DESIGN STRATEGIES FOR A NETWORK OF MARINE PROTECTED AREAS IN THE SCOTIAN SHELF BIOREGION

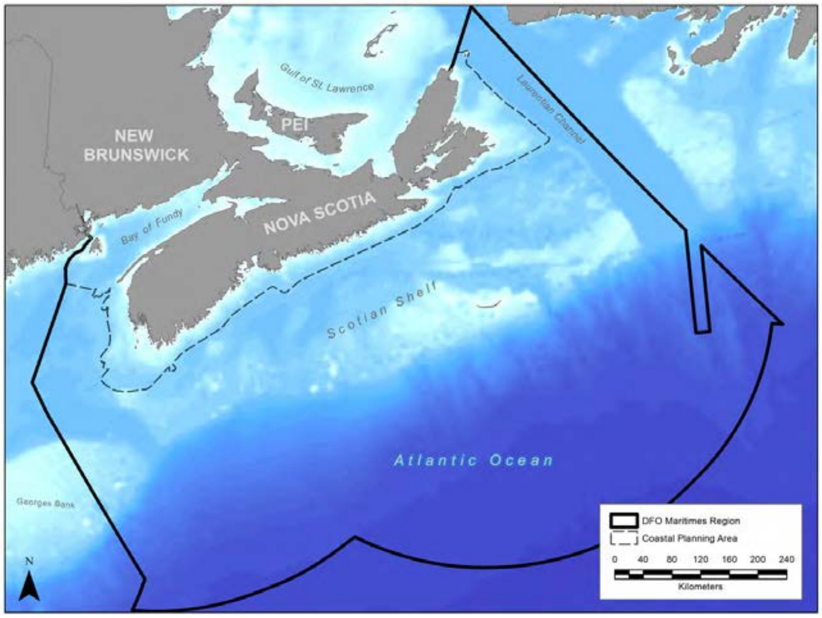

Figure 1. The DFO Maritimes Region boundary represents the Marine Protected Area network planning area for the Scotian Shelf Bioregion and has been divided into coastal and offshore components.

Context:

Canada has made domestic and international commitments to establish a national network of Marine Protected Areas (MPAs), including a commitment to protect 5% of coastal and marine areas by 2017 and at least 10% by 2020. Fisheries and Oceans Canada (DFO), along with federal and provincial partners, is leading the development of a national MPA network on behalf of the Government of Canada. Fisheries and Oceans Canada (DFO), Maritimes Region, is leading the development of a MPA network plan for the Scotian Shelf Bioregion, which, for planning purposes, corresponds to the current DFO Maritimes Region boundary.

Guidance on bioregional MPA network planning is set out in the National Framework for Canada's Network of Marine Protected Areas (Government of Canada 2011) and in the Convention on Biological Diversity (CBD) Conference of the Parties Decision IX/20 (UNEP 2008). Annex II of the CBD Decision indicates that effective networks should include: Ecologically or Biologically Significant Areas (EBSAs), representativity, connectivity, replicated ecological features, and adequate and viable sites.

This Science Advisory Report is from the July 6-7 and November 2-3, 2016, Design Guidance for a Network of Marine Protected Areas in the Scotian Shelf Bioregion. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

SUMMARY

- The primary focus of this meeting was to review the proposed approaches to developing Design Strategies for coastal and offshore components of a network of Marine Protected Areas (MPAs) in the Scotian Shelf Bioregion.
- Different approaches to developing Design Strategies were used for the coastal and offshore waters given the different sources and resolutions of information available for these areas. It is recognized, however, that offshore and coastal areas are connected through ecological processes, and approaches are being explored to consider this connectivity in the overall MPA network design.
- According to current Fisheries and Oceans Canada (DFO) guidance, Design Strategies are meant to specify, for each Conservation Priority: (1) the types of areas or features to be conserved, and; (2) the relative targets for each area type. Design Strategies may also specify elements of connectivity, size, and spacing, if such information exists.
- There is no single ideal method for setting conservation targets. Targets are intended to be ecologically meaningful and reflect current understanding of what is required to protect the Conservation Priority. Setting of specific conservation targets (e.g., 40% of a feature) can imply a false level of precision, so the uncertainty and limitations of targets need to be clearly articulated.
- The approaches used to set conservation targets for the offshore and coastal components of a network of MPAs in the Scotian Shelf Bioregion are intended to be practical, logic-based, qualitative, and reproducible.
- Conservation targets should be revised and adapted over time as more information becomes available, with periodic review to assess progress in achieving the targets.
- Science advice is only one source of information to be used in establishing a MPA network design for the Scotian Shelf Bioregion. A consultation process is underway to gather input from the public, industry, non-governmental organizations, and other government agencies, including First Nations and Aboriginal organizations. This input will also inform MPA network design.

Offshore Approach

- Two categories of Conservation Priorities have been defined for the offshore component of the network of MPAs in the Scotian Shelf Bioregion: 1) course-filter features, including geomorphic units, oceanographic units, scope for growth, natural disturbance, and functional groups, and 2) fine-filter features, including areas of high species richness, biogenic habitats, and depleted species.
- A minimum target of 10% was used as the initial target for each offshore Conservation Priority. Some targets were then increased based on their characteristics and conservation value.
    - o The conservation targets for coarse-filter features, including geomorphic units, oceanographic units, and functional groups, were proportionate to their surface area and ranged from 10% to 54%.
    - o Conservation targets for areas of high species richness ranged from 20% to 40%.

  - Conservation targets for biogenic habitats were based on their uniqueness/rarity and vulnerability and ranged from 10% to 100%. At the meeting, a minimum target of 30% was proposed for all biogenic habitat classifications.
  - Conservation targets for depleted species were based on their vulnerability and current status and ranged from 10% to 100%.

- The methods and data used to assess size, uniqueness/rarity, vulnerability and current status of the Conservation Priorities were reviewed and accepted (with agreed to revisions), as was the approach to establishing a conservation target based on these assessments. The resulting targets will be validated by relevant experts.

- Review of MARXAN scenarios demonstrated some responsiveness to input parameters (target levels); however, there was considerable consistency in site selection among runs and increased target levels only moderately increased the total area of the selected network. Different site configurations are expected when potential socioeconomic cost data are incorporated and trade-offs are considered in the MARXAN analysis.

Coastal Approach

- Coarse- and fine-filter Conservation Priorities have also been identified for the coastal region. The coarse-filter features include a coastal subtidal habitat classification (eco-units) and a coastline classification, and the fine-filter features are based on features described for previously identified Ecologically and Biologically Significant Areas (EBSAs).

- Size, spacing, and connectivity have not yet been taken specifically into account using this approach, but they will be considered at a later stage.

- At this meeting, it was initially proposed that targets for each type of area be set to protect at least one example of each course filter feature. However, there was some concern that this approach would not adequately address MPA network design principles of representativity, connectivity, and replication to ensure adequate and viable coastal sites. To help address this concern, it was subsequently recommended that at least two representative examples of each eco-unit and coastline class be included.

- Because of their vulnerability, the target for some invertebrate biogenic habitats (e.g., Horse Mussel reefs, stalked tunicates, and habitat-forming sponges) was to protect all known significant concentrations (with significant areas identified and described through science advice). For oyster beds and erect bryozoan turf, it was to protect at least two examples in the Bras d’Or eco-unit and to protect at least one example area of adequate size for all other eco-units where relevant

- The EBSAs, or parts of an EBSA, that achieve multiple fine and/or coarse-filter Conservation Priorities will be prioritized for consideration into the coastal network.

- Species of cultural importance (inshore and offshore), e.g., eels and salmon, and non-commercial invertebrates were identified as data gaps. Approaches to incorporating species and areas of cultural importance into the site selection process need to be developed and implemented in the MPA network planning process. Consideration will need to be given to ensure the identification of species and areas of cultural importance are conducted according to appropriate protocols and with adequate time.

- The Bras d’Or Lake and mid-inner Bay of Fundy eco-units have a high level of substructure/diversity and are globally unique. However, since the entire Bras d’Or Lakes eco-unit is identified as an EBSA and only a small number of EBSAs are identified within the mid-inner Bay of Fundy eco-unit, the approach to site selection may require further consideration. For example, further refinement of existing EBSAs or identification of new EBSAs may be warranted as future work.

Connectivity

- Connectivity is recognized as an important characteristic of a MPA network that can add conservation value to what could otherwise be a collection of independent protected areas.
- Connectivity typically is incorporated into MPA network design directly through parameterization of design algorithms (e.g., boundary length to area ratio in MARXAN) or indirectly through post-hoc alterations ensuring network designs adhere to size and spacing guidelines (i.e., "*rules of thumb*"). These approaches offer pragmatic tools to incorporate some aspects of connectivity into MPA network design. Approaches which seek a combination of realized connectivity (gene flow) and landscape connectivity offer a tool to incorporate comprehensive connectivity information directly into the design process, identifying important dispersal corridors for a network of protected areas. Habitat suitability models derived from this process provide a mechanism to predict how species distribution, habitat suitability, and connectivity itself may respond to changing environmental conditions.
- Next steps include identifying the Conservation Priorities that would particularly benefit from considerations of connectivity, understanding what connectivity information is available and then assessing proposed network designs in terms of their relative connective value for those Conservation Priorities.

Sources of Uncertainty

- As with any target setting exercise, considerable uncertainty exists around the targets that have been proposed through the application of this approach.

BACKGROUND

Oceans Management Context

Fisheries and Oceans Canada (DFO) Oceans has developed national guidance for regional Marine Protected Area (MPA) network development. This includes an objectives hierarchy to promote consistency in approach and terminology among regional processes (Table 1).

Table 1. Hierarchy of objectives for the development of regional MPA networks in Canada.

Level in Hierarchy	Description
1. National Goals	High-level statements that outline what the National MPA Network aims to achieve. Contained in the National Framework.
2. Strategic Objectives	Relatively high-level statements that outline what a regional MPA network aims to achieve.
3. Conservation Priorities	Specific species, habitats or other ecological features a regional MPA network aims to protect.
4. Operational Objectives	Specific and measurable statements that indicate the desired state for each Conservation Priority for a regional MPA network.
5. 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, or low).

National Goals are contained in the National Framework (Government of Canada 2011).

Strategic Objectives for the Scotian Shelf Bioregional MPA Network, as developed through the MPA Technical Working Group are to:

- Protect unique, rare, or sensitive ecological features in the bioregion.
- Protect representative examples of identified ecosystem and habitat types in the bioregion.
- Help maintain ecosystem structure, functioning and resilience within the bioregion.
- Contribute to the recovery and conservation of depleted species.
- Help maintain healthy populations of species of commercial, recreational, and/or Aboriginal importance.

Conservation Priorities, and their related Operational Objectives, for the Scotian Shelf Bioregion were developed through the MPA Technical Working Group, and continue to evolve.

It has been determined that Design Strategies would be reviewed through DFO's science peer-review and advisory process (i.e., through a Canadian Science Advisory Secretariat (CSAS) meeting). Data layers, and their sources of uncertainty, were evaluated at previous CSAS meetings (DFO 2012, 2014, and 2016).

A flow diagram to illustrate the steps that will be used to develop the MPA network plan for the Scotian Shelf Bioregion is provided in Figure 2. This illustrates how the network design will incorporate both ecological information (and targets), as well as other sources of information. The final network design will incorporate input from a variety of perspectives.

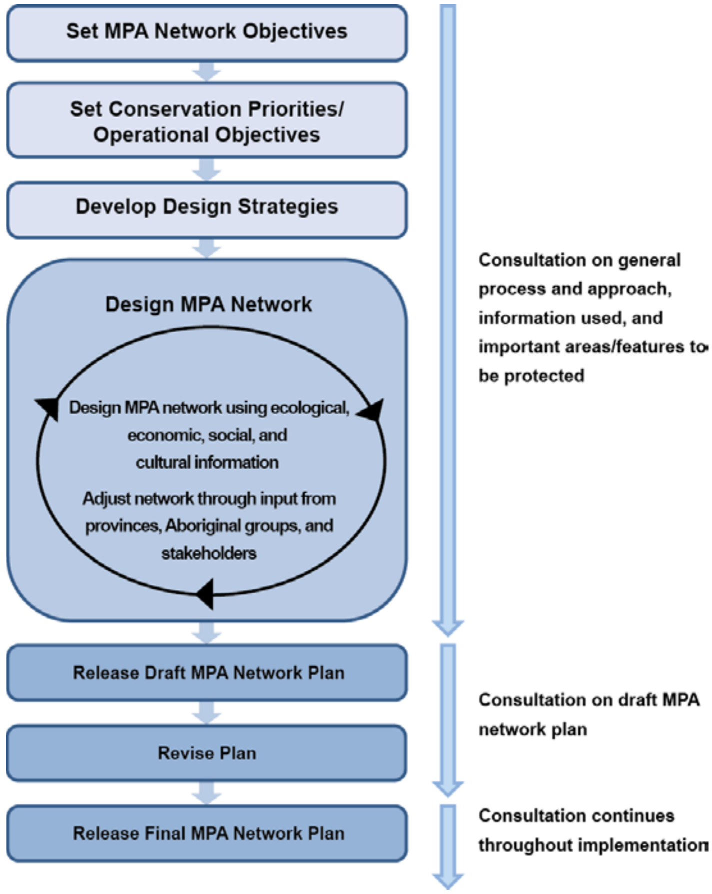

Figure 2. General process steps for the development of a MPA network plan for the Scotian Shelf Bioregion.

Planning Area

The DFO Maritimes Region boundary represents the MPA network planning area for the Scotian Shelf Bioregion. The planning area includes the waters of the 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 with the landward boundary as the high water mark) and the Bay of Fundy, while the offshore component encompasses the remaining waters.

ASSESSMENT

The primary focus of this meeting was to review the proposed approaches to developing Design Strategies for coastal and offshore components of a network of MPAs in the Scotian Shelf Bioregion. According to current DFO guidance, Design Strategies are meant to specify, for each Conservation Priority: (1) the types of areas or features to be conserved, and (2) the relative targets for each area type. Design Strategies may also specify elements of connectivity, size, and spacing, if such information exists.

Setting conservation targets is a key step in systematic conservation planning. Targets specify how much of a conservation feature a protected area network will be designed to protect.

Therefore, targets have an influence on the size and configuration of protected area networks. Setting targets provides a clear basis for conservation decisions and allows for the measurement of success during the implementation phase of network development. Targets also increase accountability and transparency.

There is no single ideal method for setting conservation targets. Targets are intended to be ecologically meaningful and reflect current understanding of what is required to protect the Conservation Priority. Setting of specific conservation targets (e.g., 40% of a feature) can imply a false level of precision, so the uncertainty and limitations of targets need to be clearly articulated.

Different approaches to developing Design Strategies were used for coastal and offshore waters given the different sources and resolutions of information available for these areas. It is recognized, however, that offshore and coastal areas are connected through ecological processes, and approaches are being explored to consider this connectivity in the overall MPA network design.

Offshore

Comprehensive MPA networks should capture representative examples of broad-scale ecosystem or habitat types in a region (coarse-filter features), as well as smaller scale special natural features and priority species (fine-filter features).

Two categories of Conservation Priorities have been defined for the offshore component of the network of MPAs in the Scotian Shelf Bioregion: 1) coarse-filter features, including geomorphic units, oceanographic units, scope for growth, natural disturbance, and functional groups, and 2) fine-filter features, including areas of high species richness, biogenic habitats, and depleted species.

Approach to Setting Targets

The approach used to set conservation targets for the offshore Conservation Priorities was adapted from the approach used by Gerhartz (2015), and is intended to be practical, logic-based, qualitative, and reproducible.

A minimum target of 10% was used as an initial target for each Conservation Priority. This was then increased for certain Conservation Priorities based on their characteristics and conservation value.

Four primary factors or characteristics (size, uniqueness/rarity, vulnerability, and status) were then considered to establish the relative conservation value of Conservation Priorities and determine if, and by how much, the target should be increased. Not all primary factors were applied to all types of Conservation Priorities (Table 2).

Table 2. Primary factors or characteristics considered when adjusting targets for the different Conservation Priority categories ("x" indicates that the factor was applied to the Conservation Priority).

<table>
<tr><th colspan="3" rowspan="2"></th><th colspan="4">Primary Factors (Characteristics)</th></tr>
<tr><th>Size</th><th>Uniqueness/Rarity</th><th>Vulnerability</th><th>Current Status</th></tr>
<tr><th rowspan="8">Conservation Priority Categories</th><td rowspan="5">Coarse-filter Features</td><td>Oceanographic Units</td><td>X</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Geomorphic Units</td><td>X</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Scope for Growth</td><td>X</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Natural Disturbance</td><td>X</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Functional Groups</td><td>X</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="3">Fine-filter Features</td><td>Areas of High Species Richness</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Biogenic Habitats</td><td>-</td><td>X</td><td>X</td><td>-</td></tr>
<tr><td>Depleted Species</td><td>-</td><td>-</td><td>X</td><td>X</td></tr>
</table>

Size was the only factor considered for coarse-filter Conservation Priorities because the objective for these features is simply to capture a representative example of each within the MPA network. Uniqueness/rarity and vulnerability were found to be useful for evaluation of biogenic habitats. Vulnerability and current status were found to be useful for depleted species. None of the primary factors were found to be useful in differentiating the areas of high species richness. Since the areas to be conserved for fine-filter priorities are smaller and highly important, the targets for these features are expected to be higher than those for coarse-filter features.

Coarse-Filter Features

Targets for coarse-filter features were based solely on the size of the feature, where size is defined as the total area covered by the feature to be conserved. Under this approach, smaller coarse-filter features are assigned a higher target than larger features. This is based on the assumption that smaller features are more susceptible to changes or disturbances, including catastrophic events. Spatial data for all coarse-filter features was normalized using a square root transformation and then targets were scaled proportionally based on their relative overall size using the approach described in Lieberknecht et al. (2010):

$$\left(\frac{x_p}{y_p}\right) \approx \left(\frac{x_t}{y_t}\right)^{0.5}$$

where x and y are two features within a given feature class, p represents the area protected of a given feature, and t represents the total area of a given feature in the network. With this method, the distribution of targets for coarse-filter features of the same general kind, fall within a continuum roughly proportional to the square root of their respective total areas.

To apply this approach, a starting target must be specified for the largest feature in the particular coarse-filter category. For example, for the Oceanographic Units, the Slope, Rise, and Abyss unit is the largest feature so a starting target had to be set for this feature to calculate the targets for the remaining features in this category. Three percent and 10% were used as the starting targets to calculate the respective low and high targets for the various coarse-filter features. In cases where using this approach yielded targets that were less than 10%, these targets were increased to 10%, which was the agreed to minimum target for all features.

Oceanographic Units

In DFO (2016) the Maritimes Region has been classified into distinct oceanographic units based on known conditions (e.g., temperature and salinity) and processes (e.g., currents). Each oceanographic unit represents a separate area or feature to be conserved.

Area to be Conserved	Targets (Low)	Targets (High)
Gulf of Maine	10	30
Baccaro and LaHave Banks	11	38
LaHave and Emerald Basins	10	26
Western and Sable Island Banks	10	31
Eastern Scotian Shelf	10	22
Laurentian Slope	10	34
Slope, Rise, and Abyss	10	10

Geomorphic Units

Geomorphic units, as defined in DFO (2016), are geomorphological features assumed to have distinct biological communities. Geomorphic units are the level below oceanographic units in the DFO (2016) hierarchical marine ecological classification system. Each geomorphic unit represents a separate area or feature to be conserved.

Area to be Conserved[1]	Targets (Low)	Targets (High)
Abyssal Plain	10	11
Continental Rise	10	10
Shelf Bank	10	14
Shelf Basin	10	32
Shelf Channel	12	39
Shelf Flat	10	19
Shelf Topo. Complex	10	30
Shelf Topo. Complex Bank	10	35
Shelf Topo. Complex Basin	16	54
Slope	11	35
Slope Channel	10	26

Scope for Growth

The Kostylev and Hannah (2007) framework for benthic habitat characterization based on observed scope for growth and natural disturbance conditions was previously reviewed and accepted as a useful tool for characterization of benthic habitats in the Scotian Shelf Bioregion (DFO 2005). Scope for Growth refers to the amount of energy in the environment available for an organisms' growth and maintenance of normal physiological functions (i.e., productivity) and was originally represented as a continuum on a scale normalized from 0–1, but it was then divided into scope for growth "classes" for this analysis. Capturing different scope for growth classes should ensure a wide range of community types is included in the network.

[1] Bay of Fundy Inlet, Bay of Fundy Flat, Bay of Fundy Basin, Inner Shelf Inlet, Inner Shelf Bank, and Inner Shelf Flat are geomorphic units that were described in DFO (2016), but they will not be considered in the offshore approach as they fall within the coastal planning area.

Area to be Conserved	Targets (Low)	Targets (High)
Very low scope for growth	10	15
Low scope for growth	10	10
Moderate scope for growth	10	13
High scope for growth	10	20
Very high scope for growth	10	19

Natural Disturbance

Natural benthic disturbance occurs as a result of processes such as tidal and circulation currents, storm and internal waves. In the Kostylev and Hannah (2007) framework, benthic disturbance was related to the frictional velocity on the seabed and critical shear stress for a given particle size. As with Scope for Growth, Disturbance was originally represented as a continuum on a scale normalized from 0–1, but it was then divided into natural disturbance "classes" for this analysis. Capturing different natural disturbance classes should ensure a wide range of community types is included in the network.

Area to be Conserved	Targets (Low)	Targets (High)
Very low natural disturbance	10	18
Low natural disturbance	10	14
Medium natural disturbance	10	10
High natural disturbance	10	17

Functional Groups (Fish)

Important habitats or core areas for each fish functional group were identified and mapped by Bundy et al. (2017) using DFO Summer Research Vessel Survey data and were included as areas or features to be conserved.

There were several small (<1000 km^2) coarse-filter features that receive high targets using this approach. To avoid causing these small areas with high targets to unduly influence the network design (through a seeding effect), and given uncertainty in their ecological importance, they were assigned a target of 0. Setting a target of 0 ensures that these features will not influence the final network configuration or size but they will still be included in the MARXAN output summaries.

Area to be Conserved	Targets (Low)	Targets (High)
Small and Medium Benthic Piscivores (East)	10	10
Small and Medium Benthic Piscivores (West)	10	17
Large Benthic Piscivores (East)	10	11
Large Benthic Piscivores (West)	10	17
Small, Medium and Large Pelagic Piscivores (East)	10	21
Small, Medium and Large Pelagic Piscivores (West)	0	0
Small Benthic Benthivores (East)	10	13
Small Benthic Benthivores (West)	10	22
Medium Benthic Benthivores (East)	10	11
Medium Benthic Benthivores (West)	10	17
Large Benthic Benthivores (East)	10	12
Large Benthic Benthivores (West)	10	16
Small, Medium, and Large Pelagic Planktivores (East)	10	14

Area to be Conserved	Targets (Low)	Targets (High)
Small, Medium, and Large Pelagic Planktivores (West)	10	18
Small, Medium, and Large Benthic Zoopiscivores (East)	10	15
Small, Medium, and Large Benthic Zoopiscivores (West)	10	17
Small, Medium, and Large Pelagic Zoopiscivores (East)	10	24
Small, Medium, and Large Pelagic Zoopiscivores (West)	10	33

Functional Groups (Invertebrates)

Important habitats or core areas for each invertebrate functional group were identified and mapped by Bundy et al. (2017) using DFO Summer Research Vessel Survey data.

Area to be Conserved	Targets (Low)	Targets (High)
Small Benthic Benthivores (East)	10	10
Small Benthic Benthivores (West)	10	15
Medium Benthic Benthivores (East)	10	10
Medium Benthic Benthivores (West)	10	15
Small, Medium, and Large Zoopiscivores (East)	10	31
Small, Medium, and Large Zoopiscivores (West)	10	16
Benthic Colonial Filter Feeders (East)	10	18
Benthic Colonial Filter Feeders (West)	0	0
Benthic Non-Colonial Filter Feeders (East)	10	10
Benthic Non-Colonial Filter Feeders (West)	10	20
Detritivores (East)	10	14
Detritivores (West)	10	27

Functional Groups (Seabirds)

Important habitats for each seabird functional group were identified and mapped using the seabird sightings data described in Allard et al. (2014).

Area to be Conserved	Targets (Low)	Targets (High)
Surface-Seizing Planktivores	10	27
Surface Shallow-Diving Piscivores/Generalists	10	11
Surface Shallow-Diving Coastal Piscivores	10	24
Pursuit-Diving Piscivores	10	13
Shallow Pursuit Generalists	10	10
Pursuit-Diving Planktivores	10	14
Plunge-Diving Piscivores	10	10
Ship-Following Generalists	10	13

Fine-Filter Features

Fine-filter features include areas of high species richness (5), biogenic habitats (11), and depleted species (25).

High Species Richness

A target range of 20–40% was selected for all Conservation Priorities considered in the high species richness category because it was difficult to differentiate among these features based on any of the primary factors (e.g., size or vulnerability). The area or feature to be conserved for these Conservation Priorities were areas that were within the top quantile (i.e., top 20%) for species richness during the DFO Research Vessel surveys (e.g., Ward-Paige and Bundy 2016) and other surveys.

Area to be Conserved	Target Range
Areas of high fish species richness	20–40%
Areas of high invertebrate species richness	20–40%
Areas of high small fish species richness	20–40%
Areas of high ichthyoplankton species richness	20–40%
Areas of high small invertebrate species richness	20–40%

Biogenic Habitat

The primary factors or key characteristics considered when refining targets for the biogenic habitat Conservation Priorities were uniqueness/rarity and vulnerability. A scoring system was developed for this sub-category of Conservation Priorities where separate uniqueness/rarity and vulnerability scores were generated and then combined using the square-root of the sum of squares, divided by the number of factors to determine a target score. This score was then converted to a corresponding target range (Low: 10–20%, Low-medium: 20–40%, Medium (40–60%, Medium-high: 60–80%, High: 80–100%).

Important biogenic habitats were identified and mapped using Kernel Density Estimation (KDE) and/or species distribution models (SDMs) (Kenchington et al. 2016; Beazley et al. 2017). Where KDE-derived polygons are available, these polygons will serve as the primary areas to be conserved for biogenic habitat Conservation Priorities. The species distribution models developed for several of the biogenic habitat Conservation Priorities by Beazley et al. (2017) predict the broad distribution of the different taxa based on environmental variables but do not highlight significant concentrations. In cases where a KDE-derived polygon is not available for a species group, the SDM layer can be used as a substitute, but targets for these features should be tempered because they do not point to significant concentrations.

Unique biogenic habitats that were considered highly vulnerable were assigned high targets while other Conservation Priorities in this group received lower targets. At the meeting, it was suggested that, under the *Policy for Managing the Impact of Fishing on Sensitive Benthic Areas*, all biogenic habitats that are considered vulnerable should be assigned a high target. A minimum target of 30% was also proposed for biogenic habitats.

Biogenic Habitat	Target Range
Vazella pourtalesi (sponge) concentrations[2]	80–100%
Large gorgonian coral concentrations[2]	80–100%
Small gorgonian coral concentrations[2]	60–80%
Other sponge concentrations[2]	20–40%
Sea pen fields[2]	60–80%
Lophelia pertusa (coral) reefs[3]	80–100%
Horse mussel reef[4]	80–100%
Stalked tunicate fields[4]	80–100%
Soft coral gardens[4]	10–20%
Crinoid beds[3]	60–80%
Tube-dwelling Anemone fields[3]	40–60%

Depleted Species

The primary factors considered when setting targets for depleted species were vulnerability and current status. For each depleted species, a separate score was determined for both of these factors and a combined target score was calculated using the square-root of the sum of squares, divided by the number of factors. This score was then converted to a corresponding target range. Size and uniqueness/rarity were not considered because nearly all of the depleted species in the region have large area requirements and are considered common.

All of the depleted species on the list are mobile, and many have quite large area requirements (e.g., North Atlantic Right Whale and Leatherback Turtle). The MPA network will not aim to protect the entire range of these species. Rather, the focus will be on spatially discrete areas where a species aggregates in high densities, either year round or at certain times of the year. If these important areas have not been identified, the targets cannot be fully applied. In cases where broad distribution information (e.g., a species distribution model) is the best available information, a lower target should be assigned to ensure that the depleted species receives some representation within the MPA network, while recognizing the uncertainty in its distribution. Certain depleted species may not aggregate in specific areas in the bioregion or their aggregation areas may be quite broad. These species are less suitable for spatial approaches to protection but may still be included in the network design analysis at a lower target. The area to be conserved for most depleted species will be important habitats, but, in certain cases, it will be a proportion of the broader distribution.

[2] KDE-derived polygons for *Vazella pourtalesi* (sponge) concentrations and other sponge concentrations and SDMs for gorgonian corals and sea pens identifying significant benthic areas from Kenchington et al. (2016). *Vazella pourtalesi* was mapped based on the KDE-derived polygon for all sponges and then polygons for this species were separated from all other sponges.
[3] No data available, target range based on vulnerability and rarity.
[4] KDE-derived polygons from Beazley et al. (2017).

Depleted Species	Target Range
Northern Bottlenose Whale	80–100%
North Atlantic Right Whale	80–100%
Blue whale	80–100%
Fin whale	60–80%
Sowerby’s Beaked Whale	60–80%
Harbour porpoise	10–20%
Leatherback turtle	80–100%
Loggerhead turtle	80–100%
Porbeagle Shark	80–100%
White Shark	80–100%
Blue Shark	60–80%
Basking Shark	20–40%
Atlantic Cod	60–80%
Redfish (Unit 2)	40–60%
Winter Skate	80–100%
American Plaice	20–40%
Cusk	20–40%
White Hake	40–60%
Smooth Skate	60–80%
Atlantic Wolffish	60–80%
Thorny Skate	20–40%
Spiny Dogfish	60–80%
Roundnose Grenadier	80–100%
Roughhead Grenadier	60–80%
Ocean Pout	20–40%

Coastal

The approach used to set conservation targets for the coastal component of the network of MPAs in the Scotian Shelf Bioregion is necessarily different from the offshore approach, but it is also intended to be practical, logic-based, qualitative, and reproducible.

As for the offshore component, coarse- and fine-filter Conservation Priorities have been identified for the coastal region. The coarse-filter features were based on two coastal classification systems, and the fine-filter features were based on features described for previously identified EBSAs.

Size, spacing, and connectivity have not yet been taken specifically into account using this approach, but they will be considered at a later stage.

Coarse-Filter Features

Two groups of coarse-filter coastal Conservation Priorities were identified based on coastal and nearshore habitat classification systems:

1. Eco-units: this classification provides a means of coarsely subdividing the Bay of Fundy and the nearshore waters along the Atlantic coast of Nova Scotia into nine areas that share similar subtidal oceanographic and substrate characteristics (Figure 3).

2. Coastline classes: this classification system subdivides the Bay of Fundy coastline and the Atlantic coast of Nova Scotia into one of three major substrate types – hard, mixed, or soft substrate (Greenlaw et al. 2013).

Each eco-unit or coastline class is considered a separate conservation priority.

Eco-Units

At this meeting, it was initially proposed that targets for each type of area be set to protect at least one example within each of the nine eco-units (Table 3). However, there was some concern that this approach would not adequately address MPA network design principles of representativity, connectivity, and replication to ensure adequate and viable coastal sites. Concerns were as follows:

- Representativity: Selecting one example area in each eco-unit may not ensure adequate representation of important features within each eco-unit. For example, genetic (stock) diversity may not be adequately captured for some species with only one representative sample of a species within each eco-unit. In some cases, it may be more appropriate to protect at least two examples of important features found within each eco-unit. This will need to be evaluated on a case by case basis to ensure that network-level objectives are achieved for each Conservation Priority in the final network design.
- Connectivity: Selecting one example area in each eco-unit may not ensure connectivity between sites.
- Replication: Selecting one example area in each eco-unit may not ensure adequate replication of important features and habitats found within the eco-unit. For example, lack of replication increases risk of an individual site being affected by disease or a natural disaster.

To help address these concerns, the MPA Technical Working Group subsequently recommended that at least two representative examples of each eco-unit be selected, which should comprise at least 10% of the total area of the eco-unit.

Coastline Classes

The target for coastline classes was to protect at least two examples of each of the three substrate types identified in each of the Bay of Fundy and the Atlantic Coast (six classes in total for the Scotian Shelf Bioregion).

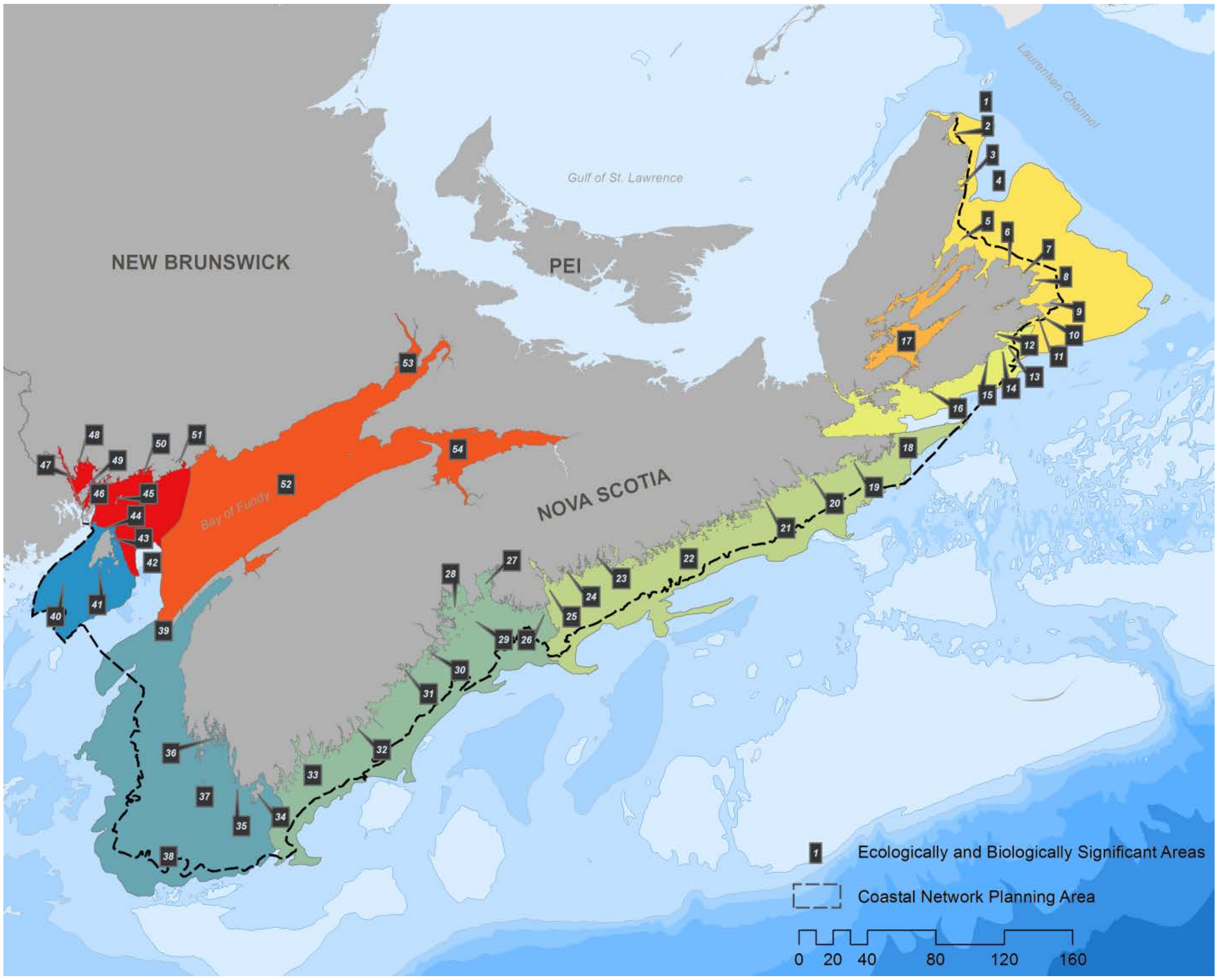

Figure 3. Coastal Ecologically and Biologically Significant Areas (EBSAs) in the Scotian Shelf Bioregion. The black numbered boxes indicate the general location of each of the 54 coastal EBSAs in the region. The coloured polygons break up the coast into eco-units, which are areas that share similar subtidal oceanographic and substrate characteristics. The dashed line indicates the approximate extent of the coastal planning area.

Fine-Filter Features

For most of the fine-filter coastal Conservation Priorities, the types of areas to be conserved were determined by examining the ecological, biological, and biophysical features of EBSAs defined in the Bay of Fundy (Buzeta 2014) and Atlantic Coast (Hastings et al. 2014) and considering only those features that would benefit from marine spatial protection.

The wording chosen for the targets reflects the current limitations of data and information available for much of the coastal planning area within the region. As further information becomes available, it may be possible to add greater specificity to the target wording (Table 3).

For highly natural ecosystems, areas of high productivity, areas of high biodiversity, complex or unique geomorphology, and persistent unique or rare oceanographic characteristics, the proposed target was to protect at least one example in each eco-unit where relevant.

Because of their vulnerability, the target for some invertebrate biogenic habitats (e.g., Horse Mussel reefs, stalked tunicates, and habitat-forming sponges) was to protect *all known significant concentrations* (with significant areas identified and described through science advice). For oyster beds and erect bryozoan turf, the target was to protect at least one example area of adequate size in each eco-unit where relevant (protect at least two examples in the Bras d'Or eco-unit).

For significant concentrations of eelgrass, saltmarsh, kelp and macro-algae, the proposed target was to protect at least one example area of adequate size for each type present in each eco-unit (protect at least two examples of each type in the Bras d'Or eco-unit).

Additional species-specific features that would benefit from protection were also identified within the classification of EBSAs. These include areas important for sensitive life history stages of seabirds, fish, invertebrates, and cetaceans as well as areas important to depleted species (e.g., Critical Habitat for Species at Risk) and for cultural purposes. For reasons of practicality, no specific targets were set for these features; however, their presence was taken into account as a secondary assessment of conservation value during the selection process.

The Bras d'Or Lake and mid-inner Bay of Fundy eco-units have a high level of substructure/diversity and are globally unique. Since the entire Bras d'Or Lakes eco-unit is identified as one EBSA and only a small number of EBSAs are identified within the mid-inner Bay of Fundy eco-unit, site selection applied to the coastal component of the network may warrant further refinement of existing boundaries or identification of new EBSAs at a finer scale.

The EBSAs, or parts of an EBSA, that achieve multiple fine and/or coarse-filter Conservation Priorities will be prioritized for consideration into the coastal network.

Table 3. Design strategies for coastal Conservation Priorities.

Coastal Conservation Priority	Type of Area to be Conserved	Target (Amount)
Representative features	1. Eco-units. 2. Coastline classes for the Bay of Fundy and Atlantic Coast of Nova Scotia.	1. Protect at least two representative example areas and at least 10% total area in each eco-unit. 2. Protect at least two representative examples of each coastline class found along the Bay of Fundy and Atlantic Coast of Nova Scotia.
Highly natural ecosystems	Areas recognized as highly natural or intact ecosystems.	Protect at least one example in each eco-unit where relevant.
Areas of high productivity	Areas with naturally occurring nutrient-rich surface waters, areas with enhanced productivity, or areas with persistent or recurring upwelling.	Protect at least one example in each eco-unit where relevant.
Areas of high biodiversity	Areas recognized as being highly biodiverse.	Protect at least one example in each eco-unit where relevant.
Complex or unique geomorphology	Complex or unique geomorphological features that support biodiversity or ecological function.	Protect at least one example in each eco-unit where relevant.
Persistent unique or	Areas with steep temperature gradients,	Protect at least one example in

Coastal Conservation Priority	Type of Area to be Conserved	Target (Amount)
rare oceanographic characteristics	strong stratification, strong tidal currents, enhanced mixing, or highly fluctuating surface salinity.	each eco-unit where relevant.
Biogenic habitats (invertebrates)	1) Significant[5] concentrations of horse mussels (*Modiolus modiolus* reefs), stalked tunicates (*Boltenia ovifera*), and habitat-forming sponges (e.g., *Haliclona oculata* and *Myxilla* spp.). 2) Oyster beds (*Crassostrea virginica*) and erect bryozoan turf (*Flustra foliacea*).	1) Protect all known significant concentrations. 2) Protect at least one example area of adequate size[6] in each eco-unit where relevant (protect at least two examples in the Bras d'Or eco-unit[7]).
Biogenic habitats (marine plants and macro-algae)	Significant concentrations of: 1) Eelgrass 2) Saltmarsh 3) Kelp 4) Other macro algae	Protect at least one example area of adequate size for each type present in each eco-unit (protect at least two examples in the Bras d'Or eco-unit[7]).

Boundaries Between Offshore and Coastal Components

Since different approaches were used to develop MPA Network Design Strategies for the coastal and offshore components of the Scotian Shelf Bioregion, boundaries between these areas had to be defined. The inshore extent of the DFO Research Vessel Survey will be used as the technical boundary that separates the Atlantic coast and offshore area. The boundary between the offshore and the Bay of Fundy will lie near the mouth of the bay seaward of Grand Manan and Brier Island (Figures 1 and 3). It was decided that setting this hard technical boundary will prevent overlap in the two network site selection processes. Once network sites have been identified in the respective areas, the sites may be adjusted, where appropriate, to bridge the gap between coastal and offshore sites.

Connectivity

Connectivity is recognized as an important feature of a MPA network that can add conservation value to what could otherwise be a collection of independent protected areas. For the purposes of this document, connectivity refers to the movement of individual species across a landscape and is defined hierarchically to reflect that it is a combination of (1) dispersal, (2) survival, (3) reproduction and (4) landscape:

1. **Demographic connectivity** (basic definition of connectivity): the rate or magnitude of exchange of individuals among spatially distinct areas.

[5] As determined by expert advice.
[6] Area must be of adequate size to ensure the function of the feature is protected. Adequate size will be determined by expert advice.
[7] Due to its isolation, the Bras d'Or lakes eco-unit is considered separately from the rest of the coastal planning area. Protecting at least two examples ensures replication for these features within the lakes.

2. **Realized connectivity**: the rate or magnitude of exchange of recruiting individuals among spatially distinct areas.
3. **Reproductive connectivity**: the rate or magnitude of exchange of recruiting individuals who successfully reproduce among spatially distinct areas.
4. **Landscape connectivity**: the degree to which the landscape facilitates or impedes movement.

Connectivity typically is incorporated into MPA network design directly through parameterization of design algorithms (e.g., boundary length to area ratio in MARXAN) or indirectly through post-hoc alterations ensuring network designs adhere to size and spacing guidelines (i.e., "*rules of thumb*" or simulated/estimated dispersal distances). These approaches offer pragmatic tools to incorporate some aspects of connectivity into MPA network design. However, directly incorporating connectivity into representative, target-based design processes is challenging, because connectivity (1-3) is not represented across the planning landscape (4). Moreover, distance-based estimates of connectivity (1) often do not consider whether connectivity is likely to be realized (2) or reproductive (3) and thus may be limited in their representation of connectivity integral to the population structure and resilience of a system. Approaches which seek a combination of reproductive connectivity (3) and landscape connectivity (4) offer a tool to incorporate comprehensive connectivity information directly into the design process. These novel approaches integrate species distribution data, habitat suitability models, and genetic population structure to identify areas of spatial connectivity for species or species groups. This information can then be used to characterize the connectivity landscape and identify important dispersal corridors for a network of protected areas. The development of habitat suitability models also provides a mechanism to predict how species distribution, habitat suitability, and connectivity may respond to changing environmental conditions.

Next steps include identifying the Conservation Priorities that would particularly benefit from considerations of connectivity (e.g., Smith and Metaxas 2018), understanding what connectivity information is available and then assessing proposed network designs in terms of their relative connective value for those Conservation Priorities.

Sensitivity Analysis Using MARXAN

MARXAN is an analytical tool that can be used to assist in MPA network design. MARXAN can generate potential network designs based on pre-determined targets and criteria, or it can be used to evaluate how well particular designs achieve pre-determined targets.

At the meeting, MARXAN was used to explore the sensitivity of network design to targets for the offshore. For example, MARXAN was used to explore the impact of changing the target ranges for different Conservation Priorities on the MARXAN solution.

For future analyses, the suggestion was made to include overlays that show 'summed-summed runs' (see Reining et al. 2006). The summed solution of each scenario and the summed solutions of all the scenarios combined are useful for showing areas that are critical (irreplaceable) to achieving the targets. Although these irreplaceable areas will not be *sufficient* to capture all of the targets, they will indicate areas that are necessary to meeting the targets. These areas are likely to capture multiple Conservation Priorities, features and targets.

The technical limitations and specifications of MARXAN need to be fully understood so that the influences of these on MPA network design are mitigated or accounted for. For example, under certain operating conditions, very small representative features can have a significant 'seeding' influence on MPA network designs generated by MARXAN, which was demonstrated in the sensitivity analysis presented at this meeting.

Sources of Uncertainty

Broad conservation goals may remain relevant over the longer term, but targets typically have a shorter lifespan and should be revised and adapted over time as more information becomes available. As noted above, one of the benefits of setting targets is the explicit guidance they provide for conservation initiatives, but they can also imply a false level of precision so the inherent uncertainty and limitations of targets must be acknowledged from the outset (Pressey et al. 2003).

As with any target setting exercise, considerable uncertainty exists around the targets that have been proposed through the application of the approach outlined here. More robust targets could be developed in the future by refining this method or through additional research on the area requirements of each Conservation Priority. Network monitoring will play an important role in assessing the effectiveness of the Design Strategies.

Data and methods used to estimate the relative distribution of Conservation Priorities can influence targets and were taken into consideration when setting target ranges here.

CONCLUSIONS AND ADVICE

The primary focus of this meeting was to review the proposed approaches to developing Design Strategies for coastal and offshore components of a network of MPAs in the Scotian Shelf Bioregion.

The methods and data used to assess size, uniqueness/rarity, vulnerability and current status of the Conservation Priorities were reviewed and accepted (with agreed revisions), as was the approach to establishing a conservation target based on these assessments. The resulting targets should be validated by relevant experts.

Review of MARXAN scenarios demonstrated some responsiveness to input parameters (target levels); however, there was considerable consistency in site selection among runs and increased target levels only moderately increased the total area of the selected network. Different site configurations are expected when potential socioeconomic cost data are incorporated and trade-offs are considered in the MARXAN analysis.

Broad conservation goals may remain relevant over the longer term; however, conservation targets typically have a shorter lifespan and should be revised and adapted over time as more information becomes available, with periodic review to assess progress in achieving the targets.

Species of cultural importance in the inshore and offshore zones (i.e., eels. salmon, and non-commercial invertebrates) were identified as data gaps. Approaches to incorporating species and areas of cultural importance into the site selection process need to be developed and implemented in the MPA network planning process. The identification of species and areas of cultural importance should be conducted according to appropriate protocols and with adequate time.

Science advice is only one source of information to be used in establishing a MPA network design for the Scotian Shelf Bioregion. A consultation process is underway to gather input from the public, industry, non-governmental organizations, and other government agencies, including First Nations and Indigenous organizations. This input will also inform MPA network design.

SOURCES OF INFORMATION

This Science Advisory Report is from the July 6-7 and November 2-3, 2016, Design Guidance for a Network of Marine Protected Areas in the Scotian Shelf Bioregion. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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