).

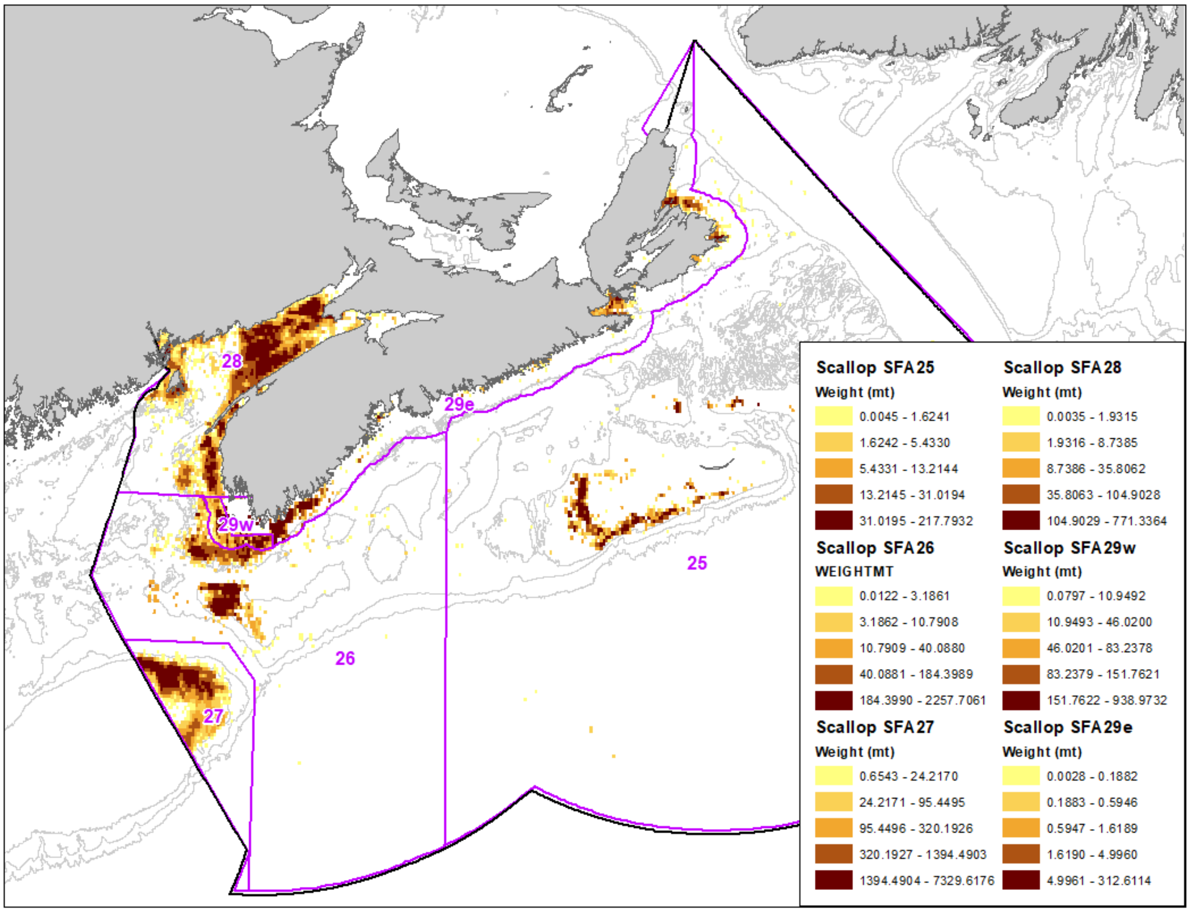

Figure 73. Scallop landings (metric tonnes) for Scallop Fishing Areas 25, 26, 27, 28, 29 East and 29 West (2005-2014).

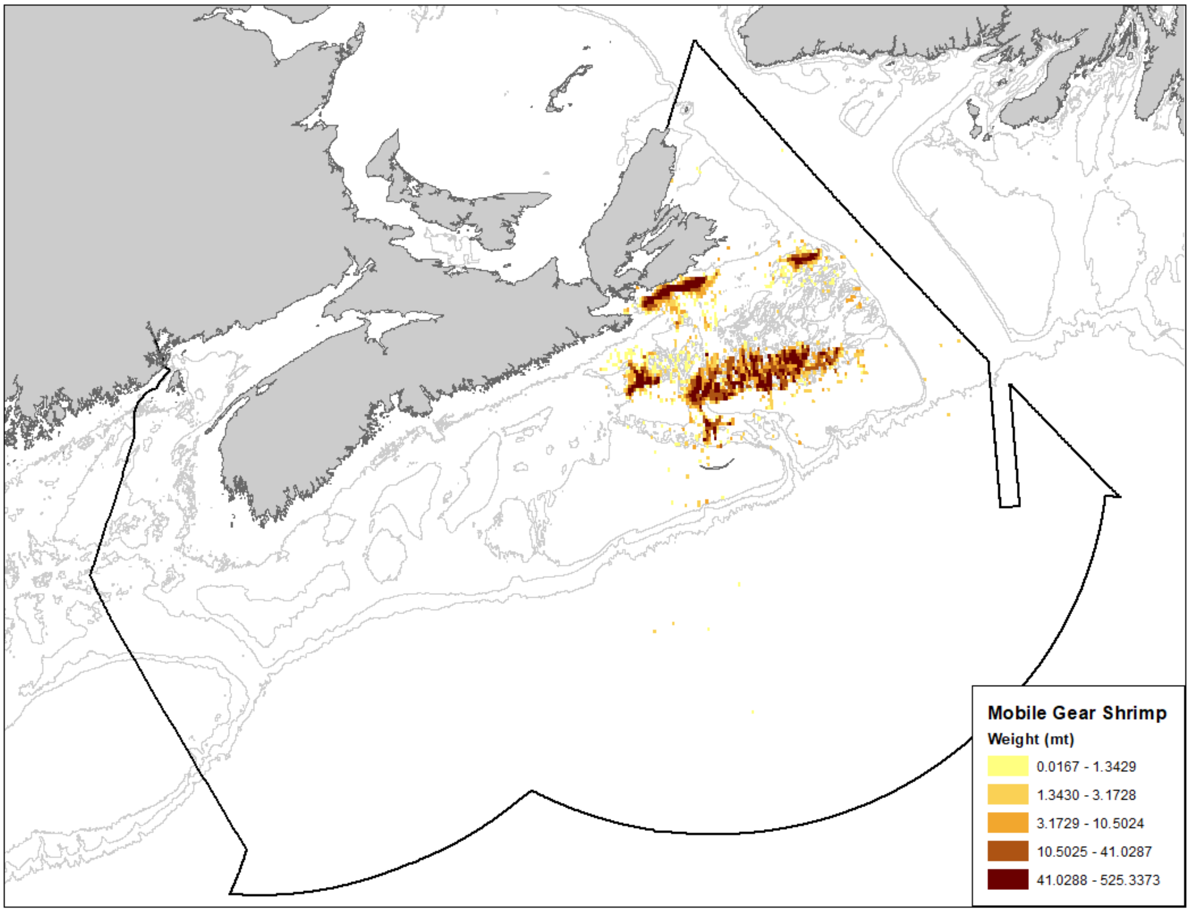

Figure 74. Mobile Gear Shrimp landings (metric tonnes) for the Scotian Shelf bioregion (2005-2014).

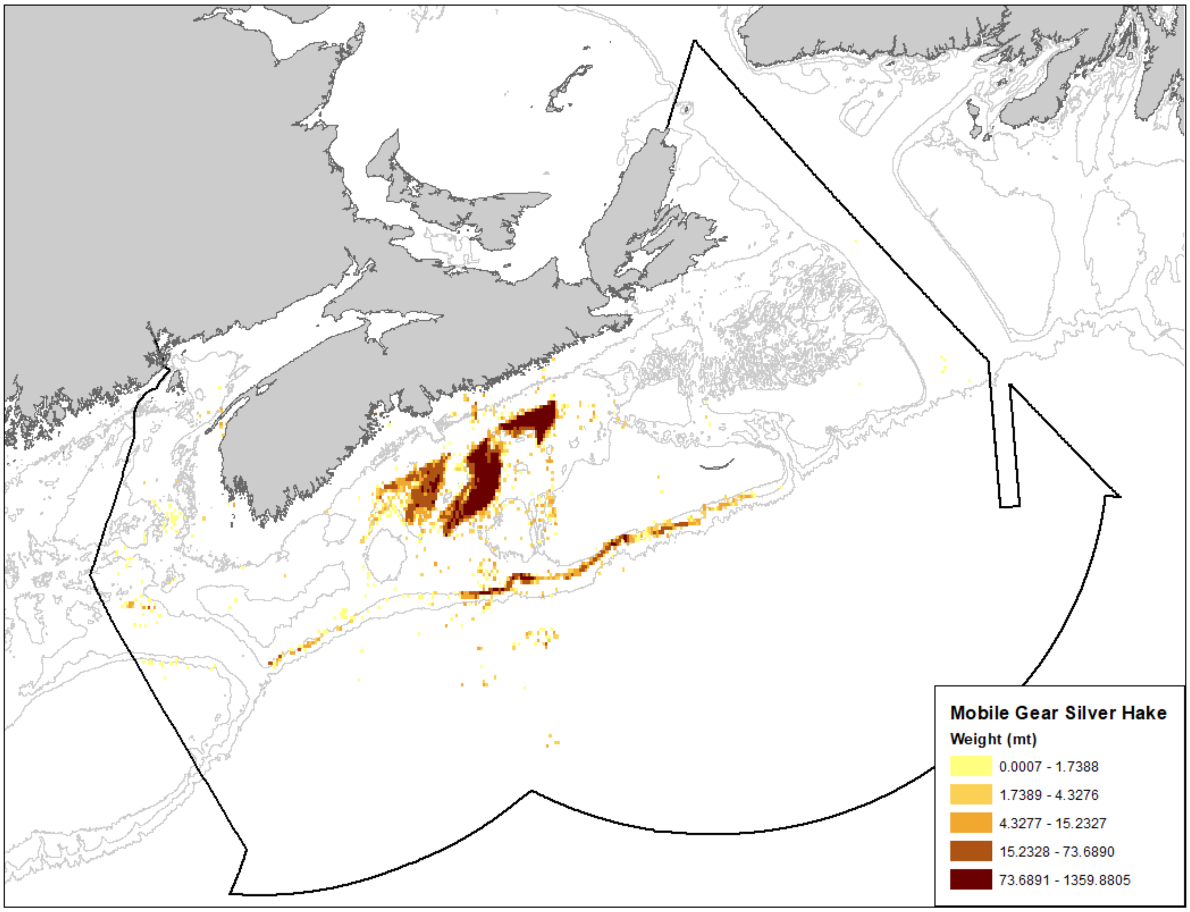

Figure 75. Mobile Gear Silver Hake landings (metric tonnes) for the Scotian Shelf bioregion (2005-2014).

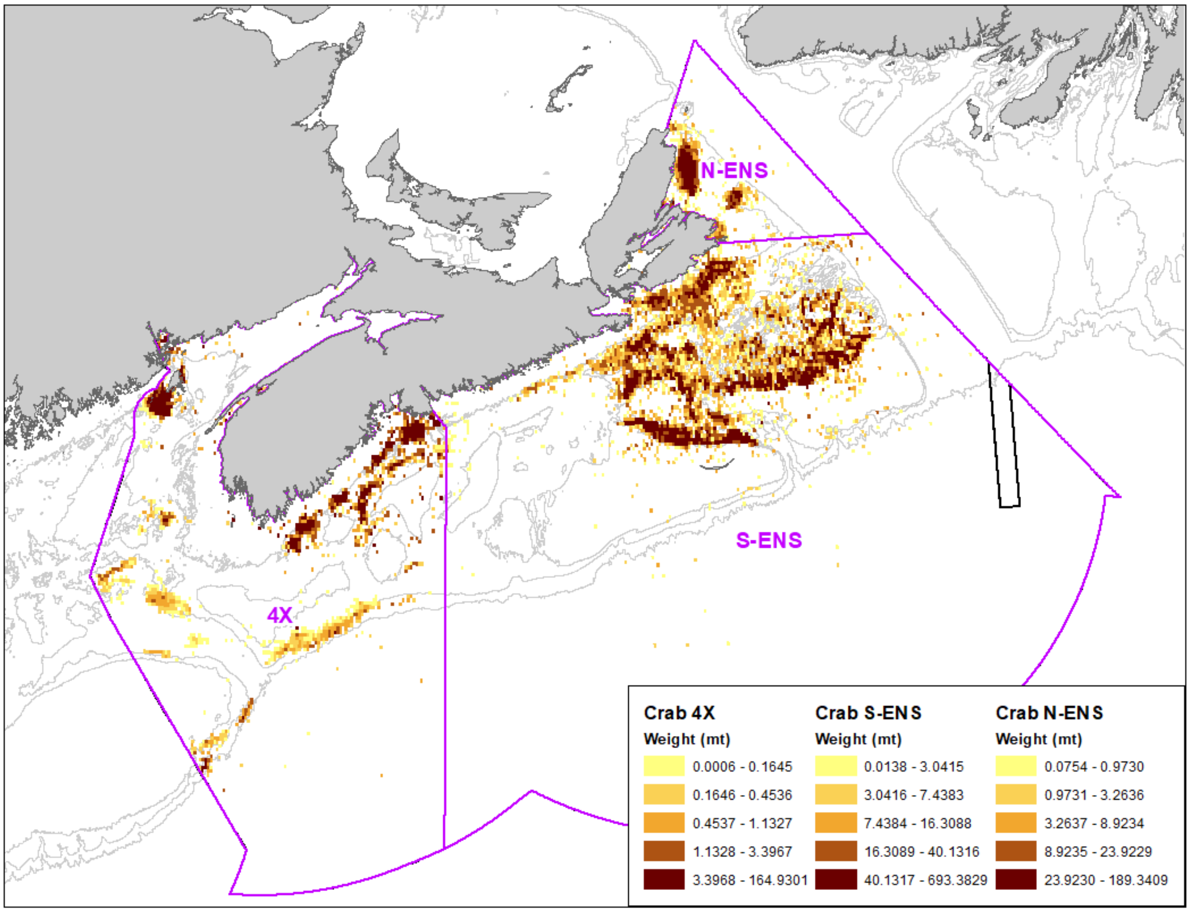

Figure 76. Crab landings (metric tonnes) for Crab Management Areas North-East Nova Scotia, South-East Nova Scotia, and 4X (2005-2014).

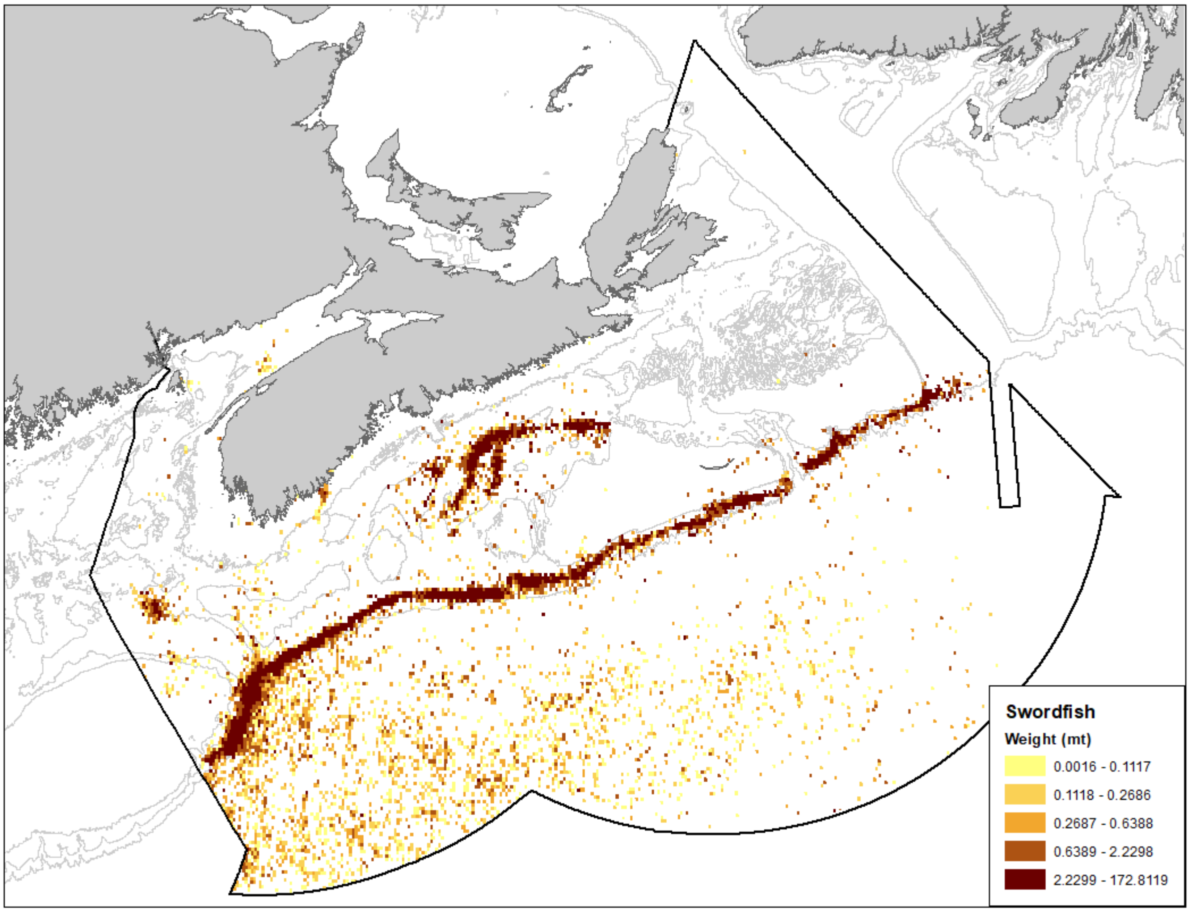

Figure 77. Swordfish landings (metric tonnes) for the Scotian Shelf bioregion (2005-2014).

3.2 OIL AND GAS

Oil and gas licenses on the Scotian Shelf were overlaid with the results of the data-driven network design analysis to inform the selection and delineation of proposed network sites. Exploration Licenses (ELs), Significant Discovery Licenses (SDLs), and Production Licenses (PLs) were considered. They are shown in Figure 78. The oil and gas moratorium area on Georges Bank is shown in Figure 79. It is important to note that oil and gas licenses, particularly ELs, expire after nine years so some of the maps presented in this section, which were based on 2017 information, will quickly become dated. The Canada-Nova Scotian Offshore Petroleum Board maintains up-to-date oil and gas license maps for the Scotian Shelf.[7]

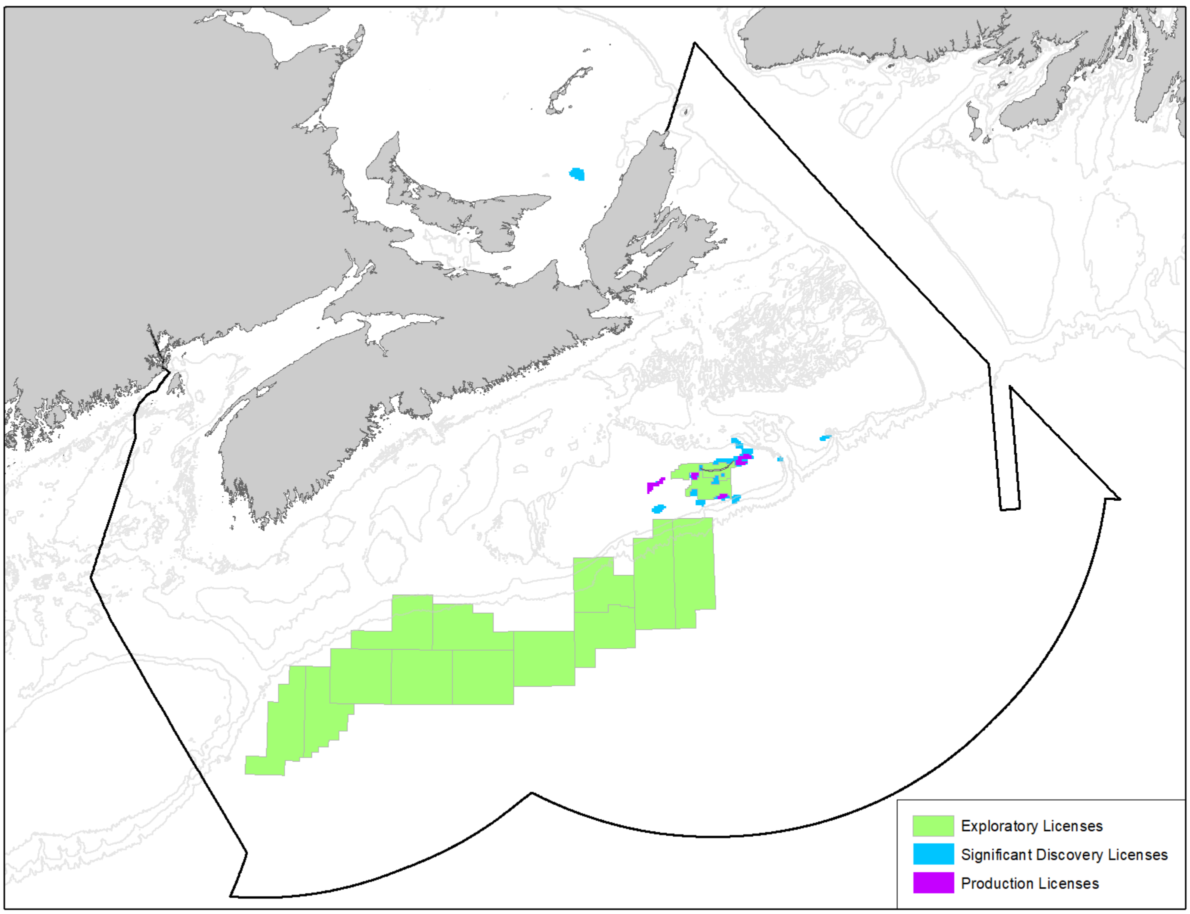

Figure 78. Oil and gas Exploration Licenses, Significant Discovery Licenses, and Production Licenses on the Scotian Shelf (as of 2017).

[7] https://www.cnsopb.ns.ca/.

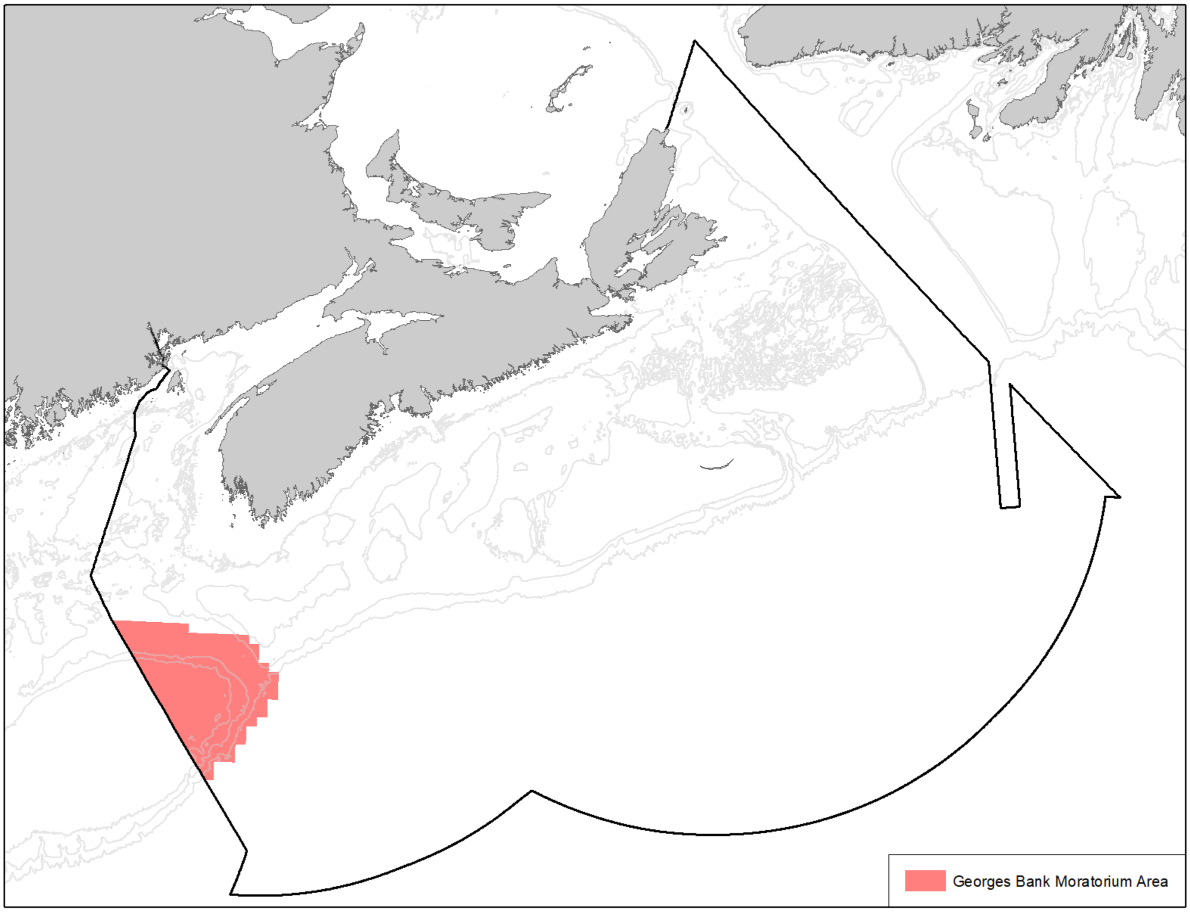

Figure 79. Oil and gas moratorium area on Georges Bank.

3.3 SHIPPING

Shipping traffic data on the Scotian Shelf were overlaid with the results of the data-driven network design analysis to inform the selection and delineation of proposed network sites. Areas of high shipping traffic were identified based on an analysis of shipping activity in the region by Koropatnick et al. (2012), using Long Range Identification and Tracking (LRIT) data. LRIT is a satellite based system that records geographic position information from any vessels subject to the Safety of Life at Sea (SOLAS) Convention, on a 6 hour reporting interval. Vessels subject to the SOLAS Convention include mobile offshore drilling rigs, passenger ships, and cargo ships > 300 tonnage on international trips (International Convention for the Safety of Life at Sea, 1974).

Koropatnick et al. (2012) used 13 months of LRIT data (February 2010 – February 2011) in their analysis, which included any Canadian flagged vessels worldwide, and any foreign vessels bound for a Canadian port. The data window for the analysis was limited to Atlantic Canada. Koropatnick et al. (2012) used the reported points to create vessel track lines, and then overlaid those tracks on a 2 minute grid to count the number of vessels within a grid cell, shown below in Figure 80. For more details on the analysis, see Koropatnick et al (2012).

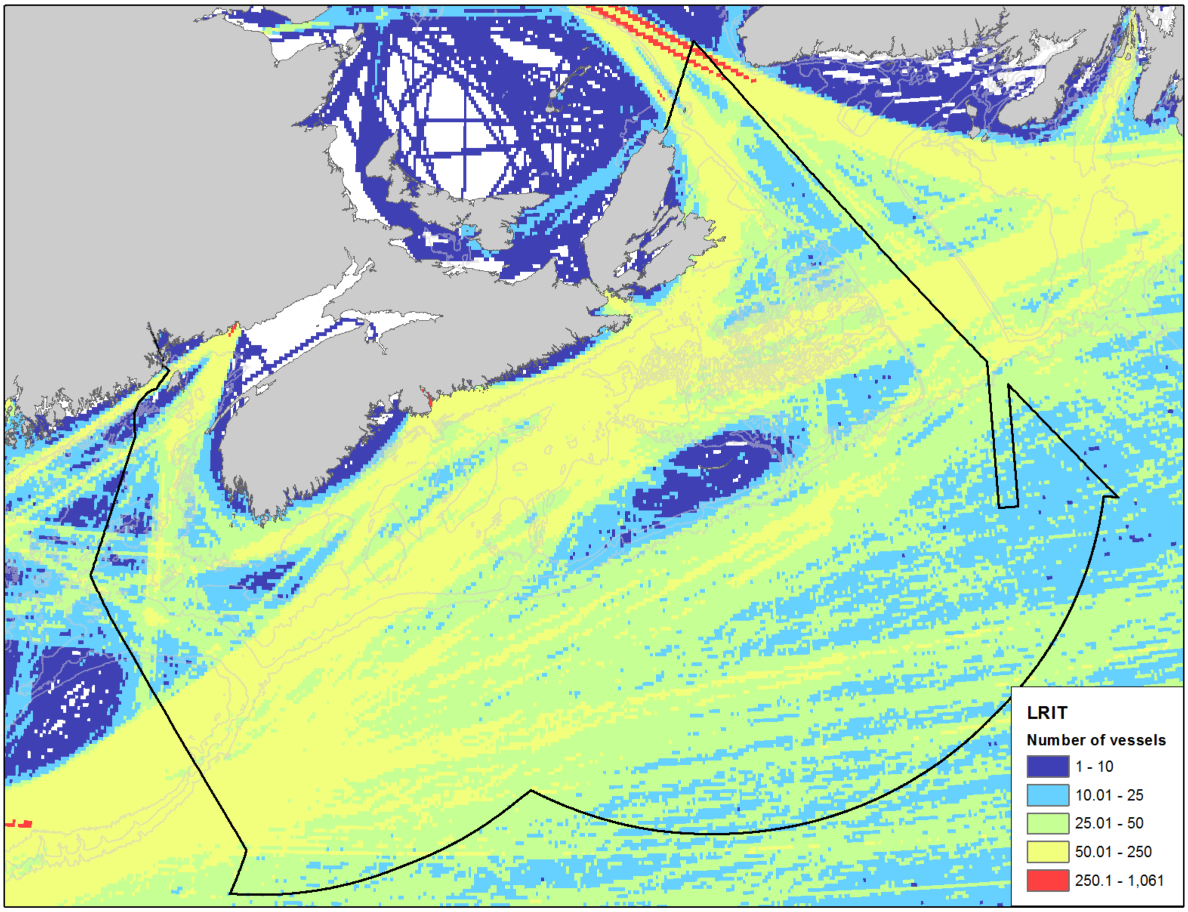

Figure 80. Vessel counts on the Scotian Shelf using Long Range Identification and Tracking data from Koropatnick et al. (2012).

4.0 UNCERTAINTY

There are a number of sources of uncertainty regarding the data layers described in this report. As stated earlier, these layers were current as of 2017 so some of them may have been updated since then, and there may be newer layers available for inclusion in future MPA network design analyses.

For the ecological data layers, some of the functional group layers can be influenced by one species if the biomass of that species is comparatively high (see Tables 2 and 3 in the Appendix for a list of fish and invertebrate species within each functional group and percent biomass they represent). In addition, some of the ecological data layers used (e.g. cusk and some of the biogenic habitat layers) are species distribution models, so they represent the predicted occurrence of that species, rather than biomass, and therefore have more uncertainty associated with them. Finally, the icthyoplankton genus richness layer is based on older survey data (1978 – 1982), so it may not represent present conditions.

For the human use data inputs, the fisheries landings layers have some uncertainty associated with them due to missing geographic coordinates from logbook records (see Butler and Coffen-Smout [2017] for the percentage of logbook entries with missing coordinates for each fishery). In addition, oil and gas licenses have changed since 2017. Finally, the shipping density layer used here was based on one year of data from 2010-2011, and the vessel track lines were inferred based on 6 hour reporting interval, so there is some uncertainty associated with that layer.

There are also several important gaps in the available data that should be acknowledged. For example, reliable distribution data do not exist for most pelagic species, including cetaceans, turtles and fishes. Another large gap in the MPA network design analysis is indigenous knowledge. DFO is working with First Nations in the bioregion to compile indigenous knowledge to inform network design and broader oceans planning and management. Future MPA network design analyses and implementation will incorporate this important information source.

Overall, while there are sources of uncertainty with the layers described in this report, it is important to note that designing and implementing a network of MPAs is an iterative process, and all of the information used should be updated whenever new information becomes available.

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APPENDIX

Table 2. List of fish species within each functional group, and the percent biomass of the group they represent (modified from Bundy et al. 2017).

Group	Name	Latin name	% of group biomass
Fish: Piscivore, Benthic, Small + Medium			
	Silver hake	*Merluccius bilinearis*	53.3
	Yellowtail flounder	*Limanda ferruginea*	29.2
	Longhorn sculpin	*Myoxocephalus octodecemspinosus*	10.9
	Sea raven	*Hemitripterus americanus*	5.9
	Off-shore hake	*Merluccius albidus*	0.6
	Brill/windowpane	*Scophthalmus aquosus*	0.1
	Greenland cod	*Gadus ogac*	< 0.1
	Longnose greeneye	*Parasudis truculenta*	< 0.1
Fish: Piscivore, Benthic, Large			
	Spiny dogfish	*Squalus acanthias*	34.4
	Cod (Atlantic)	*Gadus morhua*	27.0
	Pollock	*Pollachius virens*	17.0
	White hake	*Urophycis tenuis*	7.4
	American plaice	*Hippoglossoides platessoides*	7.3
	Winter skate	*Leucoraja ocellata*	1.9
	Monkfish, goosefish, angler	*Lophius americanus*	1.6
	Halibut (Atlantic)	*Hippoglossus hippoglossus*	1.5
	Cusk	*Brosme brosme*	0.9
	Turbot, greenland halibut	*Reinhardtius hippoglossoides*	0.9
	Barndoor skate	*Dipturus laevis*	0.2
	Summer flounder	*Paralichthys dentatus*	< 0.1
	Atlantic torpedo	*Torpedo nobiliana*	< 0.1
	Amer. John dory	*Zenopsis ocellata*	< 0.1
Fish: Piscivore, Pelagic, Small + Medium			
	Boa dragonfish	*Stomias boa*	60.6
	White barracudina	*Notolepis rissoi kroyeri*	29.0
	Viperfish	*Chauliodus sloani*	9.1
	Rainbow smelt	*Smerus mordax mordax*	1.3
Fish: Benthivore, Benthic, Small			
	Moustache (mailed) sculpin	*Triglops murrayi*	52.3
	Atlantic spiny lumpsucker	*Eumicrotremus spinosus*	11.7
	Atlantic sea poacher	*Leptagonus decagonus*	9.3
	Alligatorfish	*Aspidophoroides monopterygius*	7.2
	Gulf stream flounder	*Citharichthys arctifrons*	5.5
	Polar sculpin	*Cottunculus microps*	2.9

Group	Name	Latin name	% of group biomass
	Arctic staghorn sculpin	*Gymnocanthus tricuspis*	2.5
	Hookear sculpin, Atlantic	*Artediellus atlanticus*	1.8
	Wolf eelpout	*Lycenchelys verrilli*	1.7
	Arctic hookear sculpin	*Artediellus uncinatus*	1.2
	Atlantic seasnail	*Liparis atlanticus*	0.9
	4-Line snake blenny	*Eumesogrammus praecisus*	0.7
	Grubby (little)	*Myoxocephalus aeneus*	0.6
	Spatulate sculpin	*Icelus spatula*	0.5
	Armored sea robin	*Peristedion miniatum*	0.3
	Spotfin dragonet	*Callionymus agassizi*	0.3
	Seasnail, gelatinous	*Liparis fabricii*	0.2
	Rock gunnel (eel)	*Pholis gunnellus*	0.2
	Twohorn sculpin	*Icelus bicornis*	0.1
	Arctic sculpin	*Myoxocephalus scorpioides*	0.1
	Sea tadpole	*Careproctus reinhardi*	0.1
	Tongue fish	*Symphurus pterospilotus*	0.1
	Arctic alligatorfish	*Uleina olrikii*	< 0.1
	Inquiline seasnail	*Liparis inquilinus*	< 0.1
	Common wolf eel	*Lycenchelys paxillus*	< 0.1
Fish: Benthivore, Benthic, Medium			
	Winter flounder	*Pseudopleuronectes americanus*	43.1
	Witch flounder	*Glyptocephalus cynoglossus*	35.6
	Little skate	*Leucoraja erinacea*	8.3
	Smooth skate	*Malacoraja senta*	5.8
	Rosefish (black belly)	*Helicolenus dactylopterus*	3.2
	Checker eelpout (vahl)	*Lycodes vahlii*	2.1
	Marlin-spike grenadier	*Nezumia bairdii*	0.7
	Fourbeard rockling	*Enchelyopus cimbrius*	0.2
	Cunner	*Tautogolabrus adspersus*	0.2
	Fourspot flounder	*Paralichthys oblongus*	0.2
	Snakeblenny	*Lumpenus lumpretaeformis*	0.2
	Tomcod (Atlantic)	*Microgadus tomcod*	0.1
	Shorthorn sculpin	*Myoxocephalus scorpius*	0.1
	Laval’s eelpout	*Lycodes lavalaei*	0.1
	Spotted hake	*Urophycis regia*	< 0.1
	Threebeard rockling	*Gaidropsarus ensis*	< 0.1
	Short-nose greeneye	*Chlorophthalmus agassizi*	< 0.1
	Pallid sculpin	*Cottunculus thompsoni*	< 0.1
	Roughnose grenadier	*Trachyrhynchus murrayi*	< 0.1
	Seasnail, dusky	*Liparis gibbus*	< 0.1
	Fish doctor	*Gymnelis viridis*	< 0.1
	Slender eelblenny	*Lumpenus fabricii*	< 0.1
	Atlantic batfish	*Dibranchus atlanticus*	< 0.1

Group	Name	Latin name	% of group biomass
Fish: Benthivore, Benthic, Large			
	Haddock	*Melanogrammus aeglefinus*	87.2
	Thorny skate	*Amblyraja radiata*	8.9
	Striped Atlantic wolffish	*Anarhichas lupus*	2.9
	Ocean pout (common)	*Zoarces americanus*	0.6
	Black dogfish	*Centroscyllium fabricii*	0.3
	Northern wolffish	*Anarhichas denticulatus*	0.1
	Spotted wolffish	*Anarhichas minor*	< 0.1
	Roughhead grenadier	*Macrourus berglax*	< 0.1
	Slender snipe eel	*Nemichthys scolopaceus*	< 0.1
	Wrymouth	*Cryptacanthodes maculatus*	< 0.1
	Amer barrelfish	*Hyperoglyphe perciformis*	< 0.1
Fish: Planktivore, Pelagic, Small + Medium + Large			
	Herring (Atlantic)	*Clupea harengus*	72.7
	Northern sand lance	*Ammodytes dubius*	13.5
	Argentine (Atlantic)	*Argentina silus*	9.8
	Alewife	*Alosa pseudoharengus*	2.3
	Shad American	*Alosa sapidissima*	1.7
	Lanternfish, horned	*Ceratoscopelus maderensis*	< 0.1
	Blueback herring	*Alosa aestivalis*	< 0.1
	Radiated shanny	*Ulvaria subbifurcata*	< 0.1
	Atlantic saury, needlefish	*Scomberesox saurus*	< 0.1
	Beardfish	*Polymixia lowei*	< 0.1
Fish: Zoopiscivore, Benthic, Small + Medium + Large			
	Redfish unseparated	*Sebastes sp.*	97.6
	Squirrel or red hake	*Urophycis chuss*	1.0
	Longfin hake	*Phycis chesteri*	0.7
	Rock grenadier (roundnose)	*Coryphaenoides rupestris*	0.4
	Lumpfish	*Cyclopterus lumpus*	0.2
	Gray's cutthroat eel	*Synaphobranchus kaupi*	0.1
	American straptail grenadier	*Malacocephalus occidentalis*	< 0.1
	Red dory	*Cyttus roseus*	< 0.1
	Daubed shanny	*Leptoclinus maculates*	< 0.1
	Arctic eelpout	*Lycodes reticulatus*	< 0.1
	Frostfish	*Benthodesmus elongates simonyi*	< 0.1
	Stout beard fish	*Polymixia nobilis*	< 0.1
Fish: Zoopiscivore, Pelagic, Small + Medium + Large			
	Mackerel (Atlantic)	*Scomber scombrus*	59.0
	Capelin	*Mallotus villosus*	38.2
	Butterfish	*Peprilus triacanthus*	2.7

Group	Name	Latin name	% of group biomass
	Short barracudina	*Paralepis atlantica*	0.1
	Muller's pearlsides	*Maurolicus muelleri*	< 0.1
	Atlantic soft pout	*Melanostigma atlanticum*	< 0.1

Table 3. List of invertebrate species within each function group, and the percent biomass of the group they represent (modified from Bundy et al. 2017).

Group	Name	Latin name	% of group biomass
Invertebrate: Benthivore, Benthic, Medium			
	American lobster	*Homarus americanus*	67.1
	Snow crab (queen)	*Chionoecetes opilio*	23.9
	Purple starfish	*Asterias vulgaris*	4.8
	Purple sunstar	*Solaster endeca*	2.4
	Sun star	*Solaster papposus*	1.7
	Ceremaster granularis	*Ceremaster graularis*	0.1
	Spiny crab	*Lithodes/Neolithodes*	< 0.1
	Spiny spider crab	*Neolithodes grimaldi*	< 0.1
Invertebrate: Zoopiscivore, Small + Medium + Large			
	Long-finned squid	*Loligo pealei*	47.9
	Jellyfish	*Pelagia noctiluca*	41.4
	Sepiolidae F.	*Sepiolodae f.*	10.7
Invertebrate: Filter feeder, Benthic, Colonial			
	Paragorgia arborea	*Paragorgia arborea*	94.1
	Gold-banded/Bamboo coral	*Keratoisis ornata*	3.1
	Sea cauliflower	*Duva multiflora*	1.8
	P. resedaeformis	*Primnoa resedaeformis*	0.5
	Acanthogorgia armata	*Acanthogorgiana armata*	0.3
	Radicipes gracilis	*Radicipes gracilis*	0.2
	Acanella arbuscula	*Acanellana arbuscula*	0.1
Invertebrate: Filter feeder, Benthic, Non-colonial			
	Sea scallop	*Placopecten magellanicus*	41.9
	Russian hats	*Vazellana pourtalesi*	30.0
	Sea potato	*Boltenia sp.*	13.0
	Iceland scallop	*Chlamys islandicus*	10.9
	Common mussels	*Mytilus edulis*	1.2
	Horse mussels	*Modiolus modiolus*	1.1
	Sponge	*Rhizaxinella sp.*	1.0
	Bar, surf clam	*Spisula solidissima*	0.4

Group	Name	Latin name	% of group biomass
	Cup coral	*Flabellum sp.*	0.4
	Bank clam	*Cyrtodaria siliqua*	0.2
	Ocean quahaug	*Arctica islandica*	0.1
Invertebrate: Detritivore			
	Sea cucumbers + *Cucumaria frondosa*	*Holothuroidea c. + Cucumaria frondosa*	96.7
	Mud star	Ctenodiscus crispatus	3.0
	Ophiura sarsi	*Ophiura sarsi*	0.3
	Ophiacantha abyssicola	*Ophiacanthana abyssicola*	< 0.1
	Daisy brittle star	*Ophiopholis aculeata*	< 0.1

Table 4. List of seabird species within each function group (modified from Allard et al. 2014).

Group	**Species Name**	**Alpha Code**
Surface shallow-diving coastal piscivore		
	Common Loon	COLO
	Double-crested Cormorant	DCCO
	Great Cormorant	GRCO
	Horned Grebe	HOGR
	Red-necked Grebe	RNGR
	Red-throated Loon	RTLO
	Unspecified cormorant	UNCO
	Unspecified grebe	UNGR
	Unspecified loon	UNLO
Pursuit-diving planktivore		
	Dovekie	DOVE
Pursuit-diving piscivore		
	Atlantic Puffin	ATPU
	Black Guillemot	BLGU
	Common Murre	COMU
	Murre or Razorbill	MURA
	Razorbill	RAZO
	Thick-billed Murre	TBMU
	Unspecified Murre	UNMU
Surface shallow-diving piscivore/generalist		
	Arctic Tern	ARTE
	Black Tern	BLTE
	Black-headed Gull	BHGU
	Black-legged Kittiwake	BLKI
	Bonaparte's Gull	BOGU
	Caspian Tern	CATE
	Common Tern	COTE
	Glaucous Gull	GLGU
	Great Black-backed Gull	GBBG
	Great Skua	GRSK
	Herring Gull	HERG
	Iceland Gull	ICGU
	Iceland Gull/Kumlien's Gull - kumlieni ssp.	KUGU
	Lesser Black-backed Gull	LBBG
	Long-tailed Jaeger	LTJA
	Parasitic Jaeger	PAJA
	Pomarine Jaeger	POJA
	Ring-billed Gull	RBGU

Group	Species Name	Alpha Code
	Roseate Tern	ROST
	South Polar Skua	SPSK
	Unspecified jaegers	UNJA
	Unspecified large gull	UNLG
	Unspecified skuas	UNSK
	Unspecified small gull	UNSG
	Unspecified tern	UNTE
	Unspecified white-winged gull	UNWW
Plunge-diving piscivores		
	Northern Gannet	NOGA
Surface-seizing planktivore		
	Genus: storm-petrels (Oceanites)	
	Genus: storm-petrels (Oceanodroma)	
	Leach's Storm-Petrel	LHSP
	Red Phalarope	REPH
	Red-necked Phalarope	RNPH
	Unspecified phalaropes	UNPH
	Unspecified storm-petrel	UNSP
	Wilson's Storm-Petrel	WISP
Surface shallow-diving generalist		
	Bermuda Petrel	BEPE
	Black-capped Petrel	BCPE
	Unspecified petrel	UNPE
Ship-following generalist		
	Northern Fulmar	NOFU
Shallow pursuit generalist		
	Cory's Shearwater	COSH
	Greater Shearwater	GRSH
	Manx Shearwater	MASH
	Sooty Shearwater	SOSH
	Unspecified shearwater	UNSH