Fisheries and Oceans Canada | Pêches et Océans Canada

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DESIGN STRATEGIES FOR THE NORTHERN SHELF BIOREGIONAL MARINE PROTECTED AREA NETWORK

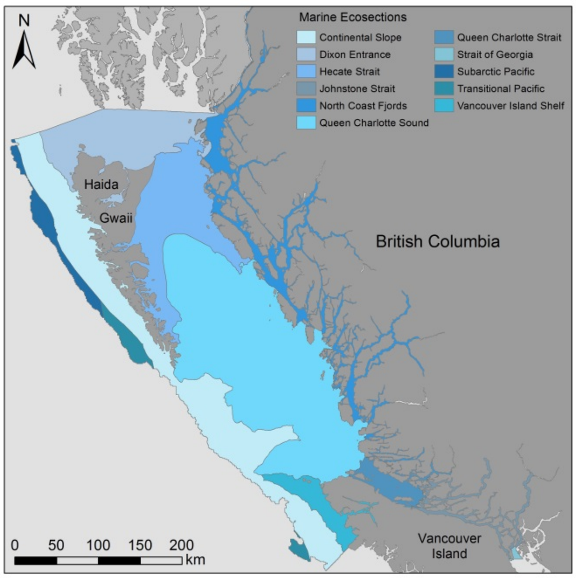

Figure 1. Map of the marine ecosections, classified based on broad-scale oceanographic and physiographic variations, within the Northern Shelf Bioregion (NSB).

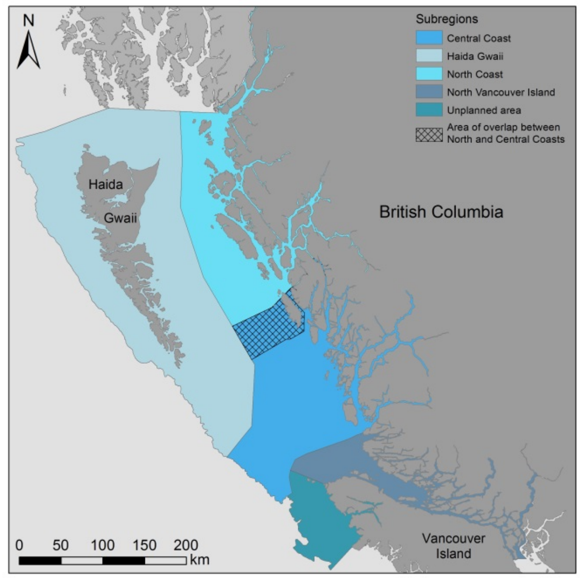

Figure 2. Map of the subregions for marine protected area network planning within the NSB.

Context:

The Government of Canada, Government of British Columbia, and 16 member First Nations are collaborating on the design and implementation of a network of marine protected areas (MPAs) in the Northern Shelf Bioregion (NSB; Figure 1). In the NSB, MPA network development is guided by the 2011 National Framework for Canada's Network of MPAs, and the 2014 Canada-British Columbia MPA Network Strategy ("the Strategy"). Focusing on ecological objectives related to Goal 1 of the Strategy, the ecological design strategies for the NSB describe how to spatially incorporate ecological conservation priorities (E-CPs) for protection within the MPA network. The design strategies include recommendations on the size, shape, connectivity, and protection level of MPAs, and the replication and representation of E-CPs, including ecological conservation targets.

Fisheries and Oceans Canada (DFO) Oceans Management Branch has requested that Science Branch provide recommendations on design strategies relevant to the development of a network of MPAs in the NSB. This advice may be applicable for the development of MPA networks in other areas in the Pacific Region.

This Science Advisory Report is from the May 23–25, 2017 regional peer review on the Review of Conservation Targets and Network Design Options for the Northern Shelf Bioregion Marine Protected Area (MPA) Network. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Canada

SUMMARY

- Ecological design strategies for the Northern Shelf Bioregional MPA Network describe how ecological conservation priorities (E-CPs), the ecological features to be prioritized in MPA network development, will be spatially incorporated in the MPA network for the Northern Shelf Bioregion (NSB).
- The design strategies focus on the E-CPs and guide achievement of Goal 1 of 6 from the Canada — British Columbia Marine Protected Area Network Strategy (2014): “to protect and maintain marine biodiversity, ecological representation and special natural features”.
- Ecological design strategies include ecological conservation targets that are quantitative estimates for how much of each spatial feature representing an E-CP should be included in the network, as well as key variables (i.e., size, shape, spacing, and protection levels of MPAs, connectivity, and the representation and replication of E-CPs).
- The design strategies provide a method for developing ecological conservation targets for the E-CPs based on recommendations in the literature, past practices, and expert opinion.
- Broad-scale coarse-filter E-CPs (i.e., ecological or habitat classification systems) are included to ensure the diversity of ecosystems and habitats are represented in the MPA network. Fine filter E-CPs include priority species or spatially discrete area-based features.
- Six spatial datasets were identified as coarse-filter features and assigned target ranges up to 10%, 20%, and 30% based on relative patch size and rarity.
- Fine-filter area-based features were scored and assigned to two target ranges based on the median of the frequency distribution of scores: low (10–30%) and high (20–60%).
- Fine-filter species-based features were scored and assigned to three target ranges: low (10–20%), medium (20–40%), and high (40–60%).
- It is recommended that these ecological conservation target ranges be used to develop initial site selection analyses that will identify potential areas that meet the ecological network objectives and ‘starting points’/’base case’ for possible MPA network configurations in the NSB. The ecological conservation target ranges are not intended as single species management recommendations.
- Areas of importance for each E-CP were identified and reviewed by experts. A decision framework was developed to select which E-CPs are appropriate for use in site selection analyses. The decision framework is based on species mobility, data availability, and data quality. This framework is appropriate to identify the E-CPs that can be used for initial site selection analyses to identify areas and network configurations that can meet the ecological network objectives.
- An approach was proposed for calculating the number of replicate areas needed to represent E-CPs based on patch size or rarity, stratified at the scale of ecosections or subregions in the NSB.
- Recommendations for MPA size and spacing are based on intermediate-sized adult/juvenile home ranges and estimated larval dispersal distance of species E-CPs identified in the literature. A minimum MPA size of 50–150 km^2 is recommended for the nearshore and shelf/slope. This minimum size does not preclude large MPAs. MPAs should be spaced between 40–200 km in the nearshore and shelf/slope. Within this range, nearshore MPAs

may be smaller, though spaced closer, while shelf/slope MPAs may be larger and further apart.

- A risk-based framework is proposed to assess the effectiveness of existing and proposed MPAs by accounting for the potential impacts of allowable human activities on E-CPs using scaling factors derived from a global meta-analysis of MPAs published in the scientific literature.
- It is recommended to designate at least 20-50% of the NSB MPA network as no-take (generally thought to correspond to International Union for Conservation of Nature (IUCN) Ia) or limited-take (generally thought to correspond to IUCN Ib-III) to be consistent with recommendations in the scientific literature that 20%-50% of ocean space be designated as no-take within a planning area.
- To inform delineation of the MPA network, the design scenario phase should include sensitivity analyses to evaluate the impacts of using different parameters.

BACKGROUND

MPA network development is underway in five priority bioregions in Canada's oceans. In the Pacific region, the Government of Canada, Government of British Columbia (BC), and 16 member First Nations are collaborating on marine planning in the Northern Shelf Bioregion (NSB) as the Marine Protected Area Technical Team (MPATT). Based on guidance provided by the Government of Canada (2011) and Canada — BC MPA Network Strategy (2014), a set of goals, objectives, principles, and design guidelines guided the development of conservation priorities, which are the ecological and cultural features to be prioritized for protection within the MPA network These factors also inform the identification of design strategies (Table 1), which describe how to spatially incorporate conservation priorities into the network.

Ecological conservation priorities (E-CPs) for the NSB have been identified (DFO 2017) and include species considered vulnerable, ecologically important, or of conservation concern, as well as areas of climate resilience, degraded areas, representative habitats, and Ecologically and Biologically Significant Areas (EBSAs). Recommendations for design strategies and spatial features (i.e., data layers) are now needed to develop robust site selection analyses that will identify areas of high conservation value based on the identified suite of E-CPs. Design strategies include ecological conservation targets (i.e., the proportion of each spatial feature representing E-CPs that will be included in the network,) as well as other key variables (i.e., size, shape, spacing, and protection levels of MPAs; connectivity; and replication). This focuses exclusively ecological design strategies related to Goal 1 of the Canada-BC MPA Network Strategy (2014), which specifies the protection and maintenance of marine biodiversity, ecological representation and special natural features. Ecological design strategies are one component of the planning process and will be incorporated with cultural, socio-economic, and recreational values and stakeholder feedback into the MPA network design in the design scenarios phase of the planning process.

Table 1. Ecological network design principles and related guideline concepts relevant to design strategies for the MPA network in the NSB (Canada-BC MPA Network Strategy 2014).

Ecological Network Design Principle	Guideline Concept Relevant to Ecological Design Strategies
Principle 1. Include the full range of biodiversity present in Pacific Canada	Representation Replication
Principle 2. Ensure ecologically or biologically significant areas (EBSAs) are incorporated	Protection of unique or vulnerable habitats Protection of foraging or breeding grounds Protection of source populations
Principle 3. Ensure ecological linkages	Connectivity
Principle 4. Maintain long-term protection	MPA protection level
Principle 5. Ensure maximum contribution of individual MPAs	Size Shape Spacing

Scope

This work:

1. Identifies ecological design strategies for MPA network planning in the NSB.
2. Focuses on E-CPs selected under Goal 1 of the Canada-BC MPA Network Strategy.
3. Does not address site selection analyses specific to any particular design scenarios.

ASSESSMENT

MPATT solicited expert advice and consulted with stakeholders to guide the application of the network design principles identified in the Canada-BC MPA Network Strategy (2014). Through this feedback, several ecological guideline concepts emerged (Table 1). We have developed design strategies to provide necessary additional guidance to facilitate the incorporation of representation, replication, MPA protection level, size, and spacing in site selection analyses.

Representation

MPA networks should include the full range of biodiversity present within the study area (Canada-BC MPA Strategy 2014). To achieve this objective, international MPA design guidance recommends that comprehensive MPA networks capture representative examples of E-CPs at both a coarse and fine scale. Coarse-filter features are broad-scale and include ecological classification systems that span the bioregion, while fine-filter features are priority species or spatially discrete area-based features. E-CPs have been subdivided into coarse- and fine-filter features and spatial targets were developed separately for each set of features. The ecological conservation targets will be used during the design scenarios phase of network planning both to inform the initial site-selection process using the Marxan decision support tool and to evaluate whether and how potential network configurations meet the ecological objectives.

Coarse-filter features

Coarse-filter features are included in site selection analyses to ensure that characteristic natural areas and a broad suite of species, habitats, and ecological processes are protected in MPA network configurations, even when detailed spatial data are not available for all features. The design guidelines (Lieberknecht et al. 2016) recommend that multiple ecological classification systems are targeted as coarse-filter features and several were identified as E-CPs. Within each classification system, best practices recommend assigning higher targets to smaller, rarer habitat classes because they are likely more susceptible to disturbance while common, widespread classes, which are generally less threatened, are assigned lower targets to optimize conservation resources (DFO 2018). Therefore, spatial targets were calculated for coarse-scale features such that the area protected for each habitat class within a classification system is proportional to the square root of the class' total area within the region divided by the smallest habitat class. This results in smaller classes with proportionally higher targets.

Fine-filter Features

To develop the target methodology for fine-filter E-CPs, the literature recommends a systematic evidence-based approach based on ecological factors and expert opinion, when data are not available for strictly quantitative approaches. Expanding upon past approaches (e.g., Ban et al. 2013, DFO 2018), ecological criteria and subject matter expert feedback were incorporated in an explicit and systematic scoring system. Similar to the method followed in the Scotian Shelf Bioregion (DFO 2018) that incorporates multiple criteria into a single score, the square root of the sum of squares was used to calculate target scores based on ecological criteria developed for the E-CPs and an additional expert review criterion.

Species-based Conservation Priorities (excluding marine birds)

Based on previous work, all taxa, with the exception of marine birds, were assigned scores based on their conservation status, vulnerability, and ecological role (DFO 2017). Conservation status is commonly used to identify E-CPs that warrant higher targets (Ban et al. 2013, DFO 2018) while vulnerability has been incorporated in fewer analyses (though see DFO 2018). Conservation status and vulnerability were incorporated as a single conservation concern criterion in the scoring matrix due to their likelihood of correlation (Figure 3). E-CPs were assigned high scores for conservation status if they were deemed highly threatened at a global, national, or provincial scale. Vulnerability scores were assigned based on an approach developed for fishes (Cheung et al. 2005), modified to incorporate subject matter expert knowledge for invertebrates.

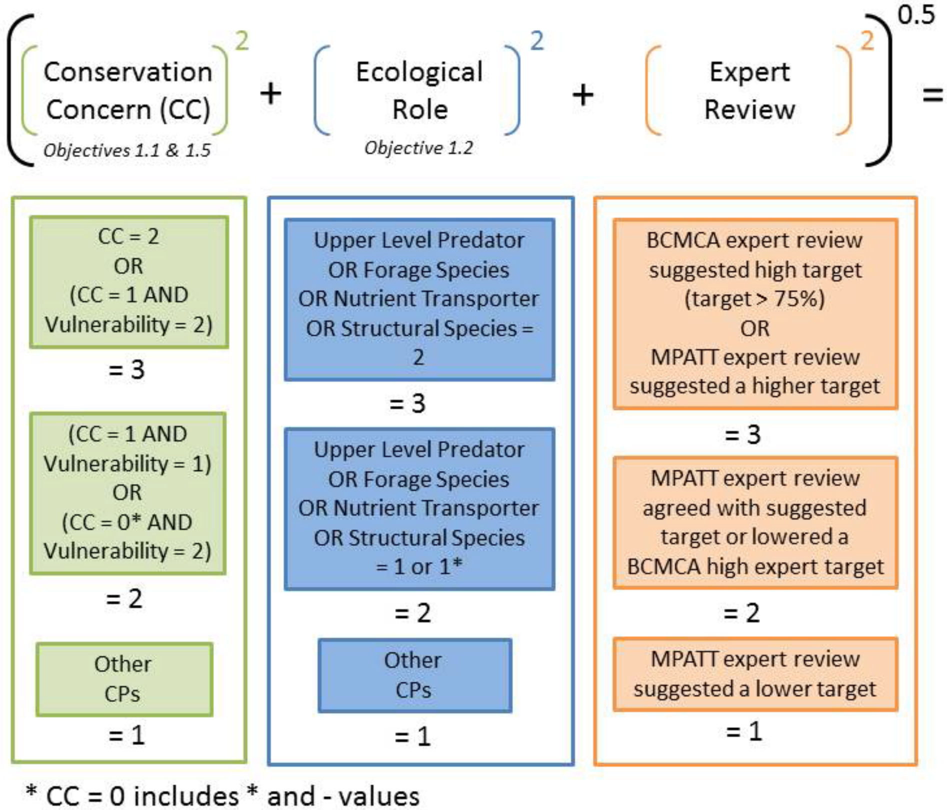

Figure 3. *Framework for assigning target scores to the species-based conservation priorities, excluding marine birds. A conservation concern score value of * indicates there was insufficient information to assign a score, and values of 0 and – indicate the criterion was not applicable for that species (DFO 2017). Ecological role scores were identified in DFO 2017.*

<u>Species-based Conservation Priorities — Marine Birds</u>

Vulnerability was not assessed explicitly when developing the list of marine bird E-CPs (DFO 2017); therefore conservation status alone was used as the conservation concern criterion for calculating target scores. The scores for conservation status are at a global, national, or provincial scale, with a higher value assigned to species deemed more threatened at any scale (DFO 2017). Priority marine bird were identified in DFO 2017 from work by Environment and Climate Change Canada (ECCC 2013) and include vulnerable species, species of conservation or management concern, and widely distributed and abundant “stewardship” species. Scores were rescaled to match the other criteria (Figure 4).

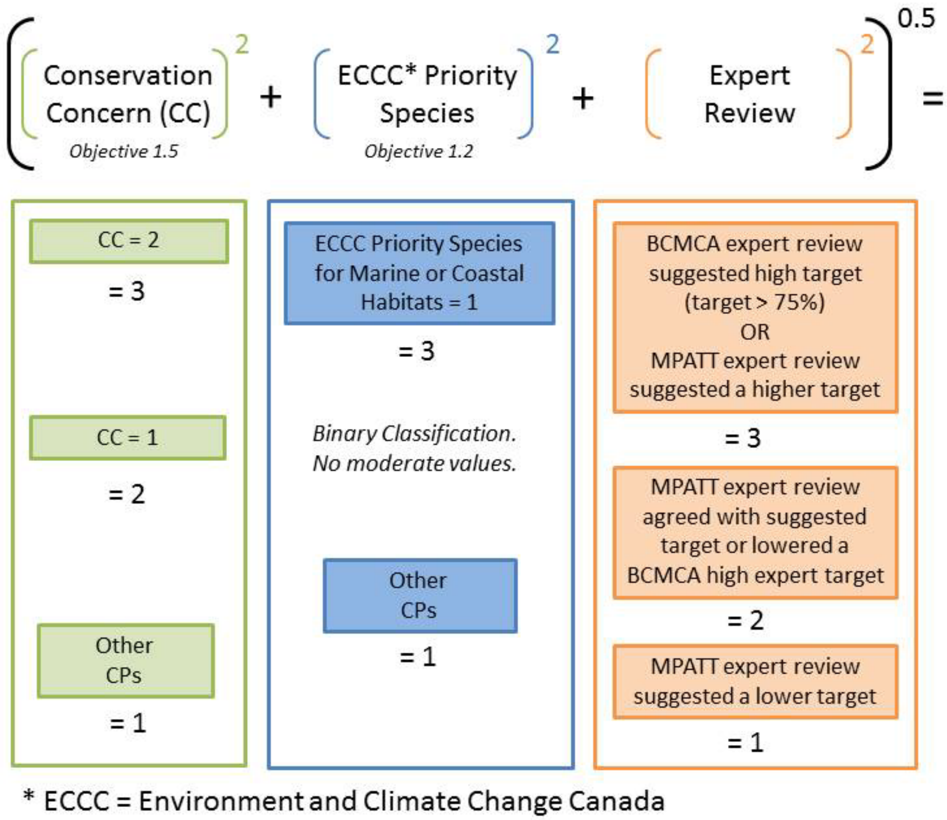

Figure 4. Framework for assigning target scores to the marine bird species-based conservation priorities.

Assignment of Ecological Conservation Targets for Species-based Conservation Priorities

Two options were provided for assigning species-based E-CPs to high, medium, or low target ranges, using either quartiles or thirds to split the frequency distribution of target scores. The low target range of 10–20% represents species of lower vulnerability, lower priority, and/or lower conservation concern. The medium target range was 20–40% and the high target range was 40–60%. These ecological conservation target ranges align well with those applied in other analyses and processes in the region and globally. It was recommended that design scenarios examine how using different quantiles for assigning target ranges influences site selection analyses in Marxan.

Area-based Conservation Priorities

Each fine-scale area-based E-CP was scored based on whether they met the relevant ecological objectives assessed (Figure 5). Scoring was binary, with values of 1 or 3 for ecological objectives to match the scale of the expert review criterion (1–3). Because the area-based E-CPs were assessed against a larger suite of ecological objectives than the species-based E-CPs, they were analyzed separately and the median value from the frequency distribution of target scores was used to assign E-CPs to two target ranges: low (10-30%) and high (20-60%).

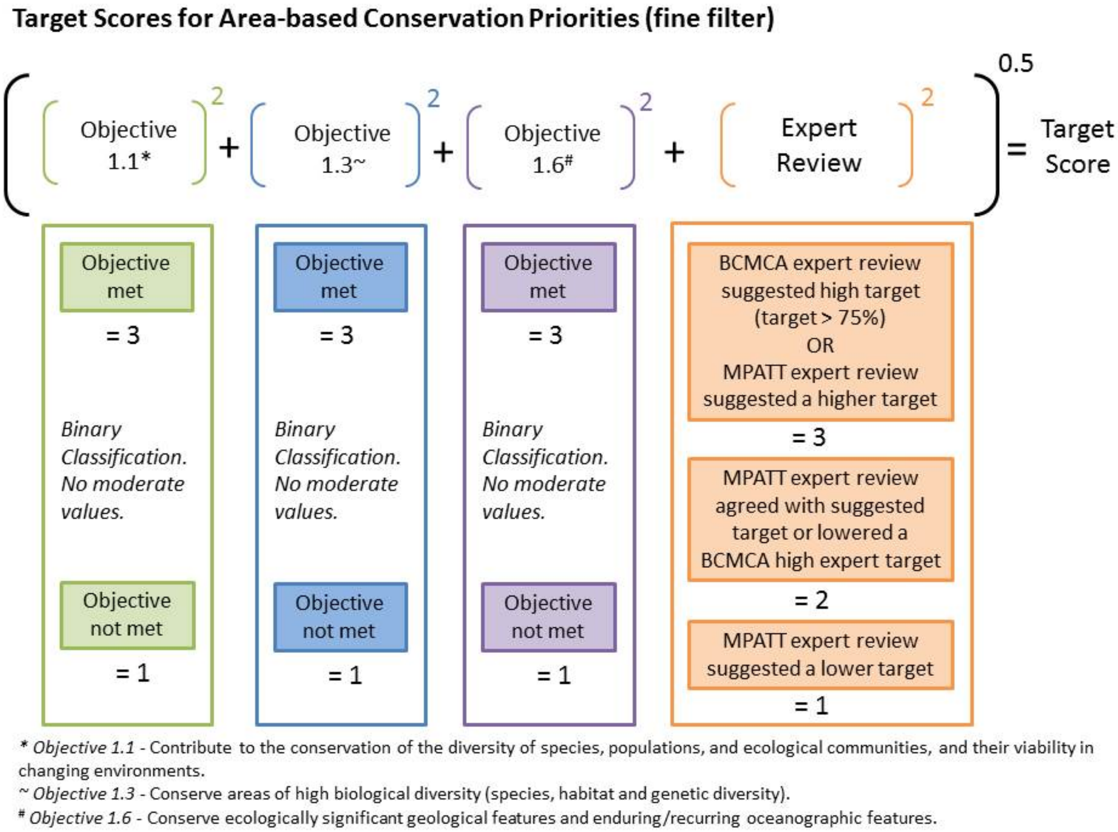

Figure 5. Framework for assigning target scores to the fine-filter area-based conservation priorities.

Subject Matter Expert Review

Expert feedback was incorporated explicitly as a criterion in the scoring approach, using scores from a prior expert engagement completed during the BCMCA process (Ban et al. 2013) and an updated expert review tailored to the E-CPs and design strategies of the NSB. We solicited a new round of expert feedback in March–June 2017. Subject matter experts from the Federal Government, the Government of BC, and First Nations were asked to review the initial target ranges and offer their support or provide a rationale for alternatives. Based on expert feedback during the peer review meeting, this review was expanded in September–October 2017 to include additional experts within the Federal Government. When experts suggested a lower target range the expert review score was decreased by 1 (Figure 3, Figure 4, Figure 5). Conversely, if a higher target range was suggested, the score was increased by 1. In addition, experts were also asked to identify the types of spatial features important for each E-CP and assess the available spatial datasets for use in site-selection analyses.

Approach to Assessing Features Appropriate for Marxan Analyses

Although all E-CPs are amenable to spatial management at an appropriate scale, the planning process should aim to set targets for those priority features that can benefit from spatial protection measures at the scale of the NSB (Lieberknecht et al. 2016). For example, highly mobile species may be difficult to protect in static MPAs, unless the species aggregates in predictable geographic locations or utilizes particular habitat types at key lifecycle stages or times of year. In such cases, the priority feature for which to set targets is the representative spatial feature (i.e., habitats or geographic locations), such as seasonal breeding, feeding, and resting areas for birds, seal haul-outs, or key staging areas along a migration route of a migratory species.

To inform the use of E-CPs in the design scenarios, a decision framework was developed for determining whether the E-CPs, and spatial features representing them, were appropriate for inclusion in site selection analyses using the Marxan decision support tool (Figure 6). If no data are available, the E-CP is documented as a 'data gap'. E-CPs with appropriate spatial data should be included in Marxan as a 'regular feature' with the assigned target. For highly mobile species, defined as having a home range greater than 50 km, spatial data for known areas of importance is prioritized and distribution data may be used as a 'low target feature' assigned the lowest target range (i.e., 10-20%). Only datasets that are of high quality, at an appropriate scale, and comprehensive for the NSB, or a subregion within the NSB, should be included in Marxan site selection analyses as a 'regular feature'. If the available data are not appropriate for Marxan analyses, the E-CP should not be included in Marxan analyses with a target but its representation in potential MPA network configurations could still be assessed post-hoc as a 'non-Marxan feature'.

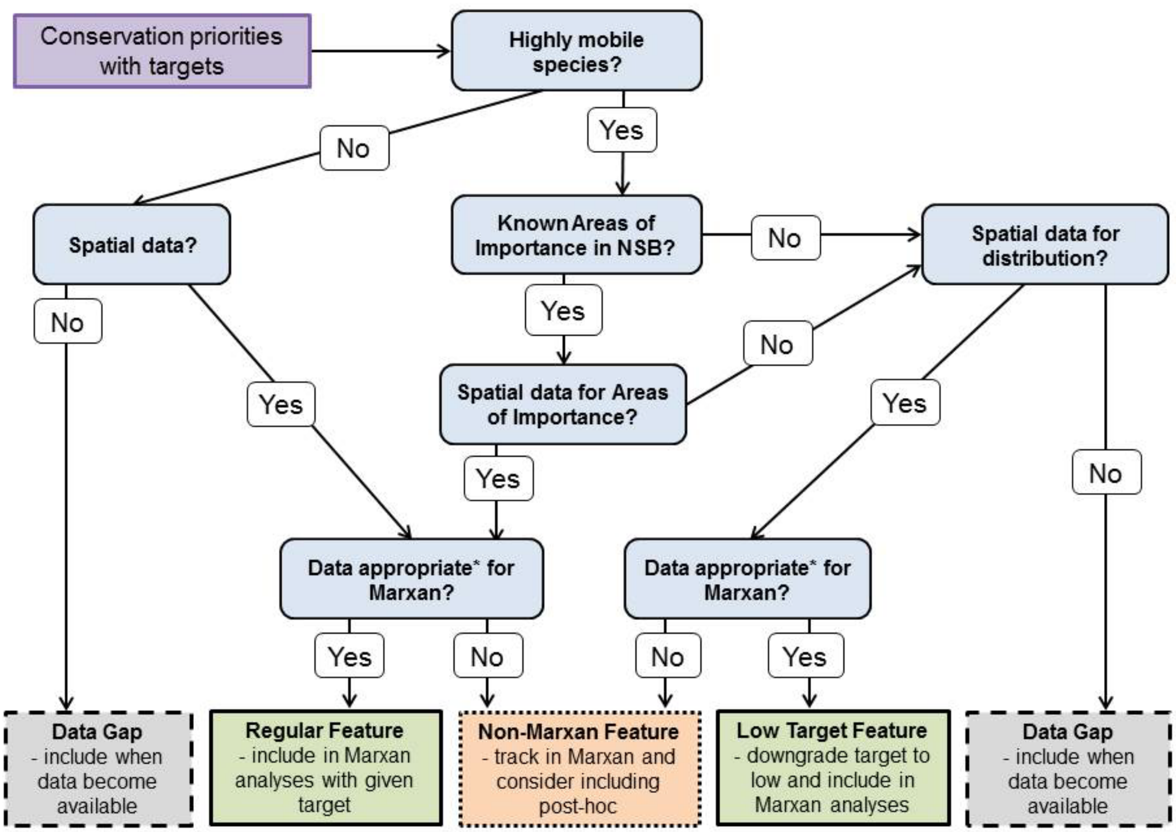

*Figure 6. Flow diagram to guide the identification of conservation priorities appropriate for inclusion in design scenarios. * Data should be high quality, at an appropriate scale, and comprehensive for the NSB to be appropriate for Marxan. Preference will be given to data that have been groundtruthed.*

Replication

MPA network design principles recommend including spatially separated replicates of representative habitats and special or vulnerable features to provide insurance against local disturbance, to encapsulate natural variation, and mitigate uncertainty associated with capturing representative habitats and features (Lieberknecht et al. 2016).

For the NSB, replication was recommended at the scale of ecosections or the NSB subregions. The ecosections are a classification based on broad-scale oceanographic and physiographic variations in the Canadian Pacific, with units 100–1000s of km in extent (Figure 1). NSB subregions (i.e., Haida Gwaii, Central Coast, North Coast, and North Vancouver Island) are planning areas demarcated with a combination of First Nation territorial and local government administrative boundaries and similar ecological characteristics (Figure 2). The subregions partition the larger ecosections north to south and east to west, and therefore ensure that replicates will be spatially dispersed.

It is also recommended that the number of replicates for each E-CP vary based on patch size and rarity, stratified at the scale of ecosections or subregions in the NSB. The recommended minimum number of replicates will vary depending on the rarity and patch size of the feature, but should be at least 2–3 per ecosection or subregion, where possible.

MPA Protection Levels

Management restrictions within MPA networks can range from strict no-take areas, where all extractive activities are prohibited, to areas that allow the sustainable use of natural resources.

A risk-based decision framework was developed to account for how individual E-CPs may be affected by allowable activities in an MPA (Figure 7). The underlying premise of the framework is that MPAs with allowed activities that impact E-CPs do not provide the same conservation benefit as MPAs with no permissible impacts on those same E-CPs. The framework provides a mechanism to down-weight the contribution of a given MPA to the targets for certain E-CPs that may be influenced by cumulative effects of allowed activities within that MPA. It is intended to be used iteratively during the design scenarios phase to ensure that an appropriate amount of area is being targeted for E-CPs, given the range of activities that occur. The method can be used to assess the levels of protection for individual E-CPs afforded by existing MPAs and evaluate proposed MPAs with management recommendations that may be considered for inclusion in the MPA network, thereby highlighting ecological conservation targets that are not being met to guide the identification of additional areas that may be considered for protection.

This general protection levels framework can incorporate any risk-based or impact-based scoring method that can evaluate whether an activity has the potential to alter a E-CP directly or indirectly to assign levels of potential impact. Using one or more of these risk assessment methods, each allowed activity within an MPA can be evaluated for its potential to impact a given E-CP. Using the resulting matrix of impact scores for each E-CP-activity interaction, potential cumulative impacts of multiple activities can be assessed and a level of potential impact can be assigned to each E-CP within a given MPA. If none of the proposed activities have the potential to impact a given E-CP, the level of potential impact for that E-CP in that MPA is negligible. If any of the proposed activities has the potential to impact the E-CP, a level of potential impact for that E-CP in that MPA is determined by following a decision framework (Figure 7).

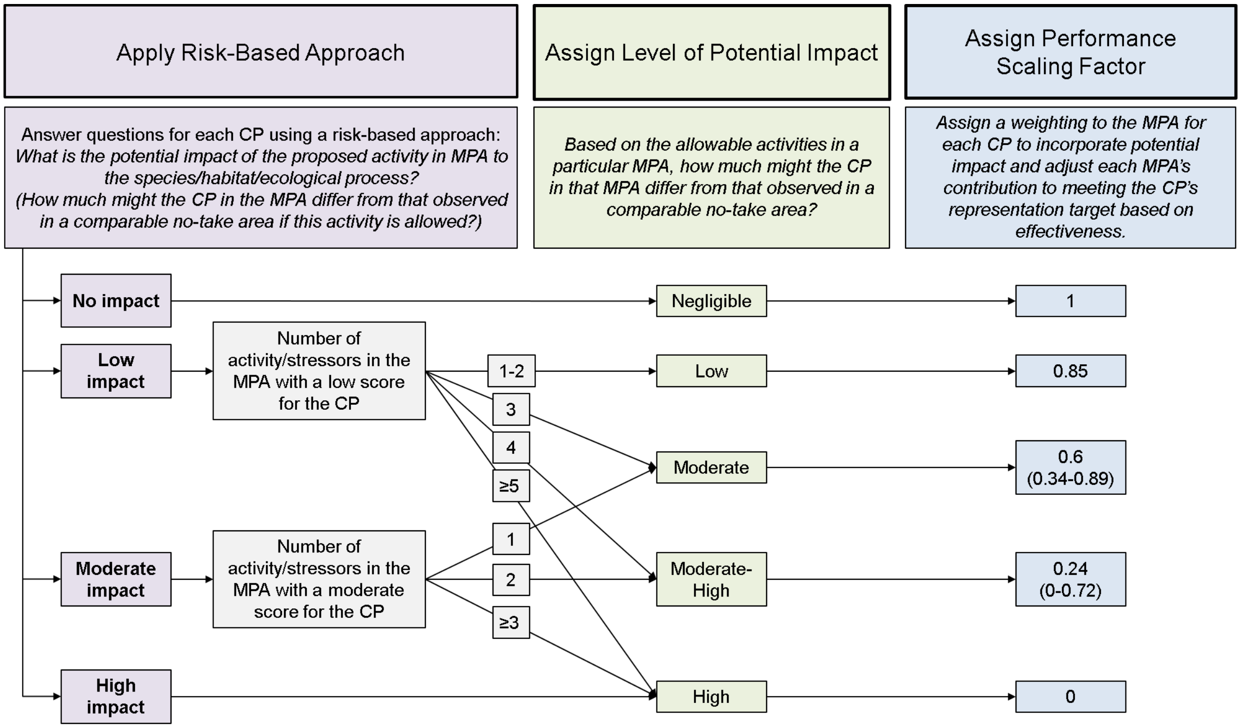

Figure 7. Decision framework for incorporating risk-based approaches to assign levels of potential impact to ecological conservation priorities (CPs) from allowable activities in each MPA and performance scaling factors (Ban et al. 2014) used to adjust the calculation of the contribution of each MPA to the ecological conservation target for each CP based on the assigned level of potential impact.

MPA Size

MPAs need to be an adequate size to protect viable populations, habitats, and ecological processes within their boundaries. Because MPAs aim to protect a variety of species with variable life history characteristics, movements, interactions, and habitat associations, there is no one ideal MPA size.

Recommendations on MPA size were developed based on the available literature on adult movements reviewed and summarized by Burt et al. (2014) for a subset of marine fish, invertebrate, and algal species in BC. Building on this synthesis by Burt et al. (2014), species were assigned into nearshore and shelf/slope categories, with the understanding that these regions likely support different suites of species, and that the adult mobility of the predominant species in these regions may vary. Where feasible, literature was used to fill gaps for species-based E-CPs that had not been reviewed by Burt et al. (2014). Next, the compiled data from the updated synthesis was used to determine the mean, median, and frequency distribution of the home range for species that use the nearshore and the slope/shelf areas for at least part of their life history. Recommendations on MPA size were generated from these metrics, adhering to the rule of thumb that MPAs should be at least twice as large as the home range of the species with intermediate home ranges sizes (Palumbi 2004).

Results from the synthesis revealed that more than half of the fish, invertebrate, and algal E-CPs that spend at least part of their post-larval life history in nearshore waters and move within a range of less than 1 km. For these species, smaller MPAs (13-50 km^2) would likely be appropriate. Species with intermediate home ranges would not necessarily be protected within these boundaries. For nearshore species with adult movements of < 1km, 1–10 km and 10–50 km (the mean home range was 7.9 km (SD 14.6 km). For species within those adult movement ranges that use the shelf-slope, the mean home range was 9.4 km (SD 15.1 km). Based on the mean home range + 1 SD for the nearshore and shelf-slope species, a minimum MPA size between 50 km^2 and 150 km^2 was recommended. Although the mean home range for these species was between 7–9 km, many species exhibit larger movements; thus, larger MPAs also should be considered. For highly mobile species (50–1000 km, >1000 km movement classes), it was recommended that MPAs target critical life stages or aggregations if they are spatially distinct, as the spatial scale of MPAs required to cover their distributions are likely prohibitively large.

MPA Spacing

Spacing is the primary tool used to date for addressing ecological connectivity within an MPA network. Spacing guidelines vary in the literature and in practice (Burt et al. 2014) and, like MPA size, are influenced by larval and nutrient transport and the movement of adults and juveniles. One commonly used heuristic approach for determining MPA spacing is based on dispersal distance estimates.

To develop spacing guidelines for the MPA network in the NSB, a list of PLD (PLD: pelagic larval duration, the time larvae spend as plankton in the water column) values for a subset of fish, invertebrate, and algae E-CPs compiled by Burt et al. (2014) was updated, adding values for species E-CPs that had not been reviewed by that synthesis. Species were grouped based on the spatial area in which they generally release their larvae/spores: intertidal (area between high and low tides), nearshore-subtidal (0–60 m depth), nearshore to shelf/slope (spawn across a broad spatial and/or depth range), or shelf/slope (larvae released offshore or at deeper depths (>60 m).

A correlation analysis of PLD and dispersal distance was conducted using data compiled from existing studies (Shanks et al 2003; Shanks 2009) and that relationship was used to estimate dispersal distance for the E-CPs for which PLD information was available. For species for which PLDs were unavailable, dispersal distance estimates were included from the literature, where available. Where both PLD and dispersal distance were available, the dispersal estimate from the literature was used.

As with MPA size, it was recommended that MPA spacing guidelines be based on the species with intermediate larval dispersal distances). For species with intermediate PLDs that use the intertidal and nearshore subtidal habitats the median estimated larval dispersal distance was 58 km ranging between 42 and 201 km. Given the ranges of estimated larval dispersal distance for species with intermediate larval dispersal, it was recommended that spacing of MPAs within the NSB should be between 40 and 200 km. Within recommended size and spacing ranges, nearshore MPAs can be smaller, though spaced closer together, whereas shelf/slope MPA can be larger but spaced further apart to accommodate differing movement and dispersal distances (Burt et al. 2014).

Challenges and Limitations

- The ecological conservation target ranges are recommended as an ecological starting point for Marxan analyses and not intended as single species management recommendations.
- Ecological classifications (coarse-filter features) are used to ensure the representation of the diversity of ecosystems and habitats in the NSB MPA network. However, due to human impacts, habitat quality or ecosystem intactness will vary across space, and highly impacted sites may not be truly ecologically representative. To overcome this limitation, an

examination of cumulative impacts could be incorporated into the site selection process. Sensitivity analyses should be performed to investigate the impact of incorporating naturalness into the coarse-filter features.

- Not all of the recommended ecological conservation target ranges matched expert recommendations due to a variety of expert opinions and the standardized scoring system, which treated all the criteria equally when calculating target scores. Because the scores for the ecological criteria were approved in a previous peer review (DFO 2017), the values were maintained in the current assessment, even in cases where subject matter experts and expert CSAS meeting participants voiced disagreement with the original scores. Any discrepancies between the final target ranges and expert recommendations have been documented and can be assessed during sensitivity analyses performed as part of the site selection analyses. Future analyses may benefit from combining the identification of E-CPs and scoring of the ecological criteria with the development of appropriate ecological conservation targets.

Sources of Uncertainty

- The full suite of spatial datasets required for the site selection analyses is currently in development. Therefore, it was not possible to perform sensitivity analyses to test the appropriateness of the recommended ecological conservation target ranges or replication parameters. Sensitivity analyses should be performed as part of the design scenarios phase.
- Although representative of the species that inhabit the study region, a limited number of species were used to develop home ranges and larval dispersal distances to guide MPA size and spacing recommendations. Furthermore, because the BC coastline is influenced by different oceanographic currents than areas where many home range and PLD estimates originate, our estimates may not accurately reflect dispersal distances for species in this region.
- The risk-based approach for assessing MPA protection levels allows for the consideration of E-CP-specific and cumulative impacts but there is uncertainty associated with assigning risk scores to interactions between activities and E-CPs and a lack of knowledge of all impacts faced by each E-CP.
- MPA performance scaling factors have high variability and were developed based on data for fish species in areas outside of BC, including tropical and temperate regions. Therefore, there is uncertainty in the application of these scaling factors to MPAs designed to protect a broader suite of species in BC.

OTHER CONSIDERATIONS

Connectivity

Ecological connectivity within MPA networks is important for maintaining biodiversity and resilience. The effectiveness of individual MPAs can increase if they are connected by a flow of dispersing eggs or larvae, migrating juveniles and adults, and/or nutrients and other materials. Ecological connectivity is often assessed post-hoc due to a general lack of guidelines for incorporating connectivity in initial phases of MPA network design. While the primary considerations in MPA design used to date to address connectivity are related to spacing and shape, there are other approaches that should be used during the design scenarios phase to assess the four levels of connectivity (genetic, population or demographic, community, and ecosystem) that can influence the effectiveness of a network of MPAs. It is recommended that connectivity metrics be considered in the evaluation of design scenarios.

Climate change

Warming sea temperatures, ocean acidification, oxygen minimum zones, and sea level rise, can act singly and cumulatively leading to complex and unprecedented impacts to local and regional marine communities (Doney et al. 2012). A coherent, well connected, and representative network of MPAs that protects biodiversity can help promote the resiliency of ecosystems to change (Carr et al. 2017). As such, the establishment of MPAs is one of the few management tools available to address broad-scale effects of environmental change, especially climate change.

Cumulative impacts

To meet the full range of objectives from MPA networks, managers must mitigate impacts from multiple stressors, both within the MPA and the surrounding ecosystems. MPAs may assist in addressing broad-scale environmental impacts but cumulative impacts from multiple stressors may compromise the effectiveness of MPAs and should be considered when characterizing risk and evaluating MPA effectiveness.

The protection levels decision framework for calculating the impact of activities to E-CPs in MPAs does consider cumulative impacts. However, additional work is needed to evaluate whether MPAs are located in areas exposed to multiple stressors and how to mitigate the potential associated effects.

CONCLUSIONS AND ADVICE

- Recommendations are provided for development of ecological MPA network design strategies, including ecological conservation targets that are quantitative estimates for how much of the spatial features representing each E-CP should be included in the network, as well as key variables (i.e., size, shape, spacing, and protection levels of MPAs, connectivity, and replication of E-CPs).
- Spatial targets were recommended for coarse-filter ecological classification features based on feature sizes and an approach was developed for fine-filter area-based and species-based E-CPs based on conservation concern, vulnerability, ecological role, and expert review.
- Application of the approach for fine-filter E-CPs assigned 55% of the area-based E-CPs to a low target range and 45% to the high target range. Target ranges for species-based E-CPs were determined using either quartiles or thirds of the frequency distribution of the scores. It is recommended that both suites of target ranges be tested in the design scenarios.
- It is recommended that these ecological conservation target ranges be used to develop initial site selection analyses that will identify potential areas that meet the ecological network objectives and as the ‘starting points’/’base case’ for possible MPA network configurations in the NSB.
- Not all E-CPs have associated spatial data appropriate for site selection analyses. An appropriate framework was developed to select which E-CPs and spatial features can be

used as inputs to Marxan analyses and which can be assessed based on the analysis results.

- An approach is proposed to determine the number of replicate areas needed to represent E-CPs based on patch size or rarity, and stratified at the scale of ecosections or subregions in the NSB.
- It is recommended that the approach for replication be used to assess how well results of initial site selection analyses meet ecological network objectives, with consideration of the availability (abundance) of E-CPs relative to the full suite of E-CPs.
- Proposed recommendations for MPA size and spacing were based on home ranges and estimated larval dispersal distances, respectively, for species-based E-CPs identified in the literature.
- A minimum MPA size of 50–150 km^2 in the nearshore and shelf-slope regions is recommended. Sessile species may also benefit from smaller MPAs, ranging from 13–50 km^2. This minimum size does not preclude the development of large MPAs.
- A guideline of 40–200 km spacing between MPAs is recommended for the NSB MPA network.
- A risk-based framework is proposed to assess the performance of existing and proposed MPAs in meeting the ecological conservation targets by accounting for potential impacts of allowable human activities on E-CPs using scaling factors derived from the scientific literature.
- It is recommended that the assessment of the proposed framework for protection levels be fully evaluated during the design scenarios phase.
- Based upon recommendations from the scientific literature that 20–50% of ocean space be designated as no-take within a planning area to meet ecological network objectives (e.g., protecting biodiversity), it is recommended that, minimally, a proportion falling within this range of the NSB MPA network be found in no-take (generally thought to correspond to IUCN Ia) or limited-take (generally thought to correspond to IUCN Ib-III) MPAs.
- Where data are lacking or areas of known importance are not reflected in existing data sets, expert review/input should be used to validate or ground truth outputs.
- It is recommended that relevant spatial data be incorporated into the analysis as they become available.
- It is recommended that sensitivity analyses be undertaken during the design scenarios phase to assess the impacts of using different parameters, including:
  - Ecological conservation target ranges, especially when there is conflicting expert opinion. This should be completed before another level of expert review is necessary.
  - Use of 10% as a minimum threshold for coarse-filter feature targets
  - Coarse filter (habitats) vs. fine filter (species) targets
  - Nearshore vs. offshore to assess the impact of variable data availability and quality
  - Incorporation of naturalness in coarse-filter features
  - Proportions of the network in no-take MPAs (e.g., 20%, 30%, 40%, etc.)
- Recognizing existing spatial protection within the NSB, it is recommended that initial design scenarios incorporate (account for) existing protected and conserved areas, and assess them for their contribution to ecological conservation targets.

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SOURCES OF INFORMATION

This Science Advisory Report is from the May 23–25, 2017 regional peer review on the Review of Conservation Targets and Network Design Options for the Northern Shelf Bioregion Marine Protected Area (MPA) Network. 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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APPENDIX A: RECOMMENDED ECOLOGICAL CONSERVATION TARGETS

Table A1. Species-based fine-filter ecological conservation priorities and recommended ecological conservation target classes and ranges based on subdividing the frequency distribution of target scores using quartiles or thirds. † indicates Orca ecotypes (i.e., not separate species).

Higher Group	Species Group	Common Name	Scientific Name	Ecological Target Class and Range (based on quartiles)	Ecological Target Class and Range (based on thirds)
Bony Fishes	Flatfishes	Arrowtooth Flounder	*Atheresthes stomias*	Medium (20–40%)	Low (10–20%)
		Dover Sole	*Microstomus pacificus*	Low (10–20%)	Low (10–20%)
		Pacific Halibut	*Hippoglossus stenolepis*	Medium (20–40%)	Medium (20–40%)
		Petrale Sole	*Eopsetta jordani*	Low (10–20%)	Low (10–20%)
		Rex Sole	*Glyptocephalus zachirus*	Low (10–20%)	Low (10–20%)
		Rock Sole	*Lepidopsetta bilineata*	Low (10–20%)	Low (10–20%)
	Forage Fishes	Capelin	*Mallotus villosus*	Medium (20–40%)	Low (10–20%)
		Eulachon	*Thaleichthys pacificus*	High (40–60%)	High (40–60%)
		Pacific Herring	*Clupea pallasii*	Medium (20–40%)	High (40–60%)
		Pacific Sand Lance	*Ammodytes hexapterus*	Medium (20–40%)	Medium (20–40%)
		Pacific Sardine	*Sardinops sagax*	Low (10–20%)	Low (10–20%)
		Surf Smelt	*Hypomesus pretiosus*	Medium (20–40%)	Low (10–20%)
	Groundfishes	Lingcod	*Ophiodon elongatus*	Medium (20–40%)	Medium (20–40%)
		Sablefish	*Anoplopoma fimbria*	Medium (20–40%)	Medium (20–40%)
		Wolf–Eel	*Anarrhichthys ocellatus*	Low (10–20%)	Low (10–20%)
	Mesopelagic Fishes	Northern Lampfish	*Stenobrachius leucopsarus*	Low (10–20%)	Low (10–20%)
		Northern Smoothtongue	*Leuroglossus schmidti*	Low (10–20%)	Low (10–20%)
	Native Salmonids	Chinook Salmon	*Oncorhynchus tshawytscha*	High (40–60%)	High (40–60%)
		Chum Salmon	*Oncorhynchus keta*	Medium (20–40%)	Medium (20–40%)
		Coho Salmon	*Oncorhynchus kisutch*	Medium (20–40%)	Medium (20–40%)
		Pink Salmon	*Oncorhynchus gorbuscha*	Medium (20–40%)	Medium (20–40%)
		Sockeye Salmon	*Oncorhynchus nerka*	Medium (20–40%)	Medium (20–40%)
		Cutthroat Trout	*Oncorhynchus clarkii*	Medium (20–40%)	Low (10–20%)
		Steelhead	*Oncorhynchus mykiss*	Medium (20–40%)	Low (10–20%)
		Dolly Varden	*Salvelinus malma lordi*	Medium (20–40%)	Medium (20–40%)
	Pelagic Fishes	Albacore Tuna	*Thunnus alalunga*	Medium (20–40%)	High (40–60%)
		Ocean Sunfish	*Mola mola*	Low (10–20%)	Low (10–20%)
	Rockfishes	Black Rockfish	*Sebastes melanops*	Medium (20–40%)	Low (10–20%)
		Blackspotted Rockfish	*Sebastes melanostictus*	High (40–60%)	High (40–60%)
		Bocaccio	*Sebastes paucispinis*	High (40–60%)	High (40–60%)

Higher Group	Species Group	Common Name	Scientific Name	Ecological Target Class and Range (based on quartiles)	Ecological Target Class and Range (based on thirds)
Bony Fishes (cont'd)	Rockfishes (cont'd)	Canary Rockfish	*Sebastes pinniger*	Medium (20–40%)	Medium (20–40%)
		China Rockfish	*Sebastes nebulosus*	Medium (20–40%)	Medium (20–40%)
		Copper Rockfish	*Sebastes caurinus*	Medium (20–40%)	Low (10–20%)
		Darkblotched Rockfish	*Sebastes crameri*	Medium (20–40%)	High (40–60%)
		Greenstriped Rockfish	*Sebastes elongatus*	Low (10–20%)	Low (10–20%)
		Pacific Ocean Perch	*Sebastes alutus*	Low (10–20%)	Low (10–20%)
		Quillback Rockfish	*Sebastes maliger*	Medium (20–40%)	Medium (20–40%)
		Redstripe Rockfish	*Sebastes proriger*	Medium (20–40%)	Low (10–20%)
		Rosethorn Rockfish	*Sebastes helvomaculatus*	Low (10–20%)	Low (10–20%)
		Rougheye Rockfish	*Sebastes aleutianus*	High (40–60%)	High (40–60%)
		Shortraker Rockfish	*Sebastes borealis*	Medium (20–40%)	Medium (20–40%)
		Silvergray Rockfish	*Sebastes brevispinis*	Low (10–20%)	Low (10–20%)
		Tiger Rockfish	*Sebastes nigrocinctus*	Medium (20–40%)	Medium (20–40%)
		Vermilion Rockfish	*Sebastes miniatus*	Low (10–20%)	Low (10–20%)
		Widow Rockfish	*Sebastes entomelas*	Medium (20–40%)	Low (10–20%)
		Yelloweye Rockfish	*Sebastes ruberrimus*	High (40–60%)	High (40–60%)
		Yellowmouth Rockfish	*Sebastes reedi*	Medium (20–40%)	Medium (20–40%)
		Yellowtail Rockfish	*Sebastes flavidus*	Low (10–20%)	Low (10–20%)
		Longspine Thornyhead	*Sebastolobus altivelis*	Medium (20–40%)	Medium (20–40%)
		Shortspine Thornyhead	*Sebastolobus alascanus*	Medium (20–40%)	Medium (20–40%)
	Roundfishes	Pacific Cod	*Gadus macrocephalus*	Medium (20–40%)	Low (10–20%)
		Pacific Hake	*Merluccius productus*	Medium (20–40%)	Medium (20–40%)
		Walleye Pollock	*Theragra chalcogramma*	Medium (20–40%)	Low (10–20%)
	Sturgeons	Green Sturgeon	*Acipenser medirostris*	Medium (20–40%)	Medium (20–40%)
	Surfperches	Shiner Perch	*Cymatogaster aggregata*	Low (10–20%)	Low (10–20%)
Elasmobranchs	Demersal Sharks	Bluntnose Sixgill Shark	*Hexanchus griseus*	High (40–60%)	High (40–60%)
		Pacific Sleeper Shark	*Somniosus pacificus*	Medium (20–40%)	Medium (20–40%)
		Spiny Dogfish	*Squalus suckleyi*	High (40–60%)	High (40–60%)
	Pelagic Sharks	Basking Shark	*Cetorhinus maximus*	Medium (20–40%)	Medium (20–40%)
		Blue Shark	*Prionace glauca*	High (40–60%)	High (40–60%)
		Salmon Shark	*Lamna ditropis*	Medium (20–40%)	Medium (20–40%)
	Skates	Big Skate	*Raja binoculata*	High (40–60%)	High (40–60%)
		Longnose Skate	*Raja rhina*	Medium (20–40%)	Medium (20–40%)
		Roughtail Skate	*Bathyraja trachura*	Medium (20–40%)	Medium (20–40%)
		Sandpaper Skate	*Bathyraja interrupta*	Low (10–20%)	Low (10–20%)
		Dall's Porpoise	*Phocoenoides dalli*	High (40–60%)	High (40–60%)

Higher Group	Species Group	Common Name	Scientific Name	Ecological Target Class and Range (based on quartiles)	Ecological Target Class and Range (based on thirds)
Marine Mammals	Dolphins and Porpoises	Harbour Porpoise	*Phocoena phocoena*	High (40–60%)	High (40–60%)
		Northern Right Whale Dolphin	*Lissodelphis borealis*	Medium (20–40%)	Medium (20–40%)
		Pacific White-sided Dolphin	*Lagenorhynchus obliquidens*	Medium (20–40%)	Medium (20–40%)
		Risso's Dolphin	*Grampus griseus*	Medium (20–40%)	Medium (20–40%)
	Orcas	Northern Resident†	*Orcinus orca*	High (40–60%)	High (40–60%)
		Offshore†	*Orcinus orca*	High (40–60%)	High (40–60%)
		Southern Resident†	*Orcinus orca*	High (40–60%)	High (40–60%)
		Transient†	*Orcinus orca*	High (40–60%)	High (40–60%)
	Pinnipeds	California Sea Lion	*Zalophus californianus*	High (40–60%)	High (40–60%)
		Harbour Seal	*Phoca vitulina*	High (40–60%)	High (40–60%)
		Northern Elephant Seal	*Mirounga angustirostris*	High (40–60%)	High (40–60%)
		Northern Fur Seal	*Callorhinus ursinus*	High (40–60%)	High (40–60%)
		Steller Sea Lion	*Eumetopias jubatus*	High (40–60%)	High (40–60%)
	Sea Otters	Sea Otter	*Enhydra lutris*	High (40–60%)	High (40–60%)
	Whales	Blue Whale	*Balaenoptera musculus*	Medium (20–40%)	Medium (20–40%)
		Common Minke Whale	*Balaenoptera acutorostrata*	Medium (20–40%)	Medium (20–40%)
		Fin Whale	*Balaenoptera physalus*	High (40–60%)	High (40–60%)
		Grey Whale	*Eschrichtius robustus*	Medium (20–40%)	Medium (20–40%)
		Humpback Whale	*Megaptera novaeangliae*	Medium (20–40%)	Medium (20–40%)
		North Pacific Right Whale	*Eubalaena japonica*	High (40–60%)	High (40–60%)
		Sei Whale	*Balaenoptera borealis*	Medium (20–40%)	Medium (20–40%)
		Sperm Whale	*Physeter macrocephalus*	High (40–60%)	High (40–60%)
Reptiles	Sea Turtles	Leatherback Sea Turtle	*Dermochelys coriacea*	Medium (20–40%)	Medium (20–40%)
Cnidarians	Coldwater Corals	Black Corals	Antipatharia	Medium (20–40%)	High (40–60%)
		Hard or Stony Corals	Scleractinia	Medium (20–40%)	High (40–60%)
		Sea Pens	Pennatulacea	Medium (20–40%)	High (40–60%)
		Soft Corals	Alcyonacea	Medium (20–40%)	High (40–60%)
Crustaceans	Barnacles	Gooseneck Barnacle	*Pollicipes polymerus*	Medium (20–40%)	Low (10–20%)
	Crabs	Dungeness Crab	*Metacarcinus magister*	Low (10–20%)	Low (10–20%)
		Deepwater Grooved Tanner Crab	*Chionoecetes tanneri*	Low (10–20%)	Low (10–20%)
		Inshore Tanner Crab	*Chionoecetes bairdi*	Low (10–20%)	Low (10–20%)
		Puget Sound King Crab	*Lopholithodes mandtii*	Low (10–20%)	Low (10–20%)
	Shrimps	Bay Ghost Shrimp	*Neotrypaea californiensis*	Low (10–20%)	Low (10–20%)
		Coonstripe/Dock Shrimp	*Pandalus danae*	Medium (20–40%)	Medium (20–40%)
		Humpback Shrimp	*Pandalus hypsinotus*	Medium (20–40%)	Medium (20–40%)

Higher Group	Species Group	Common Name	Scientific Name	Ecological Target Class and Range (based on quartiles)	Ecological Target Class and Range (based on thirds)
Crustaceans (cont'd)	Shrimps (cont'd)	Sidestripe Shrimp	*Pandalopsis dispar*	Medium (20–40%)	Medium (20–40%)
		Smooth Pink Shrimp	*Pandalus jordani*	Medium (20–40%)	Medium (20–40%)
		Spiny/Northern Pink Shrimp	*Pandalus borealis*	Medium (20–40%)	Medium (20–40%)
		Spot Prawn	*Pandalus platyceros*	Medium (20–40%)	Medium (20–40%)
	Zooplankton	Euphausiids	Euphausiacea	Medium (20–40%)	Medium (20–40%)
		Neocalanus Copepods	*Neocalanus* sp.	Medium (20–40%)	High (40–60%)
		Other Crustacean Zooplankton	Other Crustacean Zooplankton	Medium (20–40%)	Medium (20–40%)
Echinoderms	Sea Stars	Ochre Sea Star	*Pisaster ochraceus*	Medium (20–40%)	High (40–60%)
		Sunflower Sea Star	*Pycnopodia helianthoides*	Medium (20–40%)	Low (10–20%)
	Sea Urchins	Green Sea Urchin	*Strongylocentrotus droebachiensis*	Medium (20–40%)	Medium (20–40%)
		Red Sea Urchin	*Mesocentrotus franciscanus*	Medium (20–40%)	Medium (20–40%)
Molluscs	Cephalopods	Giant Pacific Octopus	*Enteroctopus dofleini*	Medium (20–40%)	Medium (20–40%)
		Opal Squid	*Doryteuthis opalescens*	Medium (20–40%)	Medium (20–40%)
	Clams and Cockles	Butter Clam	*Saxidomus gigantea*	Medium (20–40%)	Medium (20–40%)
		Cockle	*Clinocardium nuttallii*	Medium (20–40%)	Medium (20–40%)
		Geoduck	*Panopea generosa*	Medium (20–40%)	Medium (20–40%)
		Horse Clam/Fat Gaper	*Tresus capax*	Medium (20–40%)	Medium (20–40%)
		Horse Clam/Pacific Gaper	*Tresus nuttallii*	Medium (20–40%)	Medium (20–40%)
		Littleneck Clam	*Leukoma staminea*	Medium (20–40%)	Medium (20–40%)
		Razor Clam	*Siliqua patula*	Medium (20–40%)	High (40–60%)
	Epibenthic Bivalves	California Mussel	*Mytilus californianus*	Medium (20–40%)	Medium (20–40%)
		Olympia Oyster	*Ostrea lurida*	Medium (20–40%)	High (40–60%)
		Pink Scallop	*Chlamys rubida*	Low (10–20%)	Low (10–20%)
		Purple–hinged Rock Scallop	*Crassadoma gigantea*	Low (10–20%)	Low (10–20%)
		Spiny Scallop	*Chlamys hastata*	Low (10–20%)	Low (10–20%)
		Weathervane Scallop	*Patinopecten caurinus*	Low (10–20%)	Low (10–20%)
	Gastropods	*Littorina* Snail	*Littorina* sp.	Low (10–20%)	Low (10–20%)
		Northern Abalone	*Haliotis kamtschatkana*	Medium (20–40%)	Medium (20–40%)
Sponges	Sponges	Glass Sponges	Hexactinellida	High (40–60%)	High (40–60%
		Cloud Sponge	*Aphrocallistes vastus*	High (40–60%)	High (40–60%)
		Glass Sponge	*Farrea occa*	High (40–60%)	High (40–60%)
		Glass Sponge	*Heterochone calyx*	High (40–60%)	High (40-60%)
		Demosponges	Demospongiae	Medium (20-40%)	High (40-60%)
Other	Zooplankton	Non-Crustacean Zooplankton	Non-Crustacean Zooplankton	Low (10–20%)	Low (10–20%)
	Phytoplankton	Phytoplankton	Phytoplankton	Medium (20–40%)	Low (10–20%)

Higher Group	Species Group	Common Name	Scientific Name	Ecological Target Class and Range (based on quartiles)	Ecological Target Class and Range (based on thirds)
Plants and Algae	Large Algae	Bull Kelp	*Nereocystis leutkeana*	Medium (20–40%)	High (40–60%)
		Giant Kelp	*Macrocystis* sp.	Medium (20–40%)	High (40–60%)
	Seagrasses	Eelgrass	*Zostera marina*	Medium (20–40%)	High (40–60%)
		Surfgrass	*Phyllospadix* sp.	Medium (20–40%)	Medium (20–40%)
Marine Birds	Diomedeidae	Black-footed Albatross	*Phoebastria nigripes*	Medium (20–40%)	Medium (20–40%)
		Laysan Albatross	*Phoebastria immutabilis*	Medium (20–40%)	Medium (20–40%)
		Short-tailed Albatross	*Phoebastria albatrus*	High (40–60%)	High (40–60%)
	Procellariidae	Buller's Shearwater	*Ardenna bulleri*	Low (10–20%)	Low (10–20%)
		Northern Fulmar	*Fulmarus glacialis*	Low (10–20%)	Low (10–20%)
		Pink-footed Shearwater	*Ardenna creatopus.*	High (40–60%)	High (40–60%)
		Short-tailed Shearwater	*Ardenna tenuirostris*	Low (10–20%)	Low (10–20%)
		Sooty Shearwater	*Ardenna grisea*	Low (10–20%)	Low (10–20%)
	Phalacrocoracidae	Brandt's Cormorant	*Phalacrocorax penicillatus*	High (40–60%)	High (40–60%)
		Double-crested Cormorant	*Phalacrocorax auritus*	Low (10–20%)	Low (10–20%)
		Pelagic Cormorant, *pelagicus* subsp.	*Phalacrocorax pelagicus pelagicus*	High (40–60%)	High (40–60%)
		Pelagic Cormorant, *resplendens* subsp.	*Phalacrocorax pelagicus resplendens*	Medium (20–40%)	Low (10–20%)
	Anatidae	Barrow's Goldeneye	*Bucephala islandica*	Medium (20–40%)	High (40–60%)
		Black Scoter	*Melanitta americana*	Medium (20–40%)	Medium (20–40%)
		Common Goldeneye	*Bucephala clangula*	Low (10–20%)	Low (10–20%)
		Harlequin Duck	*Histrionicus histrionicus*	Medium (20–40%)	Medium (20–40%)
		Long-tailed Duck	*Clangula hyemalis*	Low (10–20%)	Low (10–20%)
		Surf Scoter	*Melanitta perspicillata*	Medium (20–40%)	Medium (20–40%)
		White-winged Scoter	*Melanitta deglandi*	Medium (20–40%)	High (40–60%)
	Haematopodidae	Black Oystercatcher	*Haematopus bachmani*	Medium (20–40%)	High (40–60%)
	Scolopacidae	Black Turnstone	*Arenaria melanocephala*	Low (10–20%)	Low (10–20%)
		Dunlin	*Calidris alpina*	High (40–60%)	High (40–60%)
		Red Knot	*Calidris canutus*	Medium (20–40%)	High (40–60%)
		Red Phalarope	*Phalaropus fulicarius*	Low (10–20%)	Low (10–20%)
		Red-necked Phalarope	*Phalaropus lobatus*	Low (10–20%)	Low (10–20%)
		Rock Sandpiper	*Calidris ptilocnemis*	Low (10–20%)	Low (10–20%)
		Ruddy Turnstone	*Arenaria interpres*	Medium (20–40%)	Medium (20–40%)
		Sanderling	*Calidris alba*	Medium (20–40%)	Medium (20–40%)
		Short-billed Dowitcher	*Limnodromus griseus*	High (40–60%)	High (40–60%)
		Surfbird	*Calidris virgata*	Medium (20–40%)	Medium (20–40%)

Higher Group	Species Group	Common Name	Scientific Name	Ecological Target Class and Range (based on quartiles)	Ecological Target Class and Range (based on thirds)
Marine Birds (cont'd)	Scolopacidae (cont'd)	Whimbrel	*Numenius phaeopus*	Medium (20–40%)	Medium (20–40%)
		Wandering Tattler	*Tringa incana*	Low (10–20%)	Low (10–20%)
		Western Sandpiper	*Calidris mauri*	Low (10–20%)	Low (10–20%)
	Alcidae	Ancient Murrelet	*Synthliboramphus antiquus*	High (40–60%)	High (40–60%)
		Cassin's Auklet	*Ptychoramphus aleuticus*	High (40–60%)	High (40–60%)
		Common Murre	*Uria aalge*	High (40–60%)	High (40–60%)
		Horned Puffin	*Fratercula corniculata*	High (40–60%)	High (40–60%)
		Marbled Murrelet	*Brachyramphus marmoratus*	High (40–60%)	High (40–60%)
		Pigeon Guillemot	*Cepphus columba*	Medium (20–40%)	Medium (20–40%)
		Rhinoceros Auklet	*Cerorhinca monocerata*	Medium (20–40%)	High (40–60%)
		Thick-billed Murre	*Uria lomvia*	High (40–60%)	High (40–60%)
		Tufted Puffin	*Fratercula cirrhata*	High (40–60%)	High (40–60%)
	Gaviidae	Common Loon	*Gavia immer*	Low (10–20%)	Low (10–20%)
		Pacific Loon	*Gavia pacifica*	Low (10–20%)	Low (10–20%)
		Yellow-billed Loon	*Gavia adamsii*	Low (10–20%)	Low (10–20%)
	Podicipedidae	Horned Grebe	*Podiceps auritus*	Low (10–20%)	Low (10–20%)
		Western Grebe	*Aechmophorus occidentalis*	High (40–60%)	High (40–60%)
	Hydrobatidae	Fork-tailed Storm-Petrel	*Hydrobates furcatus*	Low (10–20%)	Low (10–20%)
		Leach's Storm-Petrel	*Hydrobates leucorhous*	Medium (20–40%)	High (40–60%)
	Ardeidae	Cackling Goose	*Branta hutchinsii*	Low (10–20%)	Low (10–20%)
		Canada Goose (Pacific, residents & migrants)	*Branta canadensis*	Low (10–20%)	Low (10–20%)
		Great Blue Heron, *fannini* subsp.	*Ardea herodias fannini*	Low (10–20%)	Low (10–20%)
		Trumpeter Swan	*Cygnus buccinator*	Low (10–20%)	Low (10–20%)
	Laridae	California Gull	*Larus californicus*	Medium (20–40%)	High (40–60%)
		Thayer's Gull	*Larus thayeri*	Medium (20–40%)	Medium (20–40%)

Table A2. Area-based ecological conservation priorities and recommended ecological conservation target classes and ranges based on subdividing the frequency distribution of target scores using the median.

Feature or Area Recommended as Ecological CP	Ecological Target Class and Range (based on median)
Physical features (Fine-filter features)	
Areas of high habitat heterogeneity (Ecologically and Biologically Significant Area (EBSA)[1] — biodiversity)	High (20–60%)
Frontal zones (EBSA — biodiversity)	High (20–60%)
Submarine canyons (relative to surrounding slope) and steep walled troughs (EBSA — biodiversity)	High (20–60%)
Areas of upwelling (EBSA — productivity)	High (20–60%)
Tidal passes and currents (EBSA — biodiversity, productivity)	High (20–60%)
Eddies and plumes (EBSA — productivity)	Low (10–30%
Non-tidal currents (EBSA — productivity)	Low (10–30%
Marine areas influenced by freshwater discharges with high oxygen levels (areas of climate resilience)	Low (10–30%)
Underwater banks (areas of climate resilience)	Low (10–30%
Areas important for carbon sequestration/"blue carbon" (areas of climate resilience)	High (20–60%)
Degraded areas	Low (10–30%)
Modeled or measured areas (Fine-filter features)	
Areas of high species abundance, diversity or richness (for appropriate groups of species)	Low (10–30%)
Ecological Classifications (Coarse-filter features)	
Biophysical Units from Pacific Marine Ecological Classification System (PMECS) framework (Rubidge et al. 2016)	Low (10–30%)
Geomorphic Units from PMECS framework (Rubidge et al. 2016)	Low (10–30%)
Bottom Patches (nearshore only; Gregr et al. 2013)	Low (10–30%)
Ecosections (Harper et al. 1993, Zacharias et al. 1998, Axys Environmental Consulting Ltd. 2001)	Low (10–30%)
Upper Ocean Subregions (British Columbia Marine Conservation Analysis Project Team 2011)	Low (10–30%)
Shoreline ecological units from ShoreZone Coastal Classes (Howes et al. 1994)	Low (10–30%)

[1] Area-based features identified as EBSAs by Clarke and Jamieson (2006).

APPENDIX B: GLOSSARY

Biodiversity: The full range of variety and variability within and among living organisms and the ecological complexes of which they are a part (Canada-BC MPA Network Strategy 2014).

Biogenic habitat: Habitat created by a living organism (e.g., eelgrass beds, sponge reefs, etc.).

Bioregion: A biogeographic division of Canada's marine waters out to the edge of the Exclusive Economic Zone, based on attributes such as bathymetry, influence of freshwater inflows, distribution of multi-year ice, and species distribution.

Coastal and marine areas: In a Canadian MPA network planning context, this includes Canada's marine estate extending to and including the Great Lakes, from the high water mark in coastal or shoreline areas to the outer edge of the Exclusive Economic Zone.

Connectivity: Ecological spatial connectivity refers to processes by which genes, species, populations, nutrients, and/or energy move among spatially distinct populations, communities, or ecosystems (Carr et al. 2017). Genetic connectivity refers to the movement of genes (gene flow) of a single species through space. Population (or demographic) connectivity results from the movement of individuals among patchily distributed "local" or "subpopulations" of a single species. Community connectivity results from the movement of multiple species between distinct ecological communities. Ecosystem connectivity refers to the movement of multiple species among distinct ecological communities, as well as the movement of chemicals, energy, and physical materials.

Conservation: The in situ maintenance of ecosystems and natural and semi-natural habitats and of viable populations of species in their natural surroundings (International Union for Conservation of Nature).

Conservation concern: Applies to species which have been assessed/designated as "at risk" or of conservation concern through global, national and regional lists of conservation status (COSEWIC, SARA, IUCN Red List, the General Status of Species in Canada, NatureServe, BCList and CITES), supplemented by expert advice for species such as invertebrates and fishes that are under-represented on formal lists.

Design guideline: Provides guidance on the application and implementation of the principles outlined in the Strategy. Design guidelines consider ecological, socio-economic and cultural factors in the overall design of the network to influence where MPAs are located, and how they are selected, refined, and zoned to achieve the design principles.

Design principle: Specify the design, planning and management values to which the MPA network will adhere. Together with the goals and objectives, the suite of 16 ecological, cultural, and socioeconomic guiding principles help to guide site selection and shape the network planning process (Canada-BC MPA Network Strategy 2014).

Design scenario: Informed by all previous stages of the NSB MPA Network planning process, network design scenarios identify priority areas for conservation and options for possible configurations of marine protected areas in the Northern Shelf Bioregion.

Design strategy: In the NSB MPA network planning context, a design strategy is a detailed statement that specifies: (1) the types of areas or features to be conserved; (2) the relative ecological conservation targets for those area types, and; (3) guidance on the size, shape, connectivity, and protection levels of MPAs.

Ecological conservation priority (E-CP): A species, habitat or other ecological feature that the MPA network aims to protect. Fine-filter features are priority species or spatially discrete area-based features. Coarse-filter features are broad-scale ecological classification systems that span the bioregion.

Ecological conservation target: The amount or proportion of each spatial feature representing each ecological conservation priority that is recommended for inclusion in the MPA network, described as a range following best practices for Marxan analyses. Target ranges were developed based on the attributes of the E-CPs (e.g., Steller sea lion) and applied to the spatial features representing each conservation priority (e.g., Steller sea lion rookeries).

Ecological role: Within the NSB MPA network planning context, species were assessed for inclusion as a conservation priority in part due to their role(s) as an upper level predator, forage species, nutrient transporter and/or structural species.

Ecologically and Biologically Significant Area (EBSA): Area deemed to be ecologically or biologically significant because of either its structural properties and/or the function that it serves in an ecosystem (DFO 2004).

Ecosections: Habitat classification based on broad-scale oceanographic and physiographic variations in the Canadian Pacific, with units 100–1000s of km in extent (Province of British Columbia). Ecosections in the NSB include: North Coast Fjords, Johnstone Strait, Queen Charlotte Sound, Queen Charlotte Strait, Strait of Georgia, Continental Slope, Dixon Entrance, Hecate Strait, Subarctic Pacific, Transitional Pacific, and Vancouver Island Shelf.

Highly mobile species: Within the NSB bioregion MPA network planning context, highly mobile species are those with adult movement ranges beyond 50 km.

Marine protected area (MPA): A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (International Union for Conservation of Nature).

MPA network: A collection of individual MPAs that operates cooperatively and synergistically, at various spatial scales, and with a range of protection levels, in order to fulfill ecological aims more effectively and comprehensively than individual sites could alone (International Union for the Conservation of Nature).

Marxan: A software program that uses simulated annealing to generate spatial reserve systems that achieve particular biodiversity representation goals with reasonable optimality. It is a decision support tool that is being used iteratively to assist MPA network design in the Northern Shelf Bioregion.

MPA performance scaling factor: Scores derived from a global meta-analysis of fully and partially protected MPAs compared to open-fishing areas that estimate the impacts on fish assemblages based on the level of protection afforded to the MPA. Within the NSB bioregion MPA network planning context, MPA performance scaling factors are used to assess how well a potential design scenario meets ecological conservation targets in combination with a matrix of interactions between E-CPs and human activities.

Network objective: High-level statement that outlines what the MPA network in the NSB aims to achieve and describes a desired future state for a particular value. The network objectives identify and focus management priorities, provide a context for resolving issues, a rationale for decisions, and a means for assessing network effectiveness. Similar to 'strategic objectives' defined in MPA network planning processes in other Canadian bioregions.

Northern Shelf Bioregion (NSB): One of 13 ecologically distinct bioregions that have been delineated in Canada's oceans and the Great lakes. The NSB covers 101,328 km², including two-thirds of the BC coastline, and extends from Quadra Island/Bute Inlet north to the Canada-Alaska border and out to the base of the continental slope.

Pelagic larval duration (PLD): Amount of time a larva spends in the water prior to settling.

Representation: An MPA network design principle that prescribes the inclusion of areas representing the different biogeographical subdivisions of the global oceans and regional seas that reasonably reflect the full range of ecosystems, including the biotic and habitat diversity of those marine ecosystems (Convention on Biological Diversity 2008).

Replication: An MPA network design principle that prescribes the inclusion of spatially separated replicates of representative habitats and special or vulnerable features within MPA sites to provide insurance against uncertainty, natural variations, and local disturbances or environmental disasters (Convention on Biological Diversity 2008).

Spatial feature: A specific feature representing a conservation priority within the marine ecosystem that can be mapped spatially and assigned an ecological conservation target.

Subregion: A planning area demarcated with a combination of First Nation territorial and local government administrative boundaries and similar ecological characteristics in the NSB. The subregions include: Haida Gwaii, North Coast, Central Coast, and North Vancouver Island.

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