Sensitivity Analyses to Support Marine Protected Area Network Development in the Northern Shelf Bioregion

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SENSITIVITY ANALYSES TO SUPPORT MARINE PROTECTED AREA NETWORK DEVELOPMENT IN THE NORTHERN SHELF BIOREGION

by

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Acronyms

BC	British Columbia
BCMCA	British Columbia Marine Conservation Analysis
BCMEC	British Columbia Marine Ecological Classification
BLM	Boundary Length Modifier
CBD	Convention on Biological Diversity
CE	Cumulative Effects
CP	Conservation Priority
CPUE	Catch per Unit Effort
CSAS	Canadian Science Advisory Secretariat
DFO	Fisheries and Oceans Canada
EBSA	Ecologically and Biologically Significant Area
ECCC	Environment and Climate Change Canada
E-CP	Ecological Conservation Priority
EEZ	Exclusive Economic Zone
(FN)C-CP	(First Nations) Cultural Conservation Priority
IUCN	International Union for Conservation of Nature
MaPP	Marine Plan Partnership
MPA	Marine Protected Area
MPATT	Marine Protected Area Technical Team
NSB	Northern Shelf Bioregion
PMECS	Pacific Marine Ecological Classification System
PU	Planning Unit
SARA	Species at Risk Act
SSOLN	Summed Solution (also referred to as selection frequency)

Abstract

Robb, C.K., McDougall, C., Tingey, R., Bodtker, K.M., Gale, K.S.P., Martone, R.G., and Rubidge, E.M. 2024. Sensitivity Analyses to Support Marine Protected Area Network Development in the Northern Shelf Bioregion. Can. Tech. Rep. Fish. Aquat. Sci. 3638: x + 70 p. https://doi.org/10.60825/qxyq-s834

On the Pacific coast of Canada, a network of marine protected areas (MPAs) is being developed in the Northern Shelf Bioregion (NSB), which extends from Quadra Island and Bute Inlet north to the Alaska border and west to the base of the continental slope. To support this process, advice was solicited through the Fisheries and Oceans Canada's Canadian Science Advisory Secretariat (CSAS) on ecological design strategies that inform the representation and replication of ecological features, as well as network design parameters such as size, spacing, protection levels, and connectivity. The ecological design strategies can be used to develop initial site selection analyses that identify potential areas that meet ecological network objectives and are one of many inputs into the MPA network design process. Through the CSAS review, guidance was received on incorporating representation, replication, size, spacing, and protection levels into site selection analyses and several sensitivity analyses were also suggested to help evaluate the impacts of adjusting different analytical parameters. The suggested sensitivity analyses focused on: 1) developing spatial targets for the representation of ecological features; 2) conducting separate analyses for different feature types (e.g., habitat vs. species features, nearshore vs. offshore features); 3) incorporating naturalness in habitat features; and 4) varying the proportions of high protection areas within site selection analyses. Following the original CSAS review process, partners and stakeholders in the MPA network planning process suggested additional sensitivity analyses related to evaluating the targets for First Nations cultural conservation priorities and incorporating commercially-harvested species and endangered species, for which location information are considered confidential. This report documents the results of each sensitivity analyses relevant to site selection analyses that can support MPA network planning in the NSB.

Résumé

Robb, C.K., McDougall, C., Tingey, R., Bodtker, K.M., Gale, K.S.P., Martone, R.G., and Rubidge, E.M. 2024. Sensitivity Analyses to Support Marine Protected Area Network Development in the Northern Shelf Bioregion. Can. Tech. Rep. Fish. Aquat. Sci. 3638: x + 70 p. https://doi.org/10.60825/qxyq-s834

Sur la côte pacifique du Canada, un réseau d'aires marines protégées (AMP) est mis sur pied dans la biorégion du plateau Nord, qui s'étend de l'île Quadra et de l'inlet Bute, à la frontière de l'Alaska au nord et à la base du talus continental à l'ouest. Dans le cadre de ce processus, des avis ont été demandés par l'intermédiaire du Secrétariat canadien des avis scientifiques (SCAS) de Pêches et Océans Canada sur les stratégies de conception écologique qui façonnent la représentation et la répétition des caractéristiques écologiques, ainsi que sur les paramètres de conception du réseau, comme la taille, l'espacement, les niveaux de protection et la connectivité. Les stratégies de conception écologique peuvent être utilisées pour élaborer des analyses initiales de sélection de sites qui recensent les aires susceptibles de répondre aux objectifs du réseau écologique et sont l'une des nombreuses contributions au processus de conception du réseau d'AMP. À la suite de l'examen du SCAS, des orientations sont parvenues concernant l'intégration de la représentation, de la répétition, de la taille, de l'espacement et des niveaux de protection dans les analyses de sélection de sites, et plusieurs analyses de sensibilité ont également été suggérées pour aider à évaluer les répercussions de l'ajustement de différents paramètres analytiques. Les analyses de sensibilité suggérées mettaient l'accent sur : 1) l'élaboration de cibles spatiales pour la représentation des caractéristiques écologiques; 2) la réalisation d'analyses distinctes pour différents types de caractéristiques (p. ex. caractéristiques de l'habitat et caractéristiques des espèces; caractéristiques du littoral et caractéristiques au large); 3) l'incorporation du caractère naturel dans les caractéristiques de l'habitat; 4) la variation des proportions des aires de haute protection dans les analyses de sélection de sites. À la suite du processus d'examen original du SCAS, les partenaires et les parties prenantes au processus de planification du réseau des AMP ont suggéré d'autres analyses de sensibilité en lien avec l'évaluation des cibles pour les priorités des Premières Nations en matière de conservation culturelle et avec l'intégration des espèces pêchées commercialement et des espèces en voie de disparition, pour lesquelles les informations de localisation sont considérées comme confidentielles. Ce rapport documente les résultats de chaque analyse de sensibilité pertinente dans le cadre des analyses de sélection de sites qui peuvent sous-tendre la planification du réseau d'AMP dans la biorégion du plateau Nord.

Introduction

The Northern Shelf Bioregion (NSB) is an area in the Canadian Pacific extending from Quadra Island and Bute Inlet north to the Alaska border and west to the base of the continental slope (Figure 1). Within the NSB, the governments of Canada, British Columbia (BC), and 15 First Nations are collaboratively developing a network of Marine Protected Areas (MPAs). Technical work on the network is focused within four subregions of the NSB is (Figure 1) and is led by the MPA technical team (MPATT), which includes representation from all of the partner organizations.

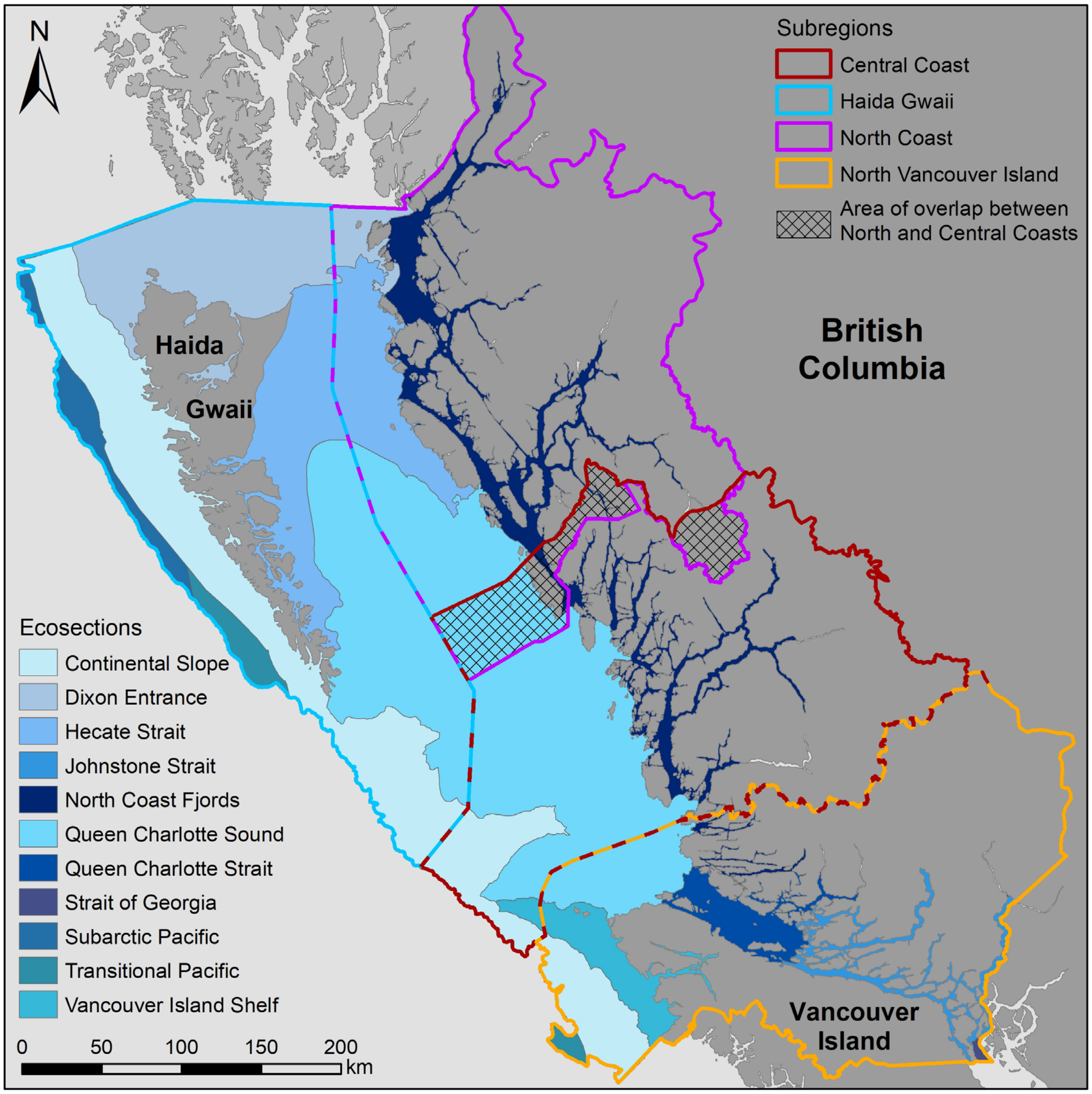

Figure 1. Planning subregions and marine ecosections (British Columbia Ministry of Sustainable Resource Management 2002) within the Northern Shelf Bioregion.

MPATT's progress is guided by goals and design principles identified in Canada's national framework for MPA networks (Government of Canada 2011) and the Canada-BC MPA Network Strategy (2014) and objectives[1] developed by MPATT with feedback from stakeholders (Figure 2, Step 1). In addition, MPATT solicited expert advice (Lieberknecht et al. 2016) and consulted with stakeholders to provide further input on applying the design principles using more specific design guidelines. Planning has followed a systematic conservation planning approach (Margules and Pressey 2000), starting with defining goals and objectives, identifying related conservation priorities and quantifiable targets, and then using iterative methods to delineate potential new areas of high conservation value to inform draft network designs.

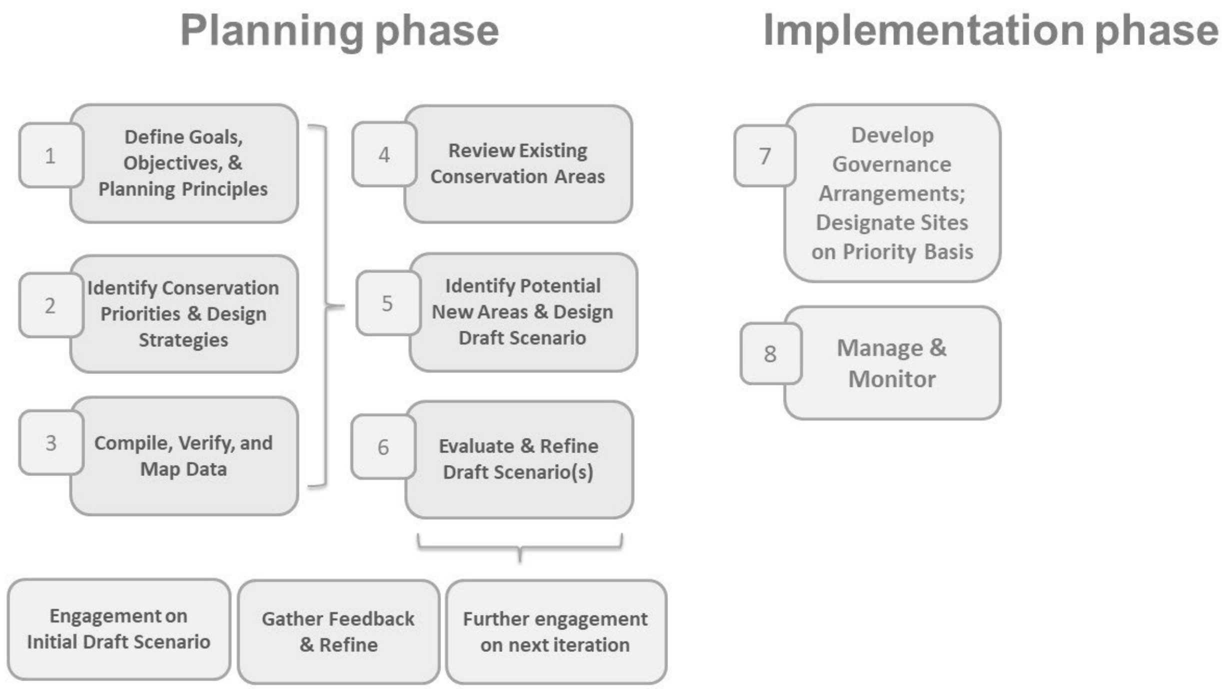

Figure 2. Key phases of the MPA network planning process in the NSB.

Goal 1 of 6 from the Canada-BC MPA Network Strategy (2014) has primacy and focuses on the need "to protect and maintain marine biodiversity, ecological representation, and special natural features." To further that goal, advice on ecological conservation priorities (E-CPs) and design strategies was obtained through the Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat's (CSAS) peer review process (Step 2, Figure 2) (DFO 2017a, 2019a; Gale et al. 2019; Martone et al. 2021). Ecological conservation priorities are the ecological features to be prioritized in MPA network development (e.g., habitat-forming species such as eelgrass) and the ecological design strategies describe how they will be spatially incorporated in the MPA network. More specifically, the design strategies help identify spatial features to best represent each conservation priority (e.g., mapped eelgrass beds) and recommend ecological conservation targets, which detail how much of each feature (e.g., 20-40% of mapped eelgrass beds) to include as a starting point in initial site selection analyses to identify potential new MPAs that help meet ecological network objectives (Figure 2, Step 5) (DFO 2019a). Ecological conservation targets were recommended for E-CPs spanning both broad-scale ecological classification systems (termed coarse-filter features) as well as species priorities and spatially discrete area-based features (termed fine-

[1] http://mpanetwork.ca/bcnorthernshelf/planning-process/#one

filter features). The full suite of ecological features and associated ecological conservation targets are listed in Appendix A. For features found throughout the NSB, the ecological conservation targets were stratified by marine ecosections (British Columbia Ministry of Sustainable Resource Management 2002) (Figure 1) as a first step towards achieving design guidelines for spatially separated replicates of the ecological conservation priorities (Lieberknecht et al. 2016).

In addition to the ecological conservation targets, the ecological design strategies also provide more specificity to the recommendations in the design principles (Canada – British Columbia Marine Protected Area Network Strategy 2014) and design guidelines (Lieberknecht et al. 2016) related to the incorporation of internationally recognized design elements for MPA network planning (e.g., representation, replication, size, spacing, and connectivity) (DFO 2019a). The ecological design strategies thereby inform iterative site selection analyses to help identify potential locations that can help meet the MPA network's ecological objectives. The outputs of these site selection analyses are one of many components, along with cultural and socioeconomic values and partner and stakeholder feedback, supporting the development of initial draft MPA network designs (Figure 2, Steps 5-6).

Details of the CSAS review of the ecological design strategies can be found in DFO (2019a) and Martone et al. (2021). In addition to confirming the proposed design strategies, participants at the CSAS review provided suggestions for sensitivity analyses to evaluate the impacts of adjusting various parameters in the site selection analyses using Marxan (DFO 2019a). Subsequent to the review process, MPATT partners and stakeholders suggested additional analyses. The proposed sensitivity analyses and the subject of this report focused on:

- Target score classification for the representation of ecological features
- Use of 10% as a minimum threshold for coarse-filter feature targets
- Targets for First Nations cultural conservation priorities
- Separating analyses for habitat (coarse-filter) vs. species (fine-filter) features
- Separating analyses for nearshore vs. offshore areas
- Incorporation of naturalness in coarse-filter (habitat) features
- Inclusion of commercially-harvested species
- Inclusion of endangered species for which location information are considered confidential
- Varying proportions of high protection areas

These sensitivity analyses were completed by the science subcommittee within MPATT (i.e., the authors of this technical report). Most of the sensitivity analyses utilized the Marxan decision support tool (Ball et al. 2009), which is a planning tool that has been used extensively in site selection analyses and reserve design within the Canadian Pacific (e.g., British Columbia Marine Conservation Analysis 2012; Ban et al. 2013) and in other jurisdictions around the globe (e.g., Fernandes et al. 2005; Smith et al. 2009). Marxan analyses are systematic and repeatable and provide decision makers with spatial information on areas of importance for different suites of features that can be considered alongside other spatial and aspatial information relevant to the planning objectives. Marxan uses simulated annealing to iterate through millions of combinations of planning units (PUs) within a planning area to identify ways of efficiently meeting targets for the representation of features while accruing the lowest possible cost (Ardron et al. 2010).

Marxan analyses can be run using a variety of parameters. Of particular relevance to this report, analyses can incorporate different features, different target options for each feature, a variety of cost layers, and can test a range of values for the boundary length modifier (BLM). The cost of including each planning unit in an analysis solution is often calculated using the area of the planning units, to create spatially efficient solutions, but can also incorporate other considerations, such as socioeconomic variables (e.g., importance for human activities, land acquisition cost). The BLM is a parameter that influences the extent to which PUs clump together and therefore the size of the resulting conservation areas in each solution. The BLM can be chosen by assessing the trade-off between a solution's cost and its boundary length or by iteratively increasing the BLM until it reaches the desired level of clumping, ideally without a significant impact to the overall cost (Ardron et al. 2010).

Each Marxan analysis is typically run 100 times to generate a range of potential solutions, though fewer runs are sometimes performed during calibration or sensitivity analyses due to processing constraints. Outputs of Marxan site selection analyses include a 'best' solution, which is the single solution with the lowest overall cost, as well as a selection frequency score (termed the summed solution (ssoln)) that can be used to generate a "heatmap" showing how often each planning unit in the study area is selected to be part of one of the potential solutions in a given analysis (Ardron et al. 2010). The 'best' solution may vary spatially from other solutions that have similar overall costs and does not necessarily indicate the optimal solution for an area given the many objectives that decision-makers must consider. When used in this report, the 'best' solution for a given analysis is considered an example of a single, spatially-optimized solution.

In addition to the sensitivity analyses described in this report, MPATT completed a suite of iterative Marxan analyses that were performed over several months to support conversations around MPA network design options. For all analyses, the NSB was subdivided into a grid of 113,839 1 km^2 square planning units. Analyses were performed using spatial features representing the 195 ecological conservation priorities (Appendix A) assigned to a low, medium, or high target class and using the ecological features together with spatial features representing First Nations cultural conservation priorities (C-CPs[2]) that were identified and ranked high, very high, and critical by MPATT's Indigenous partners[3]. Each feature was assigned a range of targets based on their target class or rank (Table 1), guided by the ecological design strategies (DFO 2019a, Appendix A) and associated sensitivity analyses. Most analyses used area as the cost layer, with the goal of identifying spatially efficient network designs. Further analyses also used socioeconomic data as input features to identify areas of high value for human activities, sometimes referred to as a 'reverse Marxan' analysis (DFO Economic Policy and Research 2017). The reverse Marxan analyses incorporated data for the commercial and recreational fishing, aquaculture, transportation, non-extractive marine recreation, and forestry industries to represent human uses within the NSB. Spatial datasets represented either the footprint of the activity (e.g., log handling tenures) or incorporated a representation of differing intensity of use (e.g., transit hours for vessel types) and were each assigned a target of 70%. A last suite of analyses was then performed that included targets for the E-CP and C-CP spatial features and a cost layer generated from the selection frequency output of the analysis using socioeconomic data (reverse Marxan). The analyses incorporating the socioeconomic costs were performed to illustrate possible design solutions that avoid areas of high value for human activities, in alignment with design principles related to minimizing conflicts or adverse impacts on marine users, when possible (Canada – British Columbia Marine Protected Area Network Strategy 2014).

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[2] First Nations Cultural Conservation Priorities were represented by different acronyms (FNCCP and C-CP) during the NSB Network planning process. C-CP is used throughout the text in this report to align with other documents from the Network process but FNCCP is used in some of the figures.

[3] Butler C., McDougall C., Heidt A., Rigg C., Cripps K., McGee G., and Diggon S. In prep. First Nations cultural conservation priorities: integrating Indigenous values into marine protected area network planning.

Table 1. Target ranges used in the suite of sensitivity analyses for the spatial features representing ecological conservation priorities and First Nations cultural conservation priorities (C-CPs). Target ranges were based on the recommendations of the ecological design strategies (DFO 2019a) and sensitivity analyses (see section on Targets for First Nations Cultural Conservation Priorities).

Ecological Conservation Target Class	Ecological Conservation Target Range	C-CP Rank	C-CP Target Range
Low	10-20%	High	20-40%
Medium	20-40%	Very High	40-60%
High	40-60%	Critical	40-60%

This report documents the results of the sensitivity analysis suggested through the CSAS review of the ecological design strategies for the NSB MPA network process (DFO 2019a). The sensitivity analyses documented here took advantage of updates to spatial features and input parameters completed as MPATT's main Marxan analyses progressed and underwent review. As a result, the parameters vary slightly for some of the sensitivity analyses. The relevant parameters are documented in the description of each analysis and are summarized in Appendix B.

Sensitivity Analyses

Target Score Classification (Thirds vs. Quartiles)

Overview

The ecological design strategies include ecological conservation targets appropriate for the spatial features that represent species-based conservation priorities. Each species had been previously assigned scores based on their conservation status, vulnerability, and ecological role (DFO 2017a). These scores were combined with expert feedback to determine an overall target score for each species (DFO 2019a; Martone et al. 2021). The distribution of target scores was then classified based on quartiles to determine which species-based conservation priorities were assigned to a low, medium, or high ecological conservation target class. Using this approach, species-based conservation priorities assigned a target score in the top quartile of the distribution were assigned to the high target class. Species with a target score in the bottom quartile were assigned to the low target class. All species falling into the middle two quartiles were assigned to the medium target class. The quartile approach was chosen because it assigns most species-based conservation priorities a medium target and specifies the high target class for those species of particular ecological importance.

During the CSAS review of the ecological design strategies (DFO 2019a), participants recommended performing a sensitivity analysis to assess the impact of using quartiles to assign an ecological conservation target range when compared to an alternative approach differentiating the target scores based on thirds. The approach based on thirds would result in a more even distribution of ecological conservation priorities in all three target classes.

To test the impact of the quartile classification approach, the target scores for each ecological conservation priority were used to assign separate target ranges (low, medium, high) to the ecological features based on a classification using quartiles or thirds and compared to the feedback on ecological conservation targets received from experts during the development of the ecological design strategies (Martone et al. 2021). Marxan analyses were then performed using the ecological features and three sets of ecological conservation targets (at the bottom, middle, and top ends of the target ranges) to determine how altering the classification of the target scores changes the Marxan outputs when the other parameters (e.g., BLM) are held constant. Each analysis used 25 runs and a BLM of 0.25 (see Appendix B for more details on the specific parameters). For each analysis, the spatial extent of the 'best' solution and high selection frequency planning units, defined for this analysis as the planning units selected to be part of a solution in at least 10 of the runs, were compared to the spatial extent of the NSB.

Results

When the approach to assigning ecological conservation target classes changed from quartiles to thirds, the classification changed for 37 (19%) species-based conservation priorities (Table 2). Of these, 22 species moved to a higher target range and 15 were downgraded to a lower target range. Expert feedback received through the review of the ecological design strategies (Martone et al. 2021) aligned with the target class assigned using the quartiles approach for a slight majority (57%) of the species-based conservation priorities whose classification changed based on the approach to assigning a target class (Table 2).

Table 2. Species-based conservation priorities for which the target class changed when the target score values was categorized based on quartiles vs. thirds and the alignment of the resulting target classes with feedback received during the Design Strategies expert review (Martone et al. 2021). A value of "-" indicates where there was no clear consensus from the experts on the appropriate target class for the ecological conservation priority.

Group	Common Name	Target Class based on Quartiles	Target Class based on Thirds	Expert Review Feedback (# of experts - score recommended)	Alignment with Experts *
Fishes	Arrowtooth Flounder	Medium	Low	2 - Low; 2 - Medium	-
Fishes	Capelin	Medium	Low	2 - Low; 1 - Medium	Thirds
Fishes	Pacific Herring	Medium	High	1 - Low; 2 - Medium; 1 - Medium/High	Quartiles
Fishes	Surf Smelt	Medium	Low	2 - Low; 1 - Medium	Thirds
Fishes	Cutthroat Trout	Medium	Low	2 - Low; 1 - Medium	Thirds
Fishes	Steelhead	Medium	Low	2 - Low; 1 - Medium	Thirds
Fishes	Albacore	Medium	High	3 - Low/Medium	Quartiles
Fishes	Black Rockfish	Medium	Low	1 - Low; 2 - Medium	Quartiles
Fishes	Copper Rockfish	Medium	Low	1 - Low; 3 - Medium	Quartiles
Fishes	Darkblotched Rockfish	Medium	High	3 - Medium; 1 - High	Quartiles
Fishes	Redstripe Rockfish	Medium	Low	2 - Low; 2 - Medium	-
Fishes	Widow Rockfish	Medium	Low	1 - Low; 2 - Medium	Quartiles
Fishes	Pacific Cod	Medium	Low	2 - Low; 1 - Medium	Thirds
Fishes	Walleye Pollock	Medium	Low	2 - Low; 1 - Medium	Thirds
Invertebrates	Black corals	Medium	High	2 - Medium; 1 - High	Quartiles
Invertebrates	Hard or stony corals	Medium	High	2 - Medium; 1 - High	Quartiles
Invertebrates	Sea pens	Medium	High	2 - Medium; 1 - High	Quartiles
Invertebrates	Soft corals	Medium	High	2 - Medium; 1 - High	Quartiles
Invertebrates	Gooseneck barnacle	Medium	Low	2 - Low; 1 - Medium	Thirds
Invertebrates	Neocalanus copepods	Medium	High	1 - Low; 1 - Medium	Quartiles
Invertebrates	Ochre star	Medium	High	1 - Low; 2 - Medium	Quartiles
Invertebrates	Sunflower sea star	Medium	Low	2 - Low; 1 - Medium	Thirds
Invertebrates	Olympia Oyster	Medium	High	2 - Medium; 1 - High	Quartiles
Invertebrates	Razor clam	Medium	High	2 - Medium; 1 - High	Quartiles

Group	Common Name	Target Class based on Quartiles	Target Class based on Thirds	Expert Review Feedback (# of experts - score recommended)	Alignment with Experts *
Invertebrates	Demospongiae	Medium	High	2 - Medium; 1 - High	Quartiles
Plants	Phytoplankton	Medium	Low	2 - Low; 1 - Medium	Thirds
Plants	Bull kelp	Medium	High	2 - High	Thirds
Plants	Giant Kelp	Medium	High	2 - High	Thirds
Plants	Eelgrass	Medium	High	2 - High	Thirds
Marine Birds	Barrow's Goldeneye	Medium	High	2 - Medium	Quartiles
Marine Birds	Black Oystercatcher	Medium	High	2 - Medium	Quartiles
Marine Birds	California Gull	Medium	High	1 - Low; 2 - Medium	Quartiles
Marine Birds	Leach's Storm-Petrel	Medium	High	2 - High	Thirds
Marine Birds	Pelagic Cormorant	Medium	Low	2 - Low; 1 - Medium	Thirds
Marine Birds	Red Knot	Medium	High	2 - Medium	Quartiles
Marine Birds	Rhinoceros Auklet	Medium	High	3 - High	Thirds
Marine Birds	White-winged Scoter	Medium	High	2 - Medium	Quartiles

Marxan analyses run using both sets of targets showed that a greater proportion of the NSB was included in the Marxan outputs when ecological conservation targets were assigned using thirds (Table 3). This increase in coverage is likely due to the increase in the number of features assigned to the high target class when thirds are used to classify the target scores.

Table 3. Spatial coverage of Marxan analysis results when target classes were assigned to the target score distribution using thirds or quartiles. Each marxan analysis was run 25 times with a BLM of 0.25 and the bottom, middle, and top of the target ranges for the ecological features, and each planning unit was assigned a selection frequency value (out of 25) based on the number of times it was chosen to be part of a solution. The 'best' solution refers to the single solution with the lowest cost.

Analysis	Target Level (point within target range)	% of NSB in 'best' solution	% of NSB where selection frequency >=10%
Ecological Conservation Priorities (Quartiles)	Bottom	20%	21%
Ecological Conservation Priorities (Quartiles)	Middle	27%	29%
Ecological Conservation Priorities (Quartiles)	Top	37%	40%
Ecological Conservation Priorities (Thirds)	Bottom	26%	28%
Ecological Conservation Priorities (Thirds)	Middle	35%	38%
Ecological Conservation Priorities (Thirds)	Top	44%	49%

Conclusions

The quartile approach assigned the majority of species-based conservation priorities a medium target and specified the high target class for those species of particular ecological importance. Given that ecological conservation targets assigned using the quartile classification were more aligned with expert feedback, the remaining sensitivity analyses proceeded with the original quartile classification recommended by Martone et al. (2021).

Target Threshold for Coarse-filter Features

Overview

Coarse-filter features are broad-scale features based on ecological classification systems that generally span the NSB and are included in analyses to ensure that the full range of NSB ecosystems and habitats are represented. Following best practices for Marxan analyses (e.g., Lieberknecht et al. 2010), the ecological conservation targets for the broad-scale ecological classification systems (i.e., the coarse-filter features) were calculated based on their relative patch size and rarity within the subregion (DFO 2019a; Martone et al. 2021). This means that the habitat classes with a smaller spatial extent were assigned proportionally higher targets, to a maximum target range of 10-30%. Because of the size distribution of the classes within a classification system, some of the calculated targets are quite small for some of the coarse-filter features with broader spatial extents. For example, the biophysical units of the Pacific Marine Ecological Classification System (PMECS, Rubidge et al. 2016) include classes ranging in area between 2,272 km^2 and 35,207 km^2. When calculating the bottom end of the low target range, the smallest class (Other Banks) was assigned a target of 10%, which resulted in a target of 2.5% for the largest class (Shelf). At the middle of the target range, those features were assigned targets of 20% and 5.1%, respectively. At the top end of the target range, those features were assigned targets of 30% and 7.6%. In this classification, the discrepancy in size between the Other Banks and Shelf biophysical units is such that the target for the largest class (Shelf) is always below 10%, even in the top end of the target range.

A detailed list of the ecological conservation targets for the coarse-filter features is found in Appendix C. At the CSAS review of the ecological design strategies (DFO 2019a), participants recommended testing the impact of using 10% as the minimum threshold for the range of targets assigned to features within a given spatial dataset in alignment with planning processes in other Canadian bioregions (e.g., DFO 2018) and international goals of protecting 10% of marine and coastal habitats (Convention on Biological Diversity (CBD) 2011). In this sensitivity analysis, features with a target below 10% were bumped up to meet the 10% minimum only for the target category in which they fell short (e.g., a feature with bottom, middle, and top targets of 5%, 15%, and 30% would be adjusted to 10% at the bottom level while the middle and top targets would remain unchanged).

To guide the initial use of coarse-filter targets in Marxan analyses, sensitivity analyses were performed using the coarse-filter features alone and testing the bottom (up to 10%) and top (up to 30%) ends of the target ranges for each feature, both with and without the use of the 10% minimum target threshold (see Appendix B for the detailed parameters used). These analyses were performed using three different BLM (clumping factor) values (1, 4, 7) to generate a range of outputs (Table 4) that aligned with guidance on MPA sizing (DFO 2019a). Subsequently, Marxan analyses were run to test whether the minimum target threshold for the coarse-filter features would be achieved incidentally when the broader suite of fine- and coarse-filter features was incorporated. This second suite of analyses included all of the E-CP and C-CP spatial features, without using the 10% minimum target, and was performed using the bottom, middle, and top ends of the target ranges and the BLMs chosen by MPATT for the final analyses (0.25, 2.5). Within these analyses, broader ecological features were assessed against their targets within each of the ecosections present in the NSB.

Coarse-filter feature groups included in the analyses:

1. Bottom patches (Gregr et al. 2013)
2. BC Shorezone: coastal classes (Howes et al. 1994)
3. BC Marine Ecological Classification (BCMEC): marine ecosections (British Columbia Ministry of Sustainable Resource Management 2002)
4. PMECS: biophysical units (Rubidge et al. 2016)
5. PMECS: geomorphic units (Rubidge et al. 2016)
6. Upper ocean subregions (British Columbia Marine Conservation Analysis (BCMCA) Project Team 2011)
7. Ecologically and biologically significant areas (EBSAs) (Clarke and Jamieson 2006)

Results

In the Marxan analyses focusing solely on the coarse-filter features, the effect of adapting the targets up to a 10% minimum varied across the target ranges. The 10% minimum had little impact on the total area contained in the Marxan solutions at the top end of the target ranges, but the total area captured in the solutions increased by almost 50% when the bottom end of the target ranges was used (Table 4). This difference is because there are more features with calculated targets below 10% at the bottom end of the target range and, subsequently, the targets for more features were adjusted to meet the minimum target threshold of 10%. For example, 13 of 16 features within the Upper Ocean Subregions were adjusted to 10% at the bottom target level while only one feature was adjusted to 10% for analyses using the top of the target range.

Table 4. Total area encompassed by the results of Marxan analyses based on the coarse-filter features, both with and without a minimum 10% target threshold.

Target Level (point within target range)	BLM (clumping factor)	Total Area (km^2) in Single Solution (original targets)	Total Area (km^2) in Single Solution (10% minimum target)	% Increase in Total Area
Bottom	1	7,692	11,319	47%
Bottom	4	7,769	11,348	46%
Bottom	7	7,871	11,424	45%
Top	1	16,129	16,659	3%
Top	4	16,586	17,121	3%
Top	7	16,931	17,494	3%

The representation of the coarse-filter features in single example solutions from the analyses using the bottom, middle, and top of the target ranges was also assessed for Marxan analyses using all of the E-CP and C-CP spatial features for which targets were not adjusted to 10%. In the bottom target analysis, 92% of the coarse-filter features met or exceeded the 10% minimum target threshold (Table 5). In the middle and top target analyses, 99% and 99.6% of the coarse-filter features met or exceeded the threshold, respectively.

Table 5. Coarse-filter features that did not meet or exceed the minimum target threshold in Marxan analyses targeting E-CP and C-CP spatial features at bottom, middle, and top points of the target ranges.

Ecological Classification System	Feature (Stratified by Ecosection)	Threshold met in Bottom Analysis	Threshold met in Middle Analysis	Threshold met in Top Analysis
PMECS Geomorphic Units	Shelf Mound (Queen Charlotte Sound)	No (9.98%)	Yes	Yes
PMECS Geomorphic Units	Slope Canyon Floor (Queen Charlotte Sound)	No (8.4%)	Yes	Yes
PMECS Geomorphic Units	Slope Wall Steep (Queen Charlotte Sound)	No (6.7%)	No (8.2%)	Yes
PMECS Biophysical Units	Dogfish Bank	No (9.5%)	Yes	Yes
Upper Ocean Subregions	Hecate Strait	No (8.5%)	Yes	Yes
Shorezone Coastal Classes	Estuary (Johnstone Strait)	No (9.8%)	Yes	Yes
Shorezone Coastal Classes	Estuary (Dixon Entrance)	No (7.5%)	Yes	Yes
Shorezone Coastal Classes	Estuary (Hecate Strait)	No (7.5%)	Yes	Yes
Shorezone Coastal Classes	Gravel Beach (Queen Charlotte Strait)	No (5.8%)	Yes	Yes
Shorezone Coastal Classes	Gravel Beach (Vancouver Island Shelf)	No (6.1%)	Yes	No (7.2%)
Shorezone Coastal Classes	Mudflat (Queen Charlotte Sound)	No (9.3%)	Yes	Yes
Shorezone Coastal Classes	Rock Cliff (Vancouver Island Shelf)	No (5.6%)	Yes	Yes
Shorezone Coastal Classes	Sand Gravel Beach (Hecate Strait)	No (9.9%)	Yes	Yes
Shorezone Coastal Classes	Sand Gravel Beach (Vancouver Island Shelf)	No (8.1%)	No (6.7%)	Yes
Shorezone Coastal Classes	Sand Gravel Flat/Fan (Hecate Strait)	No (8.4%)	Yes	Yes
Shorezone Coastal Classes	Sand Gravel Flat/Fan (Vancouver Island Shelf)	No (4.4%)	Yes	Yes
Shorezone Coastal Classes	Sand Beach (Queen Charlotte Strait)	No (9.2%)	Yes	Yes
Ecologically and Biologically Significant Areas (EBSAs)	Hecate Strait	No (7.1%)	Yes	Yes

Conclusions

For the Marxan analyses focused on the coarse-filter features alone, the spatial coverage of solutions at the bottom target level significantly increased when the 10% target threshold was incorporated. However, the assessment of the broader analyses with all E-CP and C-CP spatial features revealed that the majority of coarse-filter features were captured at or above the minimum 10% target threshold in example solutions at the bottom, middle, and top points of the target ranges, despite the threshold not being applied. In site selection analyses performed by MPATT, the coarse-filter features with targets below 10% were not adjusted to meet a minimum 10% threshold. However, there remains value in ensuring that features meet a 10% target threshold, particularly for analyses that focus on habitats or coarse-filter features alone, to ensure adequate representation of all habitat types in the region, in accordance with the CBD recommendations (Convention on Biological Diversity (CBD) 2011, 2022) and given national guidance recommending the protection of 30% of Canada's marine and coastal habitats (DFO 2019b). Further, while not assessed in these analyses, it may be important to consider it is appropriate to scale targets based on habitat class size for EBSAs given that EBSAs represent prioritized regions of particular ecological importance (Clarke and Jamieson 2006) that are not comprehensive for the study area. In future analyses, it may be more appropriate to assign targets to the individual EBSAs in the same manner as the other area-based features, for which the minimum target was 10%.

Targets for First Nations Cultural Conservation Priorities

Overview

First Nations partners identified cultural conservation priorities (C-CPs) as one way of representing culturally important areas in the MPA network. Informed by Indigenous and cultural data collected by individual partner First Nations, C-CPs helped each Nation ensure that areas of high cultural value in their territories were considered as part of the MPA network planning process[4]. C-CPs include areas that are important for harvesting, for culturally significant species, and for culture and spirituality. The C-CPs are represented by individual spatial features (polygons) and help represent cultural priorities and fill gaps in knowledge for the species and habitats represented by the ecological features. The C-CP rankings were determined separately by Indigenous partners within each of the MPATT planning subregions (Figure 1) and the proportion of C-CPs within each rank varied subregionally.

Although the proportional amounts within different rankings varied across subregions, the proportional amount identified as greater than 'moderate' for MPA network planning purposes was relatively consistent, falling between 18 – 24% of each subregion. For the Haida Gwaii subregion, this considered the 'excluded' portion within the Gwaii Haanas National Marine Conservation Area Reserve and Haida Heritage Site as being categorized as greater than moderate ranking.

Table 6. Subregional distribution of First Nations Cultural Conservation Priorities (C-CPs) by ranking.

	% of Subregion by Ranking					**Total Marine Area (km^2)**
Subregion	Critical	Very High	High	Moderate	Excluded	
Haida Gwaii	1.0%	4.8%	10.9%	75.8%	7.5%	46,057
Central Coast+	17.3%	1.8%	2.8%	78.1%	0.0%	23,750
North Coast+	7.9%	8.1%	2.4%	81.6%	0.0%	21,034
NVI (MaPP)*	0.0%	7.2%	10.5%	82.3%	0.0%	8,002
NVI (unplanned area**)	0.0%	0.0%	0.0%	0.0%	100.0%	5,887

+ The North Coast and Central Coast subregions contain ~ 3200 km^2 of overlapping marine area (Figure 1) resulting in 'double-counting' of marine area across various categories in the area of overlap.

* NVI (MaPP) boundary based on the eastern portion of the NVI planning area, using the subdivisions from the Marine Plan Partnership (MaPP) planning process (Figure 3).

** NVI (unplanned area) represents the area within broader NVI subregion west of the NVI (MaPP) planning area.

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[4] Butler C., McDougall C., Heidt A., Rigg C., Cripps K., McGee G., and Diggon S. In prep. First Nations cultural conservation priorities: integrating Indigenous values into marine protected area network planning.

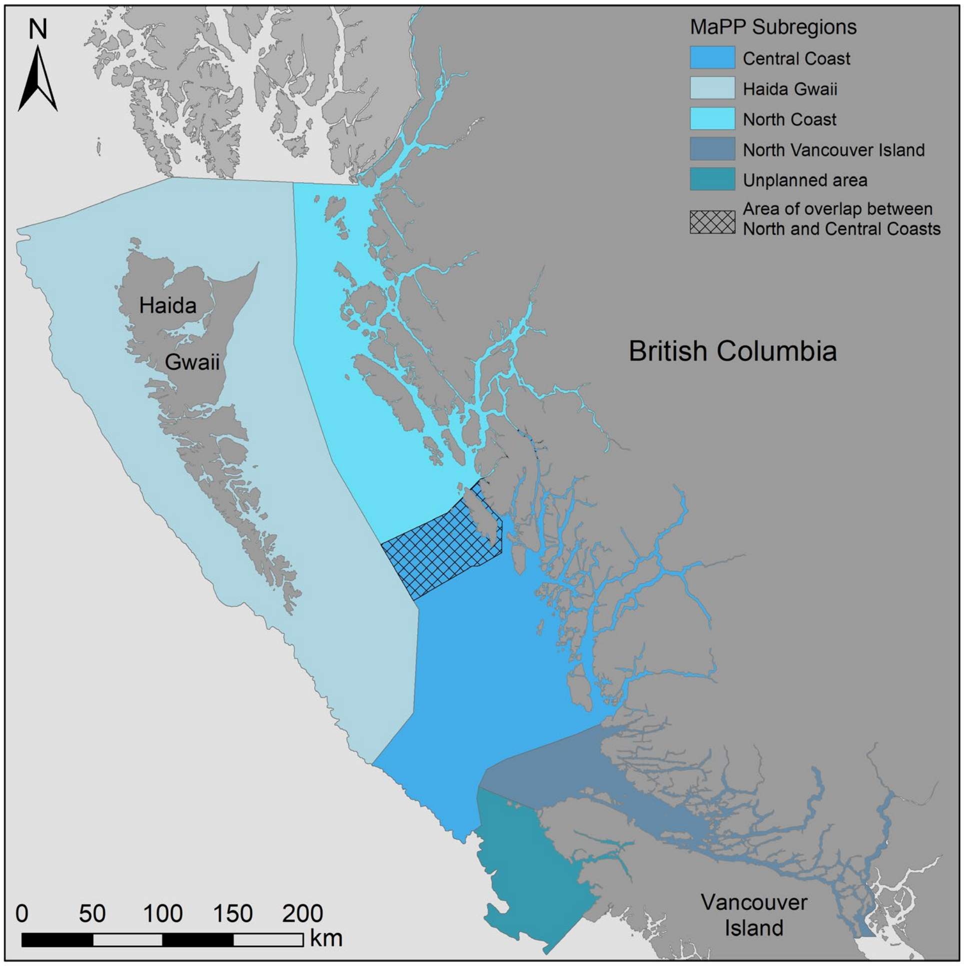


Figure 3. Marine Plan Partnership (MaPP) subregions.

Two approaches were assessed for targeting the C-CPs within the Marxan analyses supporting MPA network development in the NSB. Ecological conservation priorities were assigned to low, medium, and high conservation target classes, each with a corresponding range of targets for use in Marxan analyses (DFO 2019a). C-CPs ranked high, very high, and critical were similarly assigned a range of targets, with two proposed options for the target range for critically-ranked C-CPs (Table 7). In option 1, the critical rank is assigned a target of 60-80%. In option 2, the critical rank is assigned a target of 40-60% (i.e., the same target range as the high target ecological features). In both options 1 and 2, the high and very high C-CP rankings reflect the medium and high ecological target classes, respectively.

Table 7. Target ranges for E-CP and C-CP spatial features tested to determine appropriate starting target ranges for C-CP features in Marxan analyses to support MPA network development.

Sensitivity Analysis	Ecological Conservation Target Class	Ecological Conservation Target Range	C-CP Rank	C-CP Target Range
Option 1	Low	10-20%	High	20-40%
Option 1	Medium	20-40%	Very High	40-60%
Option 1	High	40-60%	Critical	60-80%
Option 2	Low	10-20%	High	20-40%
Option 2	Medium	20-40%	Very High	40-60%
Option 2	High	40-60%	Critical	40-60%

Marxan analyses were performed using all of the E-CP and C-CP spatial features and testing the bottom, middle, and top ends of the target ranges for both options, using 25 runs and a constant BLM of 0.25 (see Appendix B). For each analysis, the spatial extent of the 'best' solution and high selection frequency planning units were compared to the spatial extent of the NSB. In this analysis, high selection frequency planning units were defined as the planning units selected to be part of a solution in at least 10 runs (out of 25) but in subsequent sensitivity analyses, high selection frequency planning units refer to those planning units selected in at least 50% of the runs.

Results

The outputs of the suite of Marxan analyses were similar for the two options in terms of their spatial configuration and the extent of the NSB that was covered by a single solution or by the high selection frequency planning units (Table 8).

Table 8. Outputs of Marxan analyses performed using the bottom, middle, and top points of the target ranges proposed for the E-CP and C-CP spatial features.

	Option 1 Target Levels			Option 2 Target Levels		
Analytics	**Bottom**	**Middle**	**Top**	**Bottom**	**Middle**	**Top**
% of NSB covered by a single solution	21	28	38	21	28	37
% of NSB covered by high selection frequency PUs	23	31	41	22	30	41
% of high selection frequency PUs in common between both options	91	92	94	92	94	94

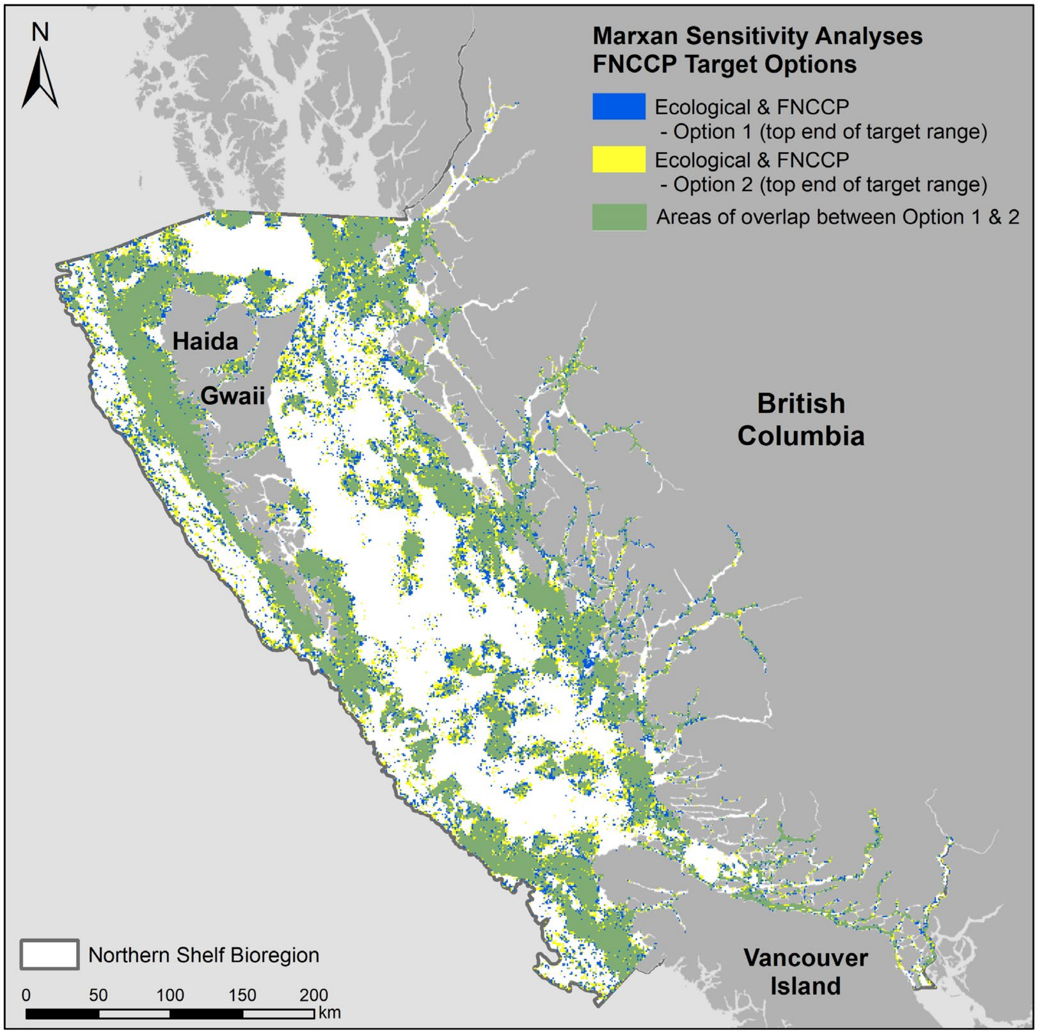


Figure 4. Example solutions from Marxan analyses using the top end of the target range for the two ecological and First Nations Cultural Conservation Priority (referred to as FNCCP on the map) target options. Blue areas indicate the planning units selected as part of the solution when option 1 targets were used. Yellow areas indicate the planning units selected as part of the solution when option 2 targets were used. Green areas indicate planning units selected in both options.

Conclusions

The C-CP features help represent cultural priorities and fill gaps in knowledge for the species and habitats represented by the ecological features. The two target range options tested for the C-CP features yielded similar spatial outputs but in option 2, the highest target ranges were aligned for both the E-CP and C-CP features. Using the same target range for very high and critical C-CPs helped reduce the subregional differences in the ranks applied to the C-CPs and further analyses could be undertaken to assess variations in the spatial coverage of the C-CPs by subregion. Subsequent Marxan sensitivity analyses were performed using the Option 2 targets.

Feature Separation: Habitats and Species

Overview

International agreements on MPA networks often refer to representation in terms of habitats, such as the goal to protect 10% of coastal and marine areas by 2020 (Aichi Target 11 in Convention on Biological Diversity (CBD) 2011) and 30% by 2030 (Convention on Biological Diversity (CBD) 2022). Spatial datasets informing habitat features, particularly those based on broad-scale ecological classification systems, may have more complete coverage throughout the study area than some of the species features and can help represent species with limited spatial information. As such, habitat data alone can be used in Marxan analyses to inform MPA network development or assessment (e.g., Evans et al. 2015; Jantke et al. 2018). Participants at the CSAS peer review of the ecological design strategies in the NSB (DFO 2019a) recommended performing sensitivity analyses to assess how the results of Marxan analyses change if spatial features for species were removed and habitat features were solely used in the analyses. These outputs could help to inform whether habitats are a sufficient proxy for areas important to species-based conservation priorities within the NSB.

Marxan analyses were run using only coarse-filter features (i.e., ecological classifications), only habitat features, only species features, and then all ecological spatial features combined. The analyses focused on only habitat features incorporated both coarse-filter and fine-filter habitat features (Table 9). Spatial features representing species that form biogenic habitats (e.g., corals, sponges, eelgrass) were included in both the habitat and species analyses (Table 9).

Table 9. Spatial features included in sensitivity analyses focused on habitat features. * denotes fine-filter features that were also included in the species analyses.

Coarse-filter Features in Habitat Analyses	Fine-filter Features in Habitat Analyses
Bottom patches	Estuaries
Coastal classes	High current EBSAs
Marine ecosections	High rugosity areas
PMECS biophysical units	Nearshore habitat richness hotspots
PMECS geomorphic units	Bull kelp beds & biobands *
Upper ocean subregions	Eelgrass beds, biobands & priority beds *
EBSAs	General kelp beds *
	Giant kelp beds & biobands *
	Surfgrass biobands *
	Coral (black, soft, stony) & sea pen predicted habitat suitability *
	Coral presence & sponge cover (CCIRA) *
	Coral, sponge & sea pen areas of high biomass *
	Sponge reefs *

Outputs were generated for each analysis using the bottom and top ends of the target ranges for each set of features and using two BLMs 0.5 and 2.5 (see Appendix B) that align with guidance on MPA sizing (DFO 2019a). The targets for the coarse-filter features were not adjusted to a minimum of 10% following the results of the sensitivity analysis on target thresholds (see section on Target Threshold for

Coarse-filter Features). The 'best' solutions from each of the outputs, representing example solutions, and the planning units with a selection frequency above 50% (termed 'high selection frequency' planning units) were compared to determine the total spatial coverage of each output and the planning units in common among the outputs.

To determine how well the species features were captured by the different analyses, the 'best' solutions from the analyses using BLM 2.5 were used as example outputs and overlaid with the spatial features that delineated discrete areas of known importance and observation locations for species-based conservation priorities. The complete list of ecological features assessed using overlays is found in Appendix D.

Results

The Marxan analyses focused on varying suites of habitat and/or species features showed that the total area covered in analysis outputs was lowest when only coarse-filter features were considered and increased when fine-filter habitat features were added for the habitat analyses (Table 10, Figure 5, Figure 6). The smaller spatial footprint of results with the coarse-filter features alone was due to the limited number of coarse-filter features and their lower targets, particularly given that a 10% minimum target threshold was not used (see section on Target Threshold for Coarse-filter Features).

Table 10. Percent of the NSB covered by an example single solution and the high selection frequency planning units from Marxan analyses using the coarse-filter features, habitat features, species features, or all ecological features. Analyses used the bottom and top ends of the target ranges and two BLM options.

Ecological Features Included	Target Level (point in target range)	BLM (clumping factor)	% of NSB in Single Solution (km^2)	% of NSB in High Selection Frequency PUs (km^2)
Coarse-filter	Bottom	0.5	4	0.3
Habitats	Bottom	0.5	11	10
Species	Bottom	0.5	20	20
All features	Bottom	0.5	19	18
Coarse-filter	Bottom	2.5	5	1
Habitats	Bottom	2.5	12	11
Species	Bottom	2.5	21	21
All features	Bottom	2.5	19	19
Coarse-filter	Top	0.5	13	3
Habitats	Top	0.5	28	27
Species	Top	0.5	36	35
All features	Top	0.5	36	36
Coarse-filter	Top	2.5	14	8
Habitats	Top	2.5	30	30
Species	Top	2.5	37	37
All features	Top	2.5	37	37

The species and all feature analyses both generated outputs with a larger spatial footprint than the habitat and coarse-filter feature analyses (Table 10, Figure 7, Figure 8). The differences were most pronounced when the bottom end of the target ranges was used. Analyses based on the species features generated solutions of a similar size to the analyses with the full suite of ecological features, though at the bottom end of the target range, solutions from the analyses using all features had slightly smaller footprints than the analyses focused on species. Incorporating the full suite of features may have improved the overall spatial efficiency of the outputs because planning units were evaluated on their contribution to a larger number of features, some of which had broad spatial extents.

The analyses that used only coarse-filter features resulted in fewer high selection frequency planning units and the proportion of the NSB covered by a single example solution was higher than that covered by the high selection frequency PUs (Table 10, Figure 5). This difference is again due to the broad-scale nature of many of the features and the low feature targets (see section on Target Threshold for Coarse-filter Features), which resulted in higher flexibility in the spatial configurations of the outputs (more areas shown in the orange to green colour range in the maps of selection frequency results). Aside from the analyses based on coarse-filter features, the spatial extents of single example solutions were similar to those of the high selection frequency planning units, as illustrated by the high proportion of planning units in red in Figures 5-7.

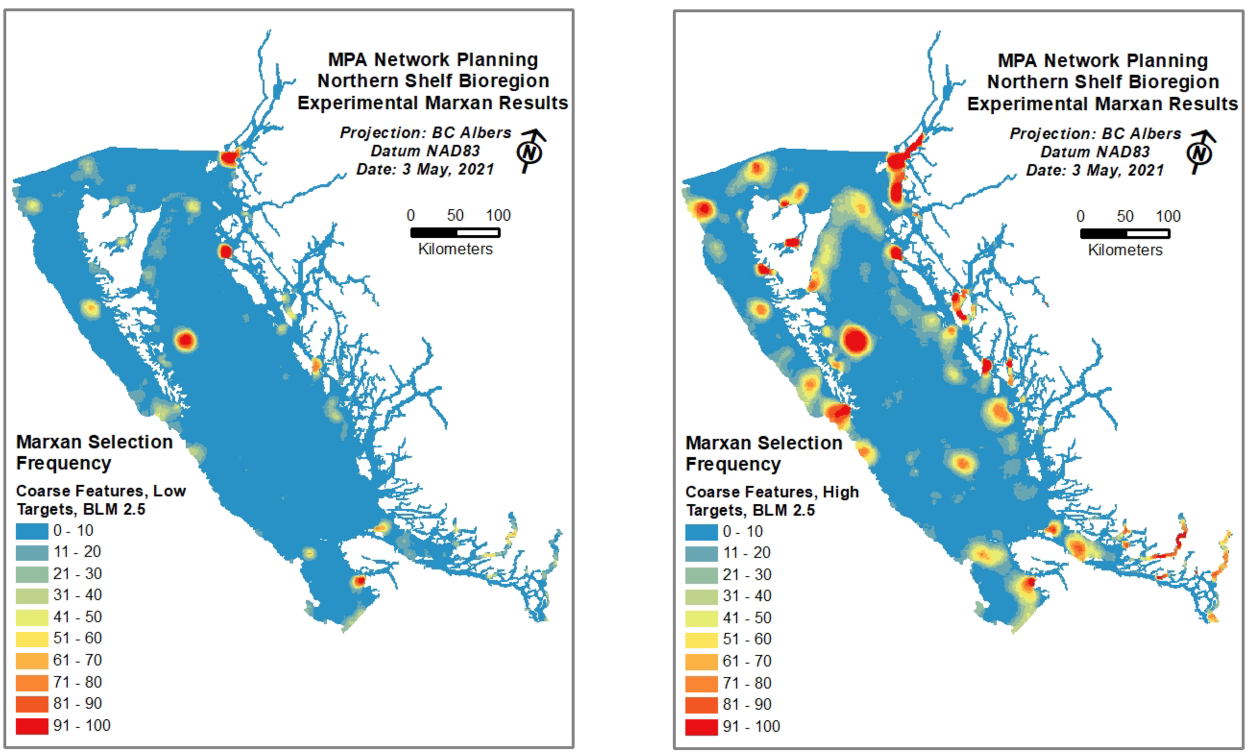


Figure 5. Selection frequency results of Marxan analyses using coarse-filter features at the bottom (left panel; denoted as low in the map legend) and top (right panel; denoted as high in the map legend) end of the target ranges and BLM 2.5.

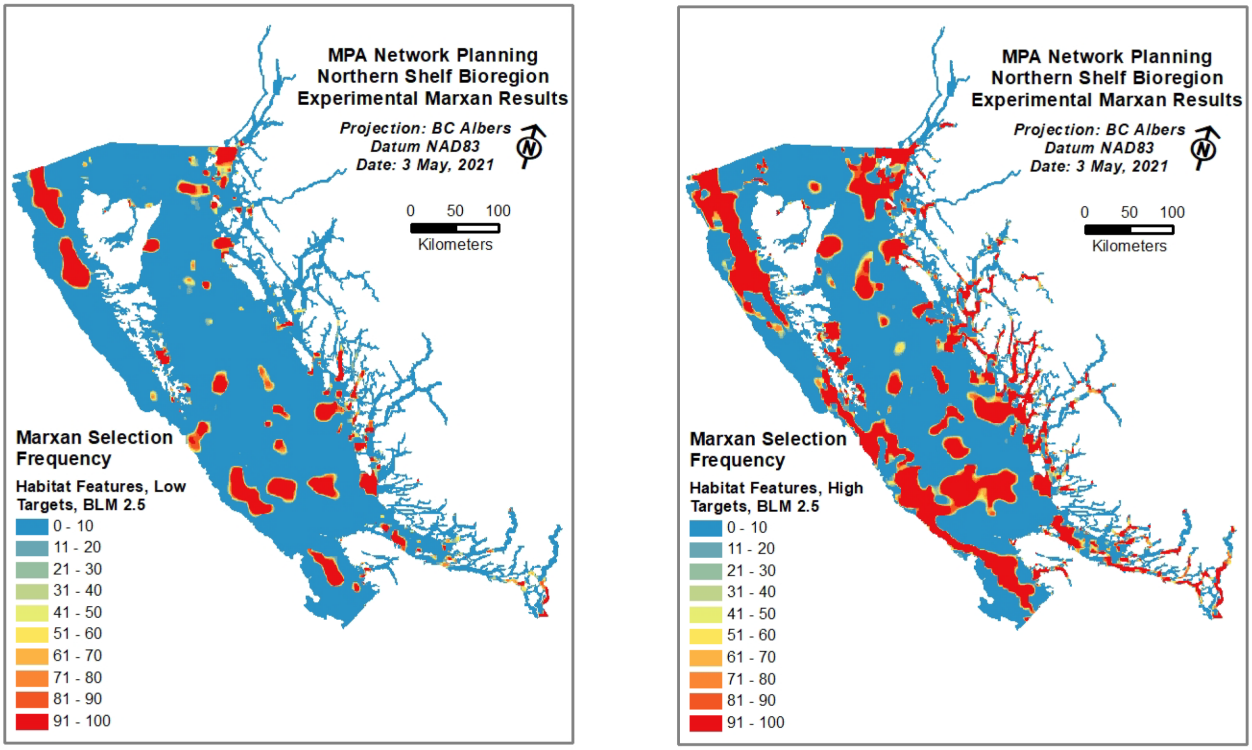


Figure 6. Selection frequency results of Marxan analyses using habitat features at the bottom end (left panel; termed low in the legend) and top end (right panel; termed high in the legend) of the target ranges and BLM 2.5.

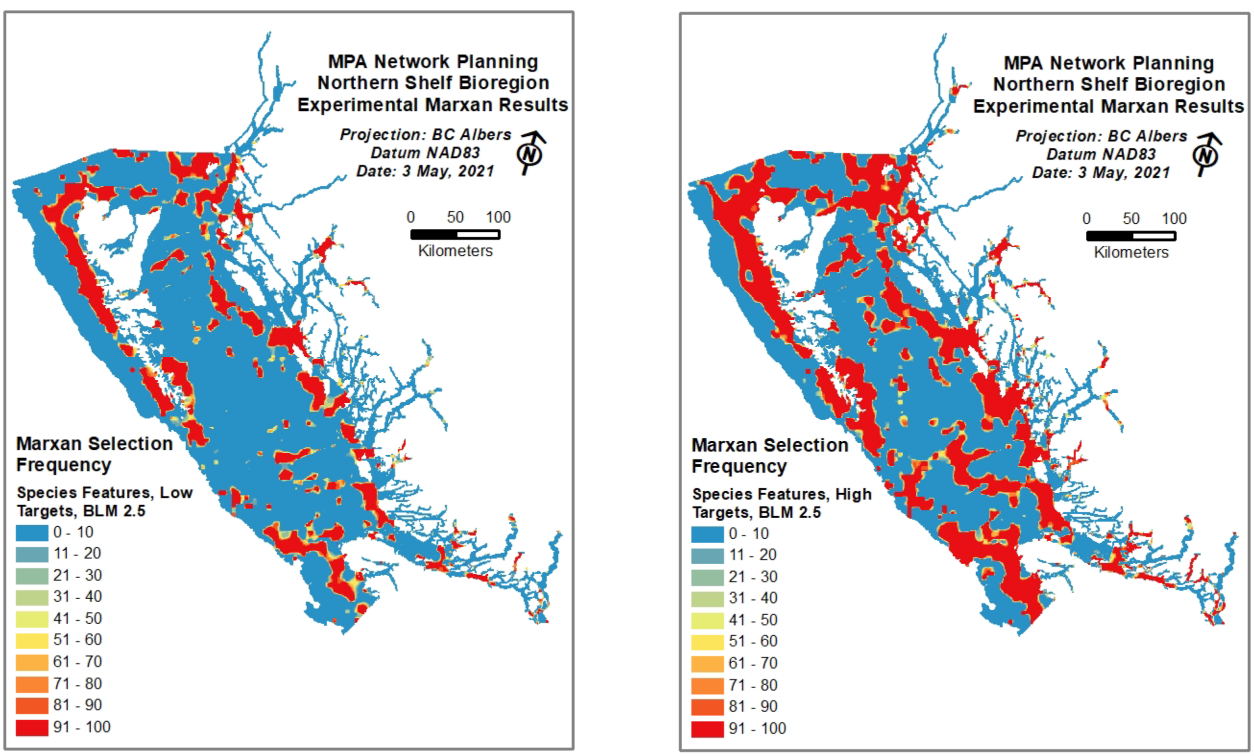


Figure 7. Selection frequency results of Marxan analyses using species features at the bottom end (left panel; termed low in the legend) and top end (right panel; termed high in the map legend) of the target ranges and BLM 2.5.

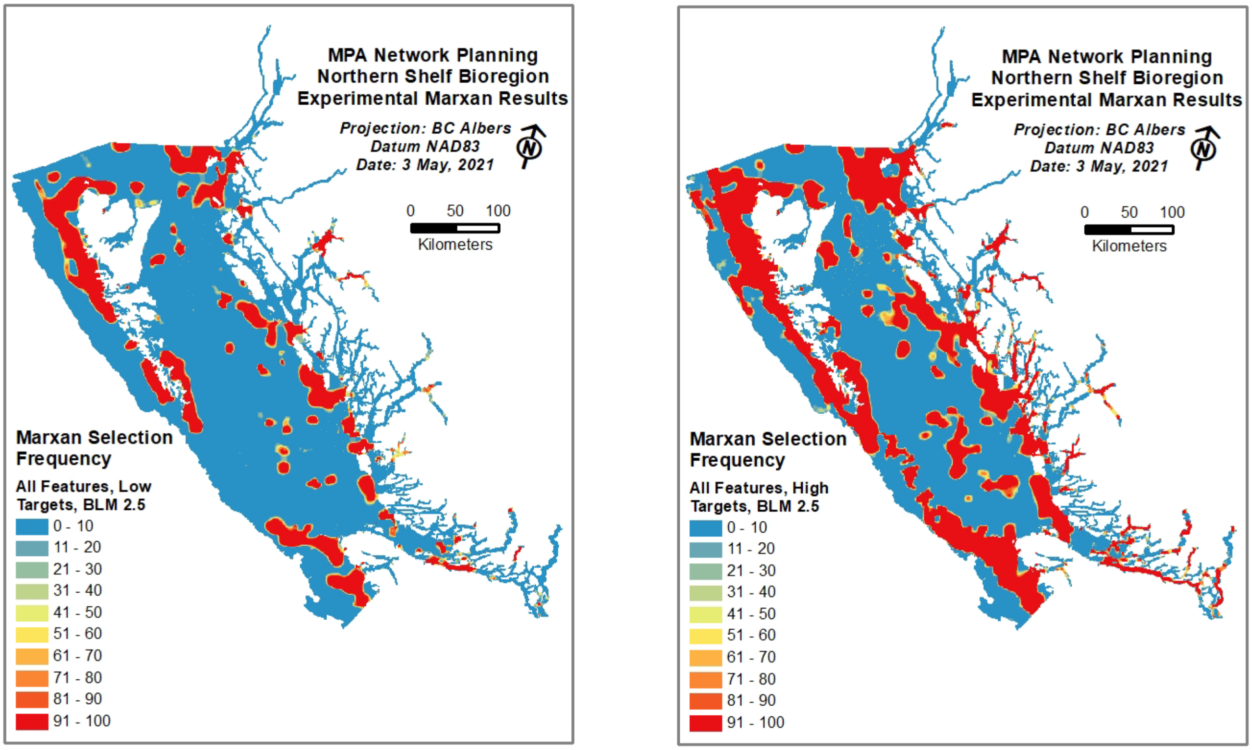


Figure 8. Selection frequency results of Marxan analyses using all ecological features at the bottom end (left panel; termed low in the legend) and top end (right panel; termed high in the legend) of the target ranges and BLM 2.5.

The high selection frequency planning units in the species and all feature analyses were more consistent with the high selection frequency planning units in the habitat analyses than the analyses based only on coarse-filter features (Table 11). Greater overlap was seen at the higher end of the target ranges. When the high end of the target range was used, 55% of the high selection frequency planning units from the analysis using the full suite of ecological features overlapped with those from the habitat-focused analysis. A higher percent overlap from the coarse-filter analysis at the low end of the target range is largely due to the low number of high frequency planning units identified in that analysis.

Table 11. Planning units in common among high selection frequency planning units from Marxan analyses using the coarse-filter features, habitat features, species features, or all ecological features. Analyses shown are based on bottom and top ends of the target ranges at BLM 2.5.

Ecological Features Included	Target Level	Count of High Selection Frequency PUs	% of High Selection Frequency PUs in common with Coarse-filter Analysis	% of High Selection Frequency PUs in common with Habitat Analysis
Coarse-filter	Bottom	1,520	-	37.5
Habitats	Bottom	12,911	4.4	-
Species	Bottom	23,659	1.3	19.1
All features	Bottom	21,827	1.7	22.1
Coarse-filter	Top	9,511	-	47.6
Habitats	Top	33,699	13.4	-
Species	Top	41,623	9.6	45.1
All features	Top	42,533	11.7	54.5

The spatial features representing discrete areas of importance for species-based conservation priorities varied in their ability to meet their ecological conservation targets based on their overlap with the 'best' solutions as examples of the analysis results. When overlaid with the species and all-feature analyses, all species features met the corresponding point within their target ranges (Table 12). The coarse-filter and habitat analyses captured fewer of the species features. For example, the analyses using the top end of the target range for the coarse-filter features only captured the top target levels for 8% of the species features but top end of the target level was met for 26% of the species features when the habitat features were also included in the analyses. However, when the top end of the target range was used for the habitat analyses, the 'best' solution captured the bottom end of the target range for 76% of the species features (Table 12).

Table 12. Results of overlay analyses with spatial features representing areas of importance and observation locations for species-based conservation priorities and the Marxan analyses targeting coarse-filter, habitat, species, and all ecological features at bottom and top ends of the target ranges with BLM 2.5. * Note that target achievement was assessed against the point within the target range used in the analysis (i.e., species features were assessed against the top end of the target range for the top target level analyses). The top end of the target ranges for the species features would not be expected to be met when analyses were performed using the bottom end of the target ranges

Ecological Features Included	Target Level	Species Features meeting Bottom Target	Species Features meeting Top Target *
Coarse-filter	Bottom	14%	2%
Coarse-filter	Top	32%	8%
Habitats	Bottom	17%	2%
Habitats	Top	76%	26%
Species	Bottom	100%	30%
Species	Top	100%	100%
All features	Bottom	100%	33%
All features	Top	100%	100%

Conclusions

The outputs of this sensitivity analysis showed that the total solution area is smallest when only the coarse-filter or habitat features are included. Analyses using these features had limited overlap with spatial data on discrete areas of importance for the species-based conservation priorities. This limited overlap is likely because the habitat features (in particular the coarse-filter features) have lower targets than many of the species features, and because fine-scale information on the distribution of species has not been included, so Marxan is selecting areas that may not have any ecological value to species of importance. As noted in the sensitivity analysis focused on the target threshold for coarse-filter features, the maximum range of targets for coarse-filter features is 10-30% for the smallest habitat class within each ecological classification system. As a result, most of the habitat classes have targets that fall below international recommendations (e.g., Convention on Biological Diversity (CBD) 2011, 2022). A minimum threshold for coarse-filter features was not used in these analyses. Incorporating a minimum target would likely have increased the total area of the outputs and may have resulted in improved overlap with the species features. The sensitivity analyses showed that when habitats were targeted at the top end of the target range, there was greatly improved achievement of the targets of the species features, though primarily that achievement was only at the bottom end of the species target ranges.

Habitats have been used as proxies for species-based features when species data are limited (e.g., Airamé et al. 2003) and the coarse-filter conservation priorities in the NSB were included to ensure the representation of the bioregion's diverse ecosystems (DFO 2019a). Coarse-filter features can also provide more continuous, coastwide coverage than some of the species- and area-based features but can lack spatial precision and may not fully represent all species considered important with the study area (Smith et al. 2009). The spatial features available to represent either broad- or fine-scale habitats in the NSB also typically lack information on varying habitat quality or viability within their bounds. Given that ecological communities can vary along environmental gradients, guidance in the literature (e.g., Virtanen et al. 2018) suggests that habitats may not be sufficient proxies in all cases and MPA network planning should incorporate species information. This is further supported by guidance on site selection analyses for MPA network planning (e.g., Smith et al. 2009; Lieberknecht et al. 2010) and the design guidelines for MPA network planning in the NSB (Lieberknecht et al. 2016), which recommend protecting both coarse- and fine-filter features within the final network.

Incorporating Naturalness in Coarse-filter Features

Overview

MPA network design often strives to incorporate both pristine and degraded areas to ensure the protection of vulnerable species and areas that may have more resilience to climate change while also facilitating the restoration of highly productive ecosystems and maximizing the potential contributions of individual MPAs (Brooks et al. 2006; Joppa and Pfaff 2009; DFO 2013; Burt et al. 2014). Indeed, 'degraded areas' were identified as ecological conservation priorities in the NSB (DFO 2017a). Design principles for MPA network planning in the Pacific Region also highlight the importance of striving to 'minimize the negative' by selecting sites for the MPA network that meet ecological objectives while minimizing adverse impacts on ocean users (Canada – British Columbia Marine Protected Area Network Strategy 2014), which would suggest the selection of areas where fewer activities occur and may be more pristine. Although coarse-filter features were included in site selection analyses to ensure the representation of the natural diversity of the NSB (Lieberknecht et al. 2016; DFO 2019a), habitat quality and condition varies within each of the broad-scale ecological classification systems and is not well captured within the available spatial features. Highly impacted areas may not be as representative of the natural system but could highlight focal sites for restoration.

Within the Canadian Pacific, spatial data for marine and terrestrial activities have been compiled and used to inform assessments of cumulative impacts (Ban et al. 2010; Clarke Murray et al. 2015). Clarke Murray and co-authors (2015) calculated a grid of cumulative effects score for marine areas along the BC coast and showed that relatively high impacts were most often observed within intertidal ecosystems but that pelagic ecosystems had the highest overall cumulative effect score because of their large spatial coverage. This work was extended to classify marine areas by their cumulative effects scores to determine whether they correspond to global ocean landscape conditions that require similar management measures (Locke et al. 2019). In an exploratory extension of that work, cumulative effects scores were classified by three natural breaks to identify areas of relatively low impact in the Canadian Pacific (cumulative effects scores <=9.78) (Agbayani and Murray 2020).

To assess how well naturalness was captured within the Marxan analyses, sensitivity analyses were performed using the 'best' solution and high selection frequency planning units (planning units selected at least half of the solutions; ssoln >=50) from two example outputs from MPATT's final suite of Marxan analyses (Appendix B). The Marxan analyses included both E-CP and C-CP spatial features but the first used area as the cost (i.e., striving for spatial efficiency in the results), while the second used socioeconomic information as the cost (i.e., striving to minimize overlap with areas important for human activities based on the selection frequency outputs of the 'reverse Marxan' analyses that incorporated data from the commercial and recreational fishing, aquaculture, transportation, non-extractive marine recreation, and forestry industries). Both sets of analyses used the midpoint of the target ranges for the E-CP and C-CP spatial features and a BLM of 0.25. These outputs were overlaid with the cumulative effects scores calculated by Clarke Murray and co-authors (2015) to determine the average cumulative effects score in each example solution, as well as the proportion of each example solution that overlapped areas considered relatively low impact (Agbayani and Murray 2020).

Results

Based on the suite of activities included in the work by Clarke Murray et al. (2015), 54% of the NSB had a cumulative effects score of 9.78 or less and was considered to be an area of relatively low impact (Agbayani and Murray 2020; adapted from Clarke Murray et al. 2015). The average cumulative effects score of the NSB was 10.97. The grid cells selected most frequently and in the single solutions of the Marxan analyses were often the same areas identified as being of relatively low impact, which is unsurprising given the similarities in the spatial configurations of the Marxan outputs. The agreement between the grid cells selected in the Marxan analyses and the areas of relatively low impact increased slightly when socioeconomic information was used as a cost to avoid areas important for human activities (Table 13, Figure 9). There was a corresponding decrease in the average cumulative effects score for the grid cells selected most frequently, or in a single solution, when socioeconomic information was incorporated into the cost.

Table 13. Overlap between areas of relatively low impact derived from cumulative effects (CE) analyses (Clarke Murray et al. 2015; Agbayani and Murray 2020) and Marxan outputs from a suite of analyses incorporating both E-CP and C-CP spatial features and using medium targets, BLM 0.25, and either area or socioeconomic information as the cost.

Marxan Analysis Cost Parameter	% of Single Solution overlapping Areas of Relatively Low Impact	Average CE Score of Single Solution	% of High Selection Frequency PUs overlapping Areas of Relatively Low Impact	Average CE Score of High Selection Frequency PUs
Area	47%	8.28	45%	8.73
Socioeconomic	50%	8.21	47%	8.5

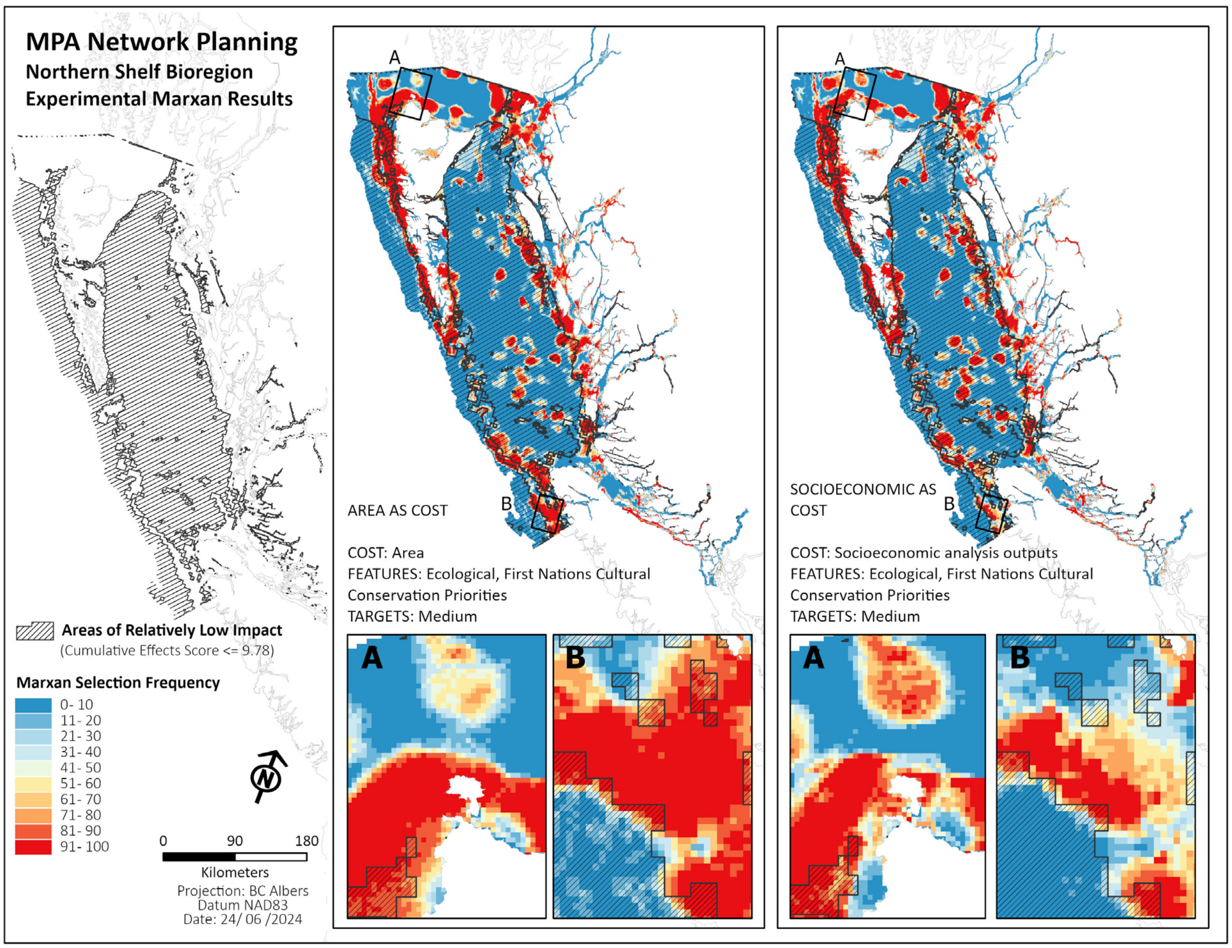


Figure 9. Overlap of areas of relatively low impact (Agbayani and Murray 2020; adapted from Clarke Murray et al. 2015) with the selection frequency results of Marxan analyses using all ecological and First Nations cultural conservation priority features with area (left panel) or socioeconomic information (right panel) as a cost and BLM 0.25.

Conclusions

The contributions of MPA networks can be enhanced when they incorporate both areas that are more pristine or natural and degraded areas that would benefit from restoration. Identification of these areas can be informed by site selection analyses that focus on ecological features, analyses that focus on areas important to human activities, and those that combine both types of data to highlight areas that achieve ecological and cultural targets while avoiding areas important for human uses.

The work of cumulative impact analyses could provide further information for decision makers by detailing the vulnerability of different habitats to human activities. The results of this sensitivity analysis showed that the areas of relatively low impact (Clarke Murray et al. 2015; Agbayani and Murray 2020) had a 45-47% overlap with the planning units chosen most often in the example Marxan analyses. These areas had a slightly lower average cumulative effects score than the average score across the entire NSB. There were not substantial differences in average cumulative effects scores or overlap with areas of relatively low impact for the example analyses incorporating socioeconomic costs from the analyses that used area as a cost. However, spatial differences were not extensive between the two Marxan analyses that were assessed, particularly in nearshore environments. Cumulative effects scores could also be used to assess the differences between the MPA network design scenarios that incorporate a variety of inputs, including the Marxan analyses. Given the size of the areas of relatively low impact identified through the cumulative impacts assessment, a simple overlay analysis may not be a sensitive enough comparison at the scale of the NSB but cumulative effects scores could be assessed within individual network zones.

Cumulative effects assessments in the Pacific (Clarke Murray et al. 2015) have included marine activities as well as land-based that can impact the marine environment and may provide a more complete picture of potentially degraded areas. However, incorporating activity information into Marxan analyses requires the spatial distributions of all human activities, or associated stressors, be combined into a single cost layer and therefore cannot represent the variable impacts of activities on ecological and First Nations cultural conservation priorities given their presence or intensity in different marine areas. However, using cumulative effects scores as the cost layer could potentially better incorporate the relative impact of activities or stressors based on vulnerabilities of different habitats. Future analyses could also make use of decision support tools such as Marxan with Zones (Watts et al. 2009) that can accommodate location- and feature-specific information for both conservation priorities and human activities. Marxan with Zones analyses could facilitate solutions that can identify areas of high importance to human activities, areas where some activities can co-occur with some conservation priorities, and areas important for high protection. These types of updated analyses would require information on compatibility among activities as well as the compatibility of activities and different ecological features. As has been tested in other jurisdictions (Markantonatou et al. 2021), analyses could take advantage of updated cumulative impact maps that are being developed for the Pacific Region to incorporate the vulnerability of habitats to different marine activities (Murray et al. 2024). Additional work would be required to further understand the vulnerability of individual species or how multiple stressors may interact and impact ecological features.

Commercially-harvested Species

Overview

The list of ecological conservation priorities includes species that are commercially-harvested (DFO 2017a). These species are listed in Appendix E. In an effort to reduce spatial and species biases that arise from targeted sampling, fishery-independent, random-stratified, effort-corrected survey data were preferred over commercial catch data to develop spatial features for all fish and invertebrate species (whether commercially-harvested or not). The exceptions were invertebrate species features based on presence-only records and features for coral and sponge biomass (Table 14). In general, subject matter experts confirmed that the fishery-independent surveys highlight areas of ecological importance and are consistent with commercial data.

Table 14. Spatial features for ecological conservation priorities that incorporate information from commercial fisheries.

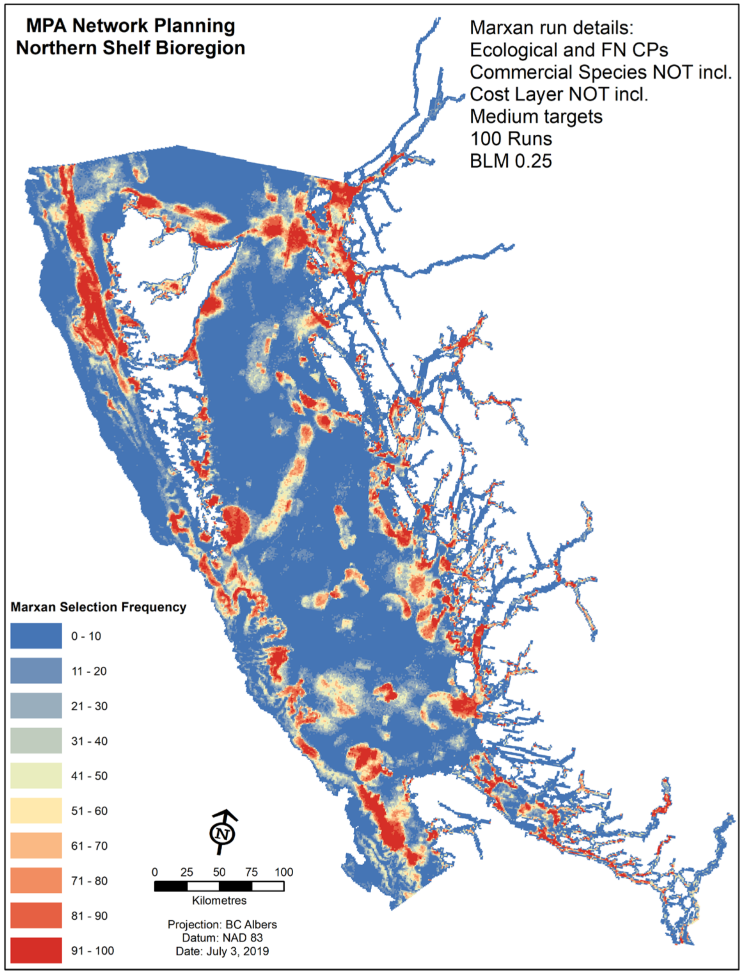
Spatial Feature	Ecological Conservation Priorities
Locations (presence-only records from a variety of research and commercial sources)	Butter clams, cockles, coonstripe/dock shrimp, Dungeness crab, geoduck, giant Pacific octopus, green urchin, horse clam, humpback shrimp, littleneck clam, northern abalone, ochre sea star, Olympia oyster, opal squid, Puget Sound king crab, purple-hinged rock scallop, red sea urchin, sidestripe shrimp, smooth pink shrimp, spiny pink shrimp, spot prawn, sunflower sea star
Catch Per Unit Effort (CPUE; from DFO surveys and commercial groundfish trawl fishery records). Commercial records were reported by at-sea observers.	Corals (not including sea pens), sea pens, sponges

Stakeholders of the MPA network process representing the commercial harvesting sector requested sensitivity analyses looking at the impact of including spatial features for the commercially-harvested species in site selection analyses. To assess how the outputs of Marxan analyses would differ when commercially-harvested species were removed, two sets of experimental Marxan analyses were run with all features except those caught in commercial fisheries (Appendix E). The list of species features removed from the analysis was inclusive to show the greatest difference in analysis outputs and included targeted and incidentally captured (bycatch) species from features created using either fishery-independent or commercial data sources. Incidentally caught features that were not removed were those associated with the following ecological conservation priorities: corals, sponges, sea pens, and sunflower sea star.

The experimental analyses removed any spatial features associated with species caught in commercial fisheries but included spatial features for the remaining E-CPs and C-CPs. The first analysis used planning unit area as the cost layer, which prioritized spatially efficient solutions. In the second analysis, socioeconomic information was used as a cost so that the analysis would aim to meet ecological objectives while reducing overlap with some of the human uses in the NSB. Both analyses used the midpoint of the feature target ranges and a BLM of 0.25 (see Appendix B). The outputs of these experimental analyses on a subset of spatial features were compared to Marxan analyses run with the full suite of spatial features for the E-CPs and C-CPs.

Results

Figure 10 illustrates the results of the experimental Marxan analysis performed without commercially-harvested species, using area as the cost, next to the results of the Marxan analysis incorporating all of the ecological features, but with all other parameters held constant. Similarly, Figure 11 shows the outputs of Marxan analyses with and without the commercially-harvested species that incorporated socioeconomic information as a cost. Both the overall footprint of high selection frequency sites and the overall proportion of area selected were higher when commercially-harvested species were included than when they were excluded (Table 15). The two scenarios also differed somewhat in their spatial configuration, based on the alignment of high selection frequency planning units between the analyses (Table 16).



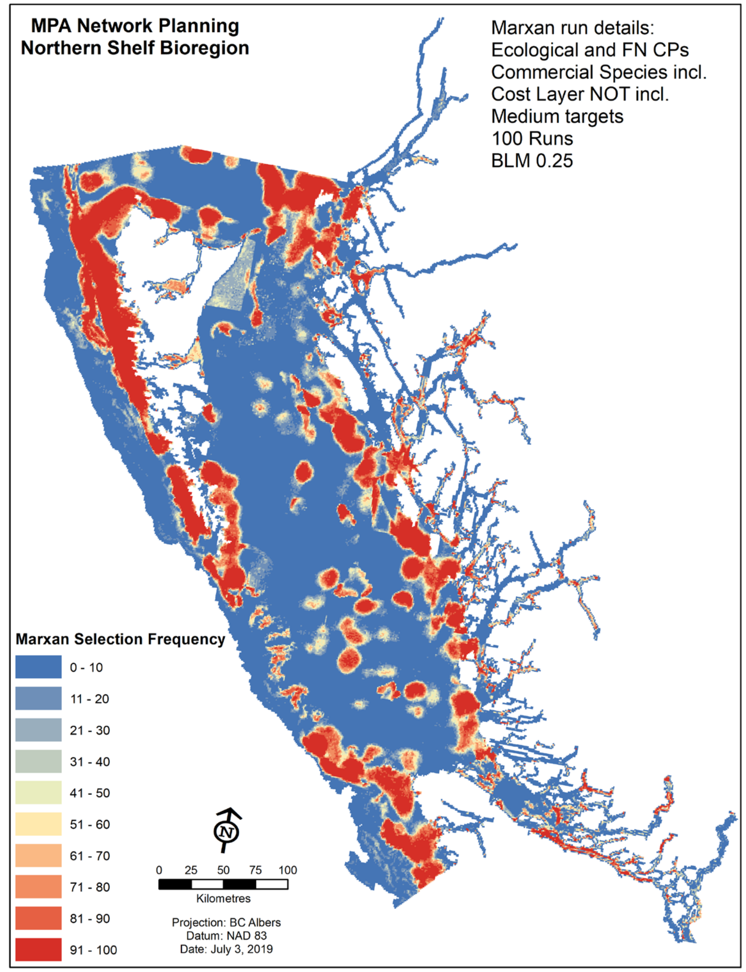
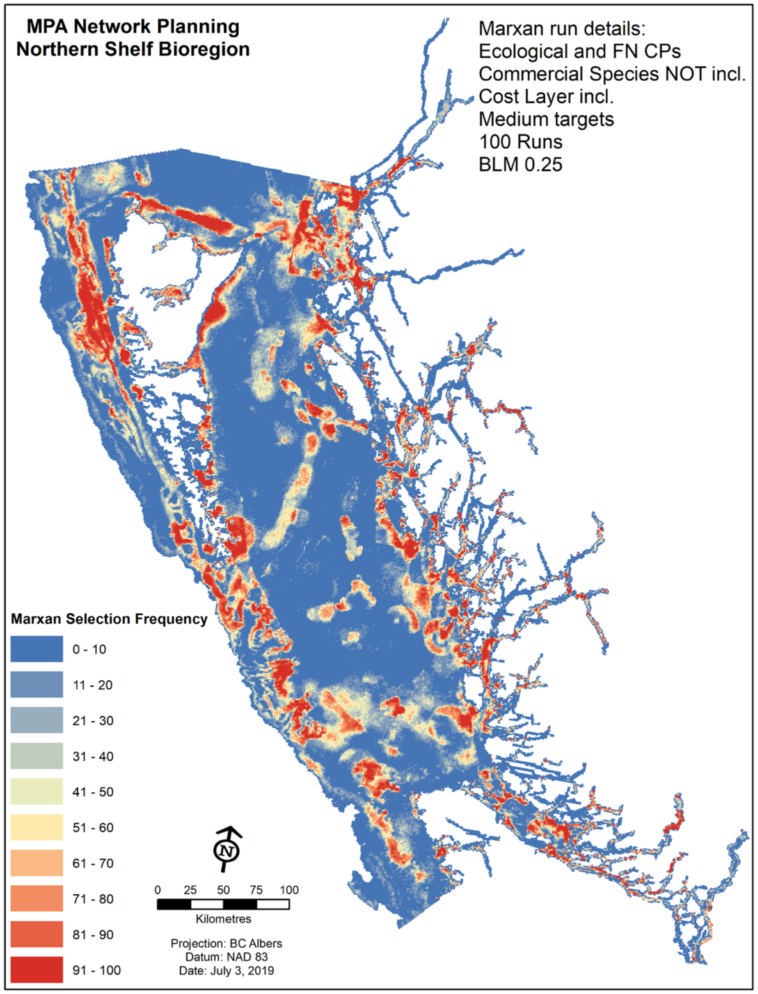


Figure 10. Marxan summed solution (selection frequency) maps for the experimental run with no commercially-harvested species (left) and with commercially-harvested species included (right) and using area as the cost layer. Categories represent the number of times a planning unit is selected into the 'solution' out of 100 independent runs with areas shown in red those that are selected most often.



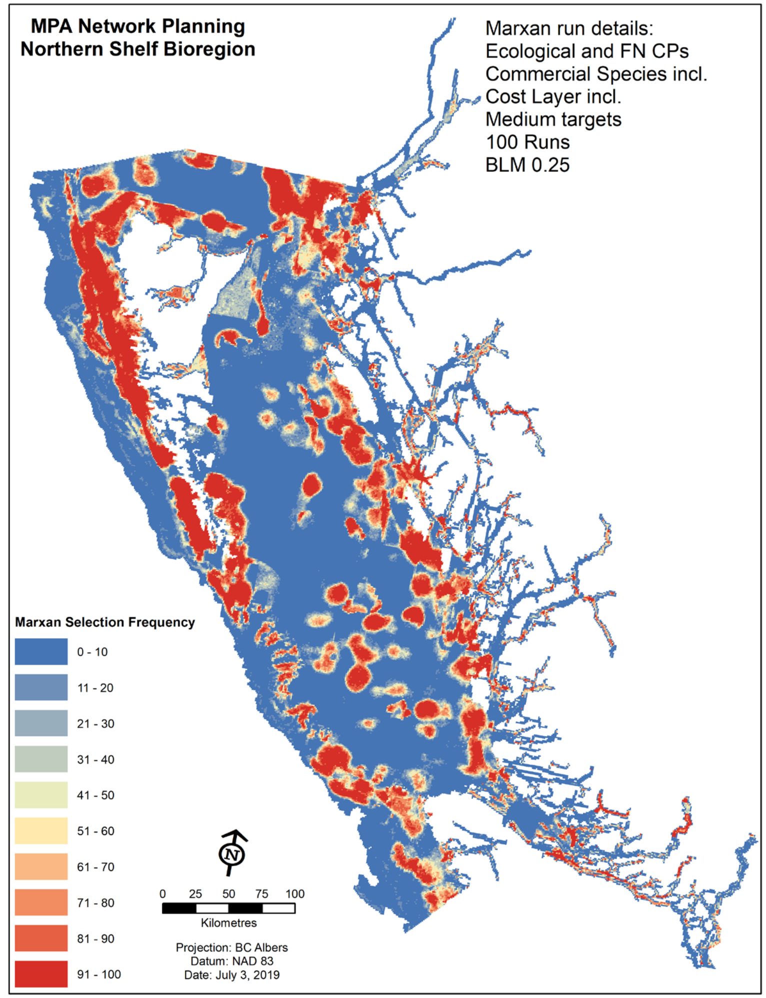


Figure 11. Marxan summed solution (selection frequency) map for experimental run with no commercially-harvested species (left) and with commercially-harvested species included (right), and using the socioeconomic cost layer. Categories represent the number of times a planning unit is selected into the 'solution' out of 100 independent runs with areas shown in red those that are selected most often.

Table 15. Proportion of planning units selected at a higher frequency and overall in Marxan analyses with and without commercially-harvested species when area was used as the cost layer.

	With commercially-harvested species	**Without commercially-harvested species**
Planning units selected more than 40/100 times	29%	23%
Planning units selected more than 85/100 times	16%	9%
Average proportion of planning units selected over 100 runs (near-optimal solutions)	28%	23%

Table 16. Proportion of planning units selected in both the experimental analysis without commercially-harvested species and the MPATT final set of Marxan analyses.

	Percent of planning units in common between experimental analyses with and without commercially-harvested species (area as cost)
Planning units selected more than 40/100 times	65%
Planning units selected more than 85/100 times	58%

Conclusions

Omitting the commercial species features from the Marxan analyses moderately changed the spatial outputs. Removing the commercially-harvested features resulted in fewer planning units included in individual solutions (i.e., smaller overall footprint), but there was some consistency in the locations that the model picked repeatedly as part of a solution (Table 15, Table 16). This is not unexpected as the removal of 71 features (the targeted and incidentally caught species) resulted in an analysis with fewer targets to be met and, therefore, outputs could be achieved in a smaller space. However, the results depend on the spatial footprint of the collection of individual features, the extent to which the features overlap, and the associated targets. The alignment of areas of high selection frequency between analyses with and without commercially-harvested species included was to be expected as over 150 targeted features remain in common. Changes in alignment are indicative of areas where commercially-harvested species are being “picked-up”, in combination with other features, such as those representing habitats, and/or non-commercial species.

Species that are important commercially are often also important ecologically and play a key role in marine food webs. Commercially-harvested species were identified as ecological conservation priorities in the NSB and other bioregions across Canada (DFO 2017a, b, 2018, 2019a) because of their ecological importance and their relevance to the primary MPA network goal related to the long-term protection of biodiversity, ecosystem function, and special natural features. Given that analyses performed using habitat data layers as a proxy did not capture targets for many species-based conservation priorities (see section on Feature Separation: Habitats vs. Species), habitats important to commercially-harvested species may not be well captured if data for those species are removed from analyses. Incorporating commercially-harvested species in analyses can also help contribute to goals and objectives related to the protection of fishery resources and their habitats and objectives related to maintaining the size and age structures of fished populations[5].

[5] http://mpanetwork.ca/bcnorthernshelf/planning-process/#one

Confidential Data – Northern Abalone

Overview

Northern Abalone is an ecological conservation priority for MPA network planning in the NSB (DFO 2017a). Northern Abalone is listed as endangered by the Species at Risk Act (SARA) with illegal harvest and habitat destruction among their primary threats (DFO 2015). Spatial data of Northern Abalone observations are compiled and held by DFO but are considered confidential because of the sedentary nature and short dispersal range of adult abalone. As a result, although Northern Abalone were assessed and assigned an ecological conservation target range of 20-40% in the ecological design strategies CSAS process (DFO 2019a), the species was not included in the Marxan analyses run by MPATT.

DFO members of the MPATT science subcommittee performed overlay analyses to assess internally how well the spatial data for Northern Abalone were represented in a range of the MPATT Marxan outputs. The Northern Abalone spatial data were overlaid with the planning units within the NSB. These PUs were then overlaid with: 1) the 'best' Marxan solutions (i.e., the solutions with the lowest overall cost) as example solutions; 2) the top two classes of the selection frequency outputs from a suite of Marxan analyses that included ecological conservation priorities only; and 3) analyses that incorporated both ecological and First Nations cultural conservation priorities. All Marxan analyses were run 25 times using a BLM (clumping factor) of 0.25 and the planning unit area as the cost (see Appendix B).

Results

The reported overlap of planning units known to contain spatial data for Northern Abalone and the outputs of the example Marxan analyses is shown in Table 17. The overlap was highest with the analyses that incorporated both E-CP and C-CP spatial features, with the overlap exceeding 90% at all target levels.

Table 17. Overlap of spatial data for Northern Abalone with a single solution and the selection frequency results of Marxan analyses focused on ecological (E-CPs) and First Nations cultural conservation priorities (C-CPs) at the bottom, middle, and top ends of the target ranges.

Analysis	Target Level (point in target range)	Overlap with 'best' solution	Overlap to top two classes of selection frequency (>=24)
E-CP features Only	Bottom	64%	23%
E-CP features Only	Middle	78%	37%
E-CP features Only	Top	87%	54%
E-CP and C-CP features	Bottom	>99%	92%
E-CP and C-CP features	Middle	>99%	98%
E-CP and C-CP features	Top	100%	>99%

Conclusions

The spatial data for Northern Abalone met or exceeded their target range within the top two classes of the selection frequency and the 'best' solutions for all Marxan outputs that were assessed as example solutions. In particular, when the C-CP spatial features were included in the analyses, almost all of the planning units that contain Northern Abalone overlapped the example Marxan outputs.

Summary of Results

This report documents the results of sensitivity analyses recommended through the CSAS peer review of the ecological design strategies (DFO 2019a), plus additional analyses suggested by partners and stakeholders of the MPA network planning process in the NSB.

The sensitivity analyses focused on the target ranges applied to the spatial features showed:

- **Species-based features:** the quartile approach recommended by Martone et al. (2021) to assign targets for species-based conservation priorities aligned best with expert feedback.
- **Coarse-filter features:** site selection analyses performed using the full suite of features met the 10% target threshold for coarse-filter features at all points in the target ranges (bottom, middle, top), even when the threshold was not applied. However, for analyses focused on smaller suites of habitat features alone, ensuring features meet a minimum target threshold would be consistent with international guidance (Convention on Biological Diversity (CBD) 2011, 2022).
- **First Nations Cultural Conservation Priority (C-CP) features:** the two target range options tested for C-CP features yielded similar spatial outputs. Using the same target range for very high and critical C-CPs helped balance subregional differences in the rank application.

The sensitivity analyses that assessed the inclusion of different suites of features highlighted:

- **Feature separation:** Analyses focused on coarse-filter or habitat features had limited overlap with spatial data on discrete areas of important for species-based conservation priorities, likely due to the low target levels for many of the coarse-filter features. The spatial features available to represent broad- or fine-scale habitats in the NSB may also lack the spatial precision and information on variations in habitat quality and usage necessary to act as proxies for all species recommended as conservation priorities. The inclusion of spatial data for both habitats and species is in accordance with the design guidelines for MPA network planning in the NSB.
- **Naturalness:** Overlays performed with the results of cumulative effects assessments (Agbayani and Murray 2020) showed that approximately 54% of the planning units selected most often in the example Marxan analyses were considered areas of relatively low impact. The contributions of MPA networks can be enhanced when they incorporate both more pristine or natural areas and degraded areas that would benefit from restoration. Future assessments could consider using decision support tools able to assess individual activities or incorporate species- and habitat-specific vulnerabilities and/or habitat condition (e.g., Klein et al. 2013).
- **Commercial species:** Outputs of Marxan analyses had smaller overall footprints when commercially-harvested features were removed from analyses. This was unsurprising given that target achievement was required for 71 fewer features. Areas no longer included in the outputs are indicative of areas where spatial data for commercially-harvested species are found along with other datasets representing habitats or non-commercial species. However, given that analyses showed that the habitat features alone did not fully capture areas important for species-based conservation priorities, and because commercially-harvested species often play important ecological roles, their inclusion in analyses is relevant to the primary MPA network goal related to the long-term protection of biodiversity, ecosystem function, and special natural features.
- **Confidential data:** Spatial data assessed internally by DFO showed that the target ranges for Northern Abalone were met or exceeded by the Marxan analyses assessed, despite these data not being included in the analyses due to their confidential nature.

Additional Sensitivity Analyses

Sensitivity analyses were not performed for two of the recommendations from the design strategies CSAS process (DFO 2019a): 1) offshore vs. nearshore features; and 2) proportions of no-take area.

Feature Separation: Offshore and Nearshore

MPA network planning in some Canadian bioregions (e.g., DFO 2018) has proceeded separately in nearshore and offshore regions due to differences in the resolution and availability of datasets. In the NSB, discrepancies in data availability might be less pronounced than in other bioregions because offshore survey effort often extends into the nearshore environment and there are additional surveys focused on nearshore areas. For example, in the nearshore region, aerial coastline surveys (Howes et al. 1994) performed over many years have generated coastwide datasets representing nearshore (intertidal and subtidal) habitats. DFO performs a variety of surveys in the nearshore environment, including those focused on habitat mapping (Davies et al. 2018), fish and invertebrate stock assessment (e.g., DFO 2021), marine mammal population assessments (e.g., Olesiuk 2018), and herring spawn events (Hay et al. 2011). Environment and Climate Change Canada (ECCC) performs marine bird surveys and habitat assessments in both offshore and nearshore environments (e.g., Rodway and Lemon 1990; Ryder et al. 2007; Kenyon et al. 2009). Non-governmental organizations in the NSB also engage in survey efforts, such as the Raincoast Conservation Foundation's surveys focused on marine birds and mammals that spanned the nearshore and offshore regions (Williams and Thomas 2007; Fox et al. 2017).

However, nearshore surveys are often localized and may not cover the broad spatial extents captured by some of the offshore surveys in the bioregion (e.g., DFO synoptic trawl surveys (Anderson et al. 2019)). Data available in the nearshore environment may be finer resolution than those available offshore, in part due to the localized nature of many nearshore surveys and the complexity of the BC coastline with its many narrow inlets and fjords. The difference in spatial resolution between nearshore and offshore spatial features has been noted and assessed in past site selection analyses performed on the Pacific coast. For example, initial Marxan analyses performed by the BCMCA tested the potential for using smaller planning units on the continental shelf and larger planning units for areas in the Canadian Pacific exclusive economic zone (EEZ) west of the continental slope to accommodate the different resolutions of the data available and facilitate data processing (Bodtker 2010). However, varying the size of the planning units was seen to introduce a bias in the analysis outputs and, in alignment with expert guidance (Ardron et al. 2010), planning units of a consistent size have typically been used for Marxan analyses in the Canadian Pacific (e.g., coastwide analyses performed by the BCMCA (Ban et al. 2013); NSB-wide analyses completed by the Marine Plan Partnership (MaPP) (Diggon et al. 2022)).

Survey data focused on both nearshore and offshore regions were used to develop the spatial features representing the ecological conservation priorities in the NSB and many span both nearshore and offshore areas. Other spatial features represent different life history stages for species with ranges that extend between near and offshore environments, such as offshore areas identified as important for summer aggregations of eulachon and nearshore areas important during the migration of eulachon towards spawning habitats. Performing separate site selection analyses for the nearshore and offshore areas would necessitate clipping spatial features to each area and determining how to assign ecological conservation targets by region, perhaps complicating analyses unnecessarily. As such, these sensitivity analyses were performed at a bioregion-wide scale with consistently sized planning units, following the precedent set by the BCMCA and MaPP analyses. However, performance measures developed by MPATT to compare different MPA network design scenarios include an evaluation of the proportion of the design within the nearshore, offshore, and inlet areas. The performance measures also assess other distinctions between nearshore and offshore regions, including MPA size and spacing guidance from the ecological design strategies (DFO 2019a) that suggest nearshore MPAs may be smaller and closer together than MPAs on the shelf and slope, given differences in adult movement ranges and estimated larval dispersal distances.

Proportions of No-Take Areas (20-50%)

The ecological design strategies recommend including 20-50% of the NSB MPA network in no-take or limited-take areas, described as generally corresponding to International Union for Conservation of Nature (IUCN) categories Ia-III (DFO 2019a). Participants at the CSAS peer review suggested sensitivity analyses might be appropriate for testing those proportions.

Sensitivity analyses using Marxan to test proportions of no-take areas within the MPA network design for the NSB area have not been completed for this report for a few reasons. Marxan does not include a user-controlled parameter related to the total proportion of the study area desired for analysis outputs because the size of an output is dependent on meeting the conservation objectives of the analyses, i.e., achieving the targets set for the E-CP and C-CP spatial features. The proportion of the study area required to achieve the targets depends on the size of the targets themselves, the spatial extents of the features and their rarity in the study area, the extent of overlap among the spatial features, and the costs associated with the planning units. However, because each feature was assigned a target range and analyses were run using the bottom, middle, and top end of the target ranges, MPATT generated a suite of solutions that provided decision makers with a range of options to use while designing the MPA network. Those options can inform conversations on the appropriate proportion of no-take areas within the final MPA network design.

Another reason why sensitivity analyses on proportions of no-take areas were not completed is that Marxan works to identify two-zone solutions (i.e., a planning unit is either part of a conservation area or not) and assumes conservation objectives can be fully met by the solution. As such, solutions assume no negative interactions with human activities that would affect the achievement of the conservation targets, analogous to networks of no-take MPAs. Management measures within a final MPA network design may not be that simple and could likely include a variety of different zone types that allow varying levels of human activity in the MPAs that make up the network. Network design principles (Canada – British Columbia Marine Protected Area Network Strategy 2014) and the design guidelines (Lieberknecht et al. 2016) each recommend the use of a range of protection levels to achieve conservation objectives. Marxan with Zones (Watts et al. 2009), extends the capabilities of the original Marxan software to allow planners to assign planning units to a suite of different zone types that can incorporate interactions with human activities and may be a more effective tool for sensitivity analyses testing proportions of no-take. However, adding consideration of multiple zones and individual activities would further complicate what were already complex analyses incorporating a large number of planning units and conservation priorities. Utilizing Marxan with Zones also requires up-front knowledge of the intended zone types with the final network design and the ecological features and human activities compatible with each. These decisions can require extensive engagement with partners and stakeholders and were not available when the sensitivity analyses were completed.

Other Considerations

The suite of sensitivity analyses recommended through the CSAS peer review of the ecological design strategies (DFO 2019a), or brought forward by partners and stakeholders involved in MPA network design within the NSB, provided valuable insights into the possibilities and limitations of Marxan analyses to inform MPA network design in the NSB. The analyses were based on the best available spatial information on the ecological features but that information may not be complete or available for all of the ecological conservation priorities. However, Marxan remains a tool to support decision makers and the solutions generated through Marxan analyses are not intended to be considered as the final spatial configuration for any conservation planning process. The Marxan site selection analyses completed for MPATT represented one of many inputs into an iterative network design process and the analysis outputs were only able to reflect a subset of the network objectives, design principles, and design guidelines. Additional considerations available to guide MPA network design in the NSB included the contributions of existing conservation areas within the NSB; ecological, socioeconomic, and Indigenous values and interactions that were not captured by the available spatial data; assessments of additional ecological design principles such as replication, connectivity, and climate change; the legal tools available for implementing spatial protection measures; and, feasibility considerations for implementing, managing, and monitoring a final MPA network design. A suite of Marxan analyses are an important source of systematic and repeatable information for partner and stakeholder consideration and discussion regarding network design and management but many of the additional considerations are not technical and extend beyond Marxan's utility as a decision support tool.

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Appendix A: Ecological Conservation Priorities, Spatial Features and Ecological Conservation Targets

Ecological conservation targets specify how much of each spatial feature representing individual ecological conservation priorities should be included in the MPA network. Ecological conservation priorities were assigned to a low (10-20%), medium (20-40%), or high (40-60%) target range, based on conservation status, vulnerability, ecological role, and expert feedback. Conservation priorities and their associated spatial features and ecological conservation targets were used in sensitivity and site selection analyses with the Marxan decision support tool (Ball et al. 2009) during the design scenarios phase of the MPA network planning process (Figure 1, Steps 5-6).

Spatial features were initially assigned the ecological conservation target range of the associated ecological conservation priority, then adjusted based on the appropriateness of the feature for inclusion in design scenarios, following the advice received through the CSAS peer review on the ecological design strategies (DFO 2019a). Target ranges were adjusted as follows:

1) Spatial features that were deemed inappropriate for use in Marxan based on expert assessment were assigned a target of 0. These 'non-Marxan' features did not influence the Marxan analyses. Spatial features were deemed inappropriate for several reasons, including limited spatial extents and low data quality or confidence.
2) For highly mobile species (ranging greater than 50 km), features representing distribution were adjusted to a low (10-20%) target range while features representing discrete/static areas or habitats of importance were not changed.

Table 18. Ecological conservation priorities (E-CPs), spatial features, and ecological conservation targets representing fishes.

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Arrowtooth Flounder	Arrowtooth Flounder CPUE	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Big Skate	Big Skate CPUE	Marxan	40-60	No	40-60
Bocaccio	Bocaccio CPUE	Marxan	40-60	No	40-60
Bocaccio	Bocaccio CPUE (CCIRA Surveys)	Marxan	40-60	No	40-60
Canary Rockfish	Canary Rockfish CPUE	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Canary Rockfish	Canary Rockfish CPUE (CCIRA Surveys)	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
China Rockfish	China Rockfish CPUE	Marxan	20-40	No	20-40
China Rockfish	China Rockfish CPUE (CCIRA Surveys)	Marxan	20-40	No	20-40
Chinook Salmon	Salmon estuaries - chinook diversity	Marxan	40-60	No (home range >= 50 km, but data identify area(s) of importance)	40-60

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Chum Salmon	Salmon estuaries - chum diversity	Marxan	20-40	No (home range >= 50 km, but data identify area(s) of importance)	20-40
Coho Salmon	Salmon estuaries - coho diversity	Marxan	20-40	No (home range >= 50 km, but data identify area(s) of importance)	20-40
Copper Rockfish	Copper Rockfish CPUE	Marxan	20-40	No	20-40
Darkblotched Rockfish	Darkblotched Rockfish CPUE	Marxan	20-40	No	20-40
Dover Sole	Dover Sole CPUE	Marxan	10-20	No (home range >= 50 km, but target already low)	10-20
Eulachon	Eulachon Important Areas - spawning	Marxan	40-60	No (home range >= 50 km, but data identify area(s) of importance)	40-60
Eulachon	Eulachon Important Areas - summer	Marxan	40-60	No (home range >= 50 km, but data identify area(s) of importance)	40-60
Green sturgeon	Green Sturgeon Important Areas	Marxan	20-40	No (home range >= 50 km, but data identify area(s) of importance)	20-40
Greenstriped Rockfish	Greenstriped Rockfish CPUE	Marxan	10-20	No	10-20
Lingcod	Lingcod CPUE	Marxan	20-40	No	20-40
Lingcod	Lingcod CPUE (CCIRA Surveys)	Marxan	20-40	No	20-40
Longnose Skate	Longnose Skate CPUE	Marxan	20-40	No	20-40
Longspine Thornyhead	Longspine Thornyhead CPUE	Marxan	20-40	No	20-40
Pacific Cod	Pacific Cod CPUE	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Pacific Hake	Pacific Hake Biomass Index	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Pacific Halibut	Pacific Halibut CPUE	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Pacific Herring	Pacific Herring Spawn Habitat Index	Marxan	20-40	No (home range >= 50 km, but data identify area(s) of importance)	20-40
Pacific Ocean Perch	Pacific Ocean Perch CPUE	Marxan	10-20	No	10-20
Pacific Sand Lance	Pacific Sand Lance CPUE	Marxan	20-40	No	20-40
Petrale Sole	Petrale Sole CPUE	Marxan	10-20	No (home range >= 50 km, but target already low)	10-20
Pink Salmon	Salmon estuaries - pink (even) diversity	Marxan	20-40	No (home range >= 50 km, but data identify area(s) of importance)	20-40

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Pink Salmon	Salmon estuaries - pink (odd) diversity	Marxan	20-40	No (home range >= 50 km, but data identify area(s) of importance)	20-40
Quillback Rockfish	Quillback Rockfish CPUE	Marxan	20-40	No	20-40
Quillback Rockfish	Quillback Rockfish CPUE (CCIRA Surveys)	Marxan	20-40	No	20-40
Redstripe Rockfish	Redstripe Rockfish CPUE	Marxan	20-40	No	20-40
Rex Sole	Rex Sole CPUE	Marxan	10-20	No (home range >= 50 km, but target already low)	10-20
Rock Sole	Rock Sole CPUE	Marxan	10-20	No	10-20
Rockfish	Midlived rockfish CPUE (CCIRA Surveys)	Marxan	20-40	No	20-40
Rosethorn Rockfish	Rosethorn Rockfish CPUE	Marxan	10-20	No	10-20
Rougheye-Blackspotted Rockfish	Rougheye-Blackspotted Rockfish CPUE	Marxan	40-60	No	40-60
Sablefish	Sablefish CPUE	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Salmon species	Salmon estuaries - biomass	Marxan	20-40	No (home range >= 50 km, but data identify area(s) of importance)	20-40
Sandpaper Skate	Sandpaper Skate CPUE	Marxan	10-20	No	10-20
Shortraker Rockfish	Shortraker Rockfish CPUE	Marxan	20-40	No	20-40
Shortspine Thornyhead	Shortspine Thornyhead CPUE	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Silvergray Rockfish	Silvergray Rockfish CPUE	Marxan	10-20	No	10-20
Silvergray Rockfish	Silvergray Rockfish CPUE (CCIRA Surveys)	Marxan	10-20	No	10-20
Sockeye Salmon	Salmon estuaries - sockeye diversity	Marxan	20-40	No (home range >= 50 km, but data identify area(s) of importance)	20-40
Spiny Dogfish	Spiny Dogfish CPUE	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Tiger Rockfish	Tiger Rockfish CPUE	Marxan	20-40	No	20-40
Tiger Rockfish	Tiger Rockfish CPUE (CCIRA Surveys)	Marxan	20-40	No	20-40
Vermilion Rockfish	Vermilion Rockfish CPUE	Marxan	10-20	No	10-20

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Walleye Pollock	Walleye Pollock CPUE	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Widow Rockfish	Widow Rockfish CPUE	Marxan	20-40	No	20-40
Yelloweye Rockfish	Yelloweye Rockfish CPUE	Marxan	40-60	No	40-60
Yelloweye Rockfish	Yelloweye Rockfish CPUE (CCIRA Surveys)	Marxan	40-60	No	40-60
Yellowmouth Rockfish	Yellowmouth Rockfish CPUE	Marxan	20-40	No	20-40
Yellowtail Rockfish	Yellowtail Rockfish CPUE	Marxan	10-20	No (home range >= 50 km, but target already low)	10-20
Pacific Herring	Pacific Herring Important Areas	Non-marxan	20-40	Yes (data not appropriate for Marxan)	0
Rosethorn Rockfish	Rosethorn Rockfish CPUE (CCIRA Surveys)	Non-marxan	20-40	Yes (data not appropriate for Marxan)	0
Roughtail Skate	Roughtail Skate CPUE	Non-marxan	20-40	Yes (data not appropriate for Marxan)	0
Albacore	N/A	Gap	20-40	N/A (no data)	N/A
Basking Shark	N/A	Gap	20-40	N/A (no data)	N/A
Black Rockfish	N/A	Gap	20-40	N/A (no data)	N/A
Blue Shark	N/A	Gap	40-60	N/A (no data)	N/A
Bluntnose Sixgill Shark	N/A	Gap	40-60	N/A (no data)	N/A
Capelin	N/A	Gap	40-60	N/A (no data)	N/A
Cutthroat Trout	N/A	Gap	20-40	N/A (no data)	N/A
Dolly Varden	N/A	Gap	20-40	N/A (no data)	N/A
Northern Lampfish	N/A	Gap	10-20	N/A (no data)	N/A
Northern Smoothtongue	N/A	Gap	10-20	N/A (no data)	N/A
Ocean Sunfish	N/A	Gap	10-20	N/A (no data)	N/A
Pacific Sardine	N/A	Gap	10-20	N/A (no data)	N/A
Pacific Sleeper Shark	N/A	Gap	20-40	N/A (no data)	N/A
Salmon Shark	N/A	Gap	20-40	N/A (no data)	N/A
Steelhead	N/A	Gap	20-40	N/A (no data)	N/A
Striped Seaperch	N/A	Gap	10-20	N/A (no data)	N/A

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Surf Smelt	N/A	Gap	20-40	N/A (no data)	N/A
Wolf eel	N/A	Gap	10-20	N/A (no data)	N/A

Table 19. Ecological conservation priorities (E-CPs), spatial features, and ecological conservation targets representing invertebrates.

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Soft Corals	Predicted habitat suitability for soft corals (Alyconacea)	Marxan	20-40	No	20-40
Black Corals	Predicted habitat suitability for black corals (Antipatharia)	Marxan	20-40	No	20-40
Butter Clam	Butter clam locations	Marxan	20-40	No	20-40
Horse clam	Horse clam locations	Marxan	20-40	No	20-40
Razor Clam	Razor clam "Important Area"	Marxan	20-40	No	20-40
Cockles	Cockle locations	Marxan	20-40	No	20-40
corals	Coral presence (CCIRA Surveys)	Marxan	20-40	No	20-40
Corals, besides sea pens	Areas of high coral biomass (excluding sea pens) on the continental shelf	Marxan	20-40	No	20-40
Dungeness Crab	Dungeness crab locations	Marxan	10-20	No	10-20
Geoduck	Geoduck locations	Marxan	20-40	No	20-40
Giant Pacific Octopus	Giant Pacific octopus locations	Marxan	20-40	No	20-40
Northern Abalone	Northern Abalone Locations	Marxan	20-40	Yes (confidential data)	N/A
Sea Pens	Predicted habitat suitability for sea pens (Pennatulacea)	Marxan	20-40	No	20-40
Sea Pens	Areas of high sea pen biomass on the continental shelf	Marxan	20-40	No	20-40
Scallops	Scallop CPUE (Synoptic Trawl Survey)	Marxan	10-20	No	10-20
Stony Corals	Predicted habitat suitability for stony corals (Scleractinia)	Marxan	20-40	No	20-40
Sunflower Sea Star	Sunflower sea star locations	Marxan	20-40	No	20-40
Sponges	Sponge cover (CCIRA Surveys)	Marxan	40-60	No	40-60

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Sponges (demosponges and glass sponges)	Areas of high sponge biomass on the continental shelf	Marxan	20-40	No	20-40
Sponge reef	Sponge reef distribution based on geological signature	Marxan	40-60	No	40-60
Opal Squid	Opal squid locations	Marxan	20-40	No	20-40
Deepwater Grooved Tanner Crab	Deepwater Tanner Crab CPUE (Sablefish Trap Survey)	Marxan	10-20	No	10-20
Green Urchin	Green sea urchin locations	Marxan	20-40	No	20-40
Red Urchin	Red sea urchin locations	Marxan	20-40	No	20-40
Littleneck Clam	Littleneck clam locations	Non-marxan	20-40	No	0
Puget Sound King Crab	Puget Sound King Crab records	Non-marxan	10-20	No	0
Dungeness Crab	Dungeness crab "Important Area"	Non-marxan	10-20	No	0
Olympia Oyster	Olympia oyster locations	Non-marxan	20-40	No	0
Prawn	Spot Prawn Records	Non-marxan	20-40	No	0
Purple-hinged Rock Scallop	Purple-hinged rock scallop records	Non-marxan	10-20	No	0
Ochre Sea Star	Ochre Sea Star Records	Non-marxan	20-40	No	0
Coonstripe/Dock Shrimp	Coonstripe/Dock Shrimp Records	Non-marxan	20-40	No	0
Humpback Shrimp	Humpback Shrimp Records	Non-marxan	20-40	No	0
Sidestripe Shrimp	Sidestripe Shrimp Records	Non-marxan	20-40	No	0
Smooth Pink Shrimp	Smooth Pink Shrimp records	Non-marxan	20-40	No	0
Spiny Pink Shrimp	Spiny Pink Shrimp Records	Non-marxan	20-40	No	0
Aphrocallistes vastus	N/A - as sponge	N/A	40-60	N/A	N/A
Demosponges	N/A - as sponge	N/A	20-40	N/A	N/A
Farrea occa	N/A - as sponge	N/A	40-60	N/A	N/A
Glass sponges	N/A - as sponge	N/A	40-60	N/A	N/A
Heterochone calyx	N/A - as sponge	N/A	40-60	N/A	N/A
Horse clam/Fat Gaper	N/A - as Tresus spp.	N/A	20-40	N/A	N/A
Horse clam/Pacific Gaper	N/A - as Tresus spp.	N/A	20-40	N/A	N/A
Inshore Tanner Crab	N/A - inlets used as proxies	N/A	10-20	N/A	N/A
Pink Scallop	N/A - as scallops	N/A	10-20	N/A	N/A

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Spiny Scallop	N/A - as scallops	N/A	10-20	N/A	N/A
Bay Ghost Shrimp	N/A	Gap	20-40	N/A (no data)	N/A
California Mussel	N/A	Gap	20-40	N/A (no data)	N/A
Crustacean Zooplankton	N/A	Gap	20-40	N/A (no data)	N/A
Euphausiids	N/A	Gap	20-40	N/A (no data)	N/A
Gooseneck Barnacle	N/A	Gap	20-40	N/A (no data)	N/A
Littorina	N/A	Gap	10-20	N/A (no data)	N/A
Neocalanus Copepods	N/A	Gap	20-40	N/A (no data)	N/A
Non-crustacean Zooplankton	N/A	Gap	10-20	N/A (no data)	N/A
Weathervane Scallop	N/A	Gap	10-20	N/A (no data)	N/A

Table 20. Ecological conservation priorities (E-CPs), spatial features, and ecological conservation targets representing mammals and reptiles.

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Dall's Porpoise	Dall's Porpoise Effort-corrected Density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Fin Whale	Fin Whale Effort-corrected Density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Grey Whale	Grey Whale Effort-corrected Density	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Harbour Seal	Harbour Seal Haulouts	Marxan	40-60	No	40-60
Humpback Whale	Humpback Whale Critical Habitat	Marxan	20-40	No	20-40
Humpback Whale	Humpback Whale Effort-corrected Density	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Northern Resident Orca	Resident Killer Whale Critical Habitat	Marxan	40-60	No	40-60
Northern Resident Orca	Resident Killer Whale Habitat of Special Importance	Marxan	40-60	No	40-60
Northern Resident Orca	Resident Killer Whale Potential Critical Habitat	Marxan	40-60	No	40-60
Pacific White-sided Dolphin	Pacific White-sided Dolphin Effort-corrected Density	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Sea Otter	Sea Otter Modeled Habitat	Marxan	40-60	No	40-60
Sperm Whale	Sperm Whale Effort-corrected Density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Steller Sea Lion	Steller Sea Lion Haulouts (Winter)	Marxan	40-60	No	40-60
Steller Sea Lion	Steller Sea Lion Haulouts (Year-round)	Marxan	40-60	No	40-60
Steller Sea Lion	Steller Sea Lion Rookeries	Marxan	40-60	No	40-60
Leatherback Turtle	Leatherback Turtle Important Areas	Marxan	20-40	No	20-40
Blue Whale	Blue Whale Important Areas	Non-Marxan	20-40	Yes (data not appropriate for Marxan)	0
California Sea Lion	California Sea Lion Haulouts	Non-Marxan	40-60	Yes (data not appropriate for Marxan)	0
Common Minke Whale	Common Minke Whale Effort-corrected Density	Non-Marxan	20-40	Yes (data not appropriate for Marxan)	0
Fin Whale	Fin Whale Habitat of Special Importance	Non-Marxan	40-60	Yes (data not appropriate for Marxan)	0
Fin Whale	Fin Whale Important Areas	Non-Marxan	40-60	Yes (data not appropriate for Marxan)	0
Grey Whale	Grey Whale Migration Routes	Non-Marxan	20-40	Yes (data not appropriate for Marxan)	0
Harbour Porpoise	Harbour Porpoise Effort-corrected Density	Non-Marxan	40-60	Yes (data not appropriate for Marxan)	0
Northern Fur Seal	Northern Fur Seal Important Areas	Non-Marxan	40-60	Yes (data not appropriate for Marxan)	0
Northern Resident Orca	Killer Whale Important Areas	Non-Marxan	40-60	Yes (data not appropriate for Marxan)	0
Northern Right Whale Dolphin	Northern Right Whale Dolphin Effort-corrected Density	Non-Marxan	20-40	Yes (data not appropriate for Marxan)	0
Sea Otter	Sea Otter Important Areas	Non-Marxan	40-60	Yes (data not appropriate for Marxan)	0
Sei Whale	Sei Whale Important Areas	Non-Marxan	20-40	Yes (data not appropriate for Marxan)	0
Sperm Whale	Sperm Whale Important Areas	Non-Marxan	40-60	Yes (data not appropriate for Marxan)	0
West Coast Transient Orca	Transient Killer Whale Habitat of Special Importance	Non-Marxan	40-60	Yes (data not appropriate for Marxan)	0
Risso's Dolphin	N/A	Gap	20-40	N/A (no data)	N/A
Offshore Orca	N/A	Gap	40-60	N/A (no data)	N/A
Southern Resident Orca	N/A	Gap	40-60	N/A (no data)	N/A

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Northern Elephant Seal	N/A	Gap	40-60	N/A (no data)	N/A
North Pacific Right Whale	N/A	Gap	40-60	N/A (no data)	N/A

Table 21. Ecological conservation priorities (E-CPs), spatial features, and ecological conservation targets representing plants and algae.

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Phytoplankton	Near-surface Chlorophyll A Concentration	Marxan	20-40	No	20-40
Bull Kelp	Bull Kelp Beds	Marxan	20-40	No	20-40
Bull Kelp	Bull Kelp Biobands	Marxan	20-40	No	20-40
Giant Kelp	Giant Kelp Beds	Marxan	20-40	No	20-40
Giant Kelp	Giant Kelp Biobands	Marxan	20-40	No	20-40
Eelgrass	Eelgrass Beds	Marxan	20-40	No	20-40
Eelgrass	Eelgrass Priority Beds	Marxan	20-40	No	20-40
Eelgrass	Eelgrass Biobands	Marxan	20-40	No	20-40
Surfgrass	Surfgrass Biobands	Marxan	20-40	No	20-40
General Kelp	General Kelp Beds	Marxan	20-40	No	20-40
Phytoplankton	Near-surface Chlorophyll A Bloom Frequency	Non-Marxan	20-40	Yes (data not appropriate for Marxan)	0

Table 22. Ecological conservation priorities (E-CPs), spatial features, and ecological conservation targets representing marine birds.

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Albatrosses	Albatross density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Ancient Murrelet	Ancient Murrelet colonies	Marxan	40-60	No	40-60
Black Oystercatcher	Black Oystercatcher breeding sites	Marxan	20-40	No	20-40
Brandt’s Cormorant	Brandt's Cormorant colonies	Marxan	40-60	No	40-60
Cassin’s Auklet	Cassin's Auklet colonies	Marxan	40-60	No	40-60
Common Murre	Common Murre colonies	Marxan	40-60	No	40-60
Cormorants	Cormorant density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Cormorants	Cormorant winter density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Geese & Swans	Goose/swan density	Marxan	10-20	No (home range >= 50 km, but target already low)	10-20
Geese & Swans	Goose/swan winter density	Marxan	10-20	No (home range >= 50 km, but target already low)	10-20
Great Blue Heron, Fannini Subspecies	Great Blue Heron winter density	Marxan	10-20	No (home range >= 50 km, but target already low)	10-20
Great Blue Heron, Fannini Subspecies	Great Blue Heron nesting sites	Marxan	10-20	No	10-20
Gulls	Gull density	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Gulls	Gull winter density	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Horned Puffin	Horned puffin colonies	Marxan	40-60	No	40-60
Loons & Grebes	Loon/grebe density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Loons & Grebes	Loon/grebe winter density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Marbled Murrelet	Marbled Murrelet winter density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Marbled Murrelet	Marbled Murrelet density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Mud or sand flat intertidal birds	Shorebird key sites	Marxan	40-60	No	40-60
Murres & Large Alcids	Murre/large alcid density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Murres & Large Alcids	Murre/large alcid winter density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Pelagic Cormorant	Pelagic Cormorant colonies	Marxan	20-40	No	20-40
Pigeon Guillemot	Pigeon Guillemot colonies	Marxan	20-40	No	20-40
Pigeon Guillemot	Pigeon Guillemot density	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Puffins	Puffin density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Rhinoceros Auklet	Rhinoceros Auklet colonies	Marxan	20-40	No	20-40
Rocky intertidal birds	Rocky intertidal bird density	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Sea ducks	Sea duck moulting density	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Sea ducks	Sea duck pre-migration staging density	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Sea ducks	Sea duck winter density	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Sea ducks	Sea duck joint venture key sites	Marxan	20-40	No	20-40
Shearwaters & Fulmars	Shearwater/fulmar density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Small alcids	Small alcid year-round density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Small alcids	Small alcid winter density	Marxan	40-60	Yes (home range >= 50 km, and distribution data)	10-20
Storm Petrels & Phalaropes	Storm petrel/phalarope density	Marxan	20-40	Yes (home range >= 50 km, and distribution data)	10-20
Storm Petrels & Phalaropes	Storm Petrel colonies	Marxan	20-40	No	20-40
Thick-billed Murre	Thick-billed Murre colonies	Marxan	40-60	No	40-60
Tufted Puffin	Tufted Puffin colonies	Marxan	40-60	No	40-60

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Mud or sand flat intertidal birds	Mud/sand flat intertidal bird density	Non-Marxan	40-60	Yes (data not appropriate for Marxan)	0
Seabirds	Seabird Important Areas	Non-Marxan	40-60	Yes (data not appropriate for Marxan)	0
Short-tailed Albatross	N/A - in albatrosses		40-60	N/A	N/A
Laysan Albatross	N/A - in albatrosses		20-40	N/A	N/A
Black-footed Albatross	N/A - in albatrosses		20-40	N/A	N/A
Canada Goose (Pacific, residents & migrants)	N/A - in geese & swans		10-20	N/A	N/A
Cackling Goose	N/A - in geese & swans		10-20	N/A	N/A
Trumpeter Swan	N/A - in geese & swans		10-20	N/A	N/A
California Gull	N/A - in gulls		20-40	N/A	N/A
Thayer's Gull	N/A - in gulls		20-40	N/A	N/A
Western Grebe	N/A - in loons & grebes		40-60	N/A	N/A
Yellow-billed Loon	N/A - in loons & grebes		10-20	N/A	N/A
Common Loon	N/A - in loons & grebes		10-20	N/A	N/A
Pacific Loon	N/A - in loons & grebes		10-20	N/A	N/A
Horned Grebe	N/A - in loons & grebes		10-20	N/A	N/A
Sanderling	N/A - in mud/sand flat intertidal birds		20-40	N/A	N/A
Dunlin	N/A - in mud/sand flat intertidal birds		40-60	N/A	N/A
Red Knot	N/A - in mud/sand flat intertidal birds		20-40	N/A	N/A
Western Sandpiper	N/A - in mud/sand flat intertidal birds		10-20	N/A	N/A
Short-billed Dowitcher	N/A - in mud/sand flat intertidal birds		40-60	N/A	N/A
Whimbrel	N/A - in mud/sand flat intertidal birds		20-40	N/A	N/A
Surfbird	N/A - in rocky intertidal birds		20-40	N/A	N/A
Ruddy Turnstone	N/A - in rocky intertidal birds		20-40	N/A	N/A
Black Turnstone	N/A - in rocky intertidal birds		10-20	N/A	N/A

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Rock Sandpiper	N/A - in rocky intertidal birds		10-20	N/A	N/A
Wandering Tattler	N/A - in rocky intertidal birds		10-20	N/A	N/A
Common Goldeneye	N/A - in sea ducks		10-20	N/A	N/A
Barrow’s Goldeneye	N/A - in sea ducks		20-40	N/A	N/A
Long-tailed Duck	N/A - in sea ducks		10-20	N/A	N/A
Harlequin Duck	N/A - in sea ducks		20-40	N/A	N/A
Black Scoter	N/A - in sea ducks		20-40	N/A	N/A
White-winged Scoter	N/A - in sea ducks		20-40	N/A	N/A
Surf Scoter	N/A - in sea ducks		20-40	N/A	N/A
Northern Fulmar	N/A - in shearwaters & fulmars		10-20	N/A	N/A
Buller’s Shearwater	N/A - in shearwaters & fulmars		10-20	N/A	N/A
Pink-footed Shearwater	N/A - in shearwaters & fulmars		40-60	N/A	N/A
Sooty Shearwater	N/A - in shearwaters & fulmars		10-20	N/A	N/A
Short-tailed Shearwater	N/A - in shearwaters & fulmars		10-20	N/A	N/A
Fork-tailed Storm-Petrel	N/A - in storm petrels & phalaropes		10-20	N/A	N/A
Leach's Storm-Petrel	N/A - in storm petrels & phalaropes		20-40	N/A	N/A
Red Phalarope	N/A - in storm petrels & phalaropes		10-20	N/A	N/A
Red-necked Phalarope	N/A - in storm petrels & phalaropes		10-20	N/A	N/A
Pelagic Cormorant, Pelagicus Subspecies	N/A		40-60	N/A (no data)	N/A

Table 23. Ecological conservation priorities (E-CPs), spatial features, and ecological conservation targets representing area-based features.

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Areas of high species abundance, diversity or richness	Benthic fish diversity (CCIRA surveys)	Marxan	10-30	No	10-30
Areas of high species abundance, diversity or richness	Fish Diversity Hotspots (nearshore and shelf)	Marxan	10-30	No	10-30
Areas of high species abundance, diversity or richness	Fish Shelf Biomass Hotspots	Marxan	10-30	No	10-30
Areas of high species abundance, diversity or richness	Invertebrate Shelf Biomass Hotspots	Marxan	10-30	No	10-30
Areas of high species abundance, diversity or richness	Invertebrate Shelf Diversity Hotspots	Marxan	10-30	No	10-30
Areas of high species abundance, diversity or richness	Nearshore Habitat Richness Hotspots	Marxan	10-30	No	10-30
Areas of high habitat heterogeneity	Areas of high rugosity	Marxan	20-60	No	20-60
Estuaries	Estuaries	Marxan	20-60	No	20-60
Tidal passes and currents	Areas of high tidal current that meet EBSA criteria	Marxan	20-60	No	20-60
Ecological classification (coarse-filter) - Bottom patches	Hard	Marxan	10-30	No	10-30
Ecological classification (coarse-filter) - Bottom patches	Mixed	Marxan	8-24	No	8-24
Ecological classification (coarse-filter) - Bottom patches	Soft	Marxan	7-22	No	7-22
Ecological classification (coarse-filter) - Coastal classes	Channel	Marxan	10-30	No	10-30
Ecological classification (coarse-filter) - Coastal classes	Estuary (Organics/Fines)	Marxan	2-6	No	2-6
Ecological classification (coarse-filter) - Coastal classes	Gravel Beach	Marxan	2-6	No	2-6
Ecological classification (coarse-filter) - Coastal classes	Gravel Flat	Marxan	5-16	No	5-16
Ecological classification (coarse-filter) - Coastal classes	Mud Flat	Marxan	6-19	No	6-19
Ecological classification (coarse-filter) - Coastal classes	Rock Cliff	Marxan	1-3	No	1-3

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Ecological classification (coarse-filter) - Coastal classes	Rock Platform	Marxan	1-4	No	1-4
Ecological classification (coarse-filter) - Coastal classes	Rock Ramp	Marxan	1-2	No	1-2
Ecological classification (coarse-filter) - Coastal classes	Sand and Gravel Beach	Marxan	2-6	No	2-6
Ecological classification (coarse-filter) - Coastal classes	Sand and Gravel Flat or Fan	Marxan	2-5	No	2-5
Ecological classification (coarse-filter) - Coastal classes	Sand Beach	Marxan	4-11	No	4-11
Ecological classification (coarse-filter) - Coastal classes	Sand Flat	Marxan	2-5	No	2-5
Ecological classification (coarse-filter) - Ecosections	Continental Slope	Marxan	4-11	No	4-11
Ecological classification (coarse-filter) - Ecosections	Dixon Entrance	Marxan	5-15	No	5-15
Ecological classification (coarse-filter) - Ecosections	Hecate Strait	Marxan	5-14	No	5-14
Ecological classification (coarse-filter) - Ecosections	Johnstone Strait	Marxan	9-28	No	9-28
Ecological classification (coarse-filter) - Ecosections	North Coast Fjords	Marxan	4-13	No	4-13
Ecological classification (coarse-filter) - Ecosections	Queen Charlotte Sound	Marxan	3-8	No	3-8
Ecological classification (coarse-filter) - Ecosections	Queen Charlotte Strait	Marxan	10-30	No	10-30
Ecological classification (coarse-filter) - Ecosections	Vancouver Island Shelf	Marxan	9-28	No	9-28
Ecological classification (coarse-filter) - PMECS	Biophysical Units - DogfishBank	Marxan	5-16	No	5-16
Ecological classification (coarse-filter) - PMECS	Biophysical Units - OtherBank	Marxan	10-30	No	10-30
Ecological classification (coarse-filter) - PMECS	Biophysical Units - Shelf	Marxan	3-8	No	3-8
Ecological classification (coarse-filter) - PMECS	Biophysical Units - Slope	Marxan	4-11	No	4-11

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Ecological classification (coarse-filter) - PMECS	Biophysical Units - Trough	Marxan	3-10	No	3-10
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Fjord, Crest	Marxan	10-30	No	10-30
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Fjord, Depression	Marxan	6-17	No	6-17
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Fjord, Depression floor	Marxan	10-30	No	10-30
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Fjord, Mound	Marxan	8-24	No	8-24
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Fjord, Wall, steeply sloping	Marxan	6-19	No	6-19
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Shelf, Crest	Marxan	4-12	No	4-12
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Shelf, Depression	Marxan	3-8	No	3-8
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Shelf, Depression floor	Marxan	5-14	No	5-14
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Shelf, Mound	Marxan	2-7	No	2-7
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Shelf, Wall, sloping	Marxan	3-10	No	3-10
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Slope, Canyon floor	Marxan	6-17	No	6-17
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Slope, Ridge	Marxan	6-18	No	6-18
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Slope, Wall, sloping	Marxan	10-29	No	10-29
Ecological classification (coarse-filter) - PMECS	Geomorphic Units - Slope, Wall, steeply sloping	Marxan	3-10	No	3-10
Ecological classification (coarse-filter) - Upper ocean subregions	Aristazabal Banks Upwelling	Marxan	6-18	No	6-18
Ecological classification (coarse-filter) - Upper ocean subregions	Cape Scott Tidal Mixing	Marxan	4-13	No	4-13
Ecological classification (coarse-filter) - Upper ocean subregions	Cape St. James Tidal Mixing	Marxan	9-28	No	9-28

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Ecological classification (coarse-filter) - Upper ocean subregions	Coastal Mixing Region	Marxan	3-8	No	3-8
Ecological classification (coarse-filter) - Upper ocean subregions	Dixon Entrance Coastal Flow Region	Marxan	5-16	No	5-16
Ecological classification (coarse-filter) - Upper ocean subregions	Dogfish Bank Frontal Region	Marxan	9-28	No	9-28
Ecological classification (coarse-filter) - Upper ocean subregions	Eastern Queen Charlotte Sound	Marxan	6-17	No	6-17
Ecological classification (coarse-filter) - Upper ocean subregions	Hecate Strait	Marxan	4-12	No	4-12
Ecological classification (coarse-filter) - Upper ocean subregions	Johnstone Strait	Marxan	9-27	No	9-27
Ecological classification (coarse-filter) - Upper ocean subregions	Low Flow Nearshore	Marxan	8-24	No	8-24
Ecological classification (coarse-filter) - Upper ocean subregions	Mainland Fjords	Marxan	5-14	No	5-14
Ecological classification (coarse-filter) - Upper ocean subregions	Northern Strait of Georgia	Marxan	10-30	No	10-30
Ecological classification (coarse-filter) - Upper ocean subregions	Rose Spit Eddy	Marxan	10-30	No	10-30
Ecological classification (coarse-filter) - Upper ocean subregions	SE Alaska Mixing Region	Marxan	5-16	No	5-16
Ecological classification (coarse-filter) - Upper ocean subregions	West Coast QCI Upwelling Region	Marxan	6-19	No	6-19
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - Bella Bella nearshore	Marxan	4-12	No	4-12
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - Brooks Peninsula	Marxan	5-15	No	5-15
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - Cape St. James	Marxan	3-8	No	3-8
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - Central Mainland	Marxan	3-8	No	3-8
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - Chatham Sound	Marxan	3-9	No	3-9
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - Dogfish Banks	Marxan	3-9	No	3-9

Conservation Priority	Spatial Feature	Feature Type	Original E-CP Target Range (%)	Target Range Adjusted for Marxan	Final Marxan Target Range (%)
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - Haida Gwaii nearshore	Marxan	3-10	No	3-10
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - Hecate Strait	Marxan	3-9	No	3-9
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - Learmouth Bank	Marxan	10-30	No	10-30
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - McIntyre Bay	Marxan	4-12	No	4-12
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - North Island Straits	Marxan	3-8	No	3-8
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - Scott Islands	Marxan	2-5	No	2-5
Ecologically and Biologically Significant Areas (EBSAs)	EBSAs - Shelf Break	Marxan	1-3	No	1-3
Areas of high species abundance, diversity or richness	Important Bird Areas	Non-Marxan	10-30	Yes (data not appropriate for Marxan)	0
Tidal passes and currents	Areas of high tidal current	Non-marxan	20-60	Yes (data not appropriate for Marxan)	0
Degraded areas	Degraded areas	Gap	10-30	N/A (no data)	N/A
Areas important for carbon sequestration/"blue carbon" (areas of climate resilience)	N/A - in estuaries, kelp, eelgrass	N/A	20-60	N/A	N/A
Areas of upwelling	N/A - in EBSAs	N/A	20-60	N/A	N/A
Eddies and plumes	N/A - in EBSAs	N/A	10-30	N/A	N/A
Frontal zones	N/A - in EBSAs	N/A	20-60	N/A	N/A
Marine areas influenced by freshwater discharges with high oxygen levels (climate refugia)	N/A - in estuaries	N/A	10-30	N/A	N/A
Submarine canyons and steep walled troughs	N/A - in geomorphic units, EBSAs	N/A	20-60	N/A	N/A
Tidal passes and currents	N/A - in EBSAs	N/A	20-60	N/A	N/A
Underwater banks (climate refugia)	N/A - in geomorphic units, biophysical units	N/A	10-30	N/A	N/A

Appendix B: Marxan Parameters for each Sensitivity Analysis

Table 24. Marxan parameters set for each of the sensitivity analyses. The targets displayed are those selected from the point in the target range (bottom, middle, top) for each feature class that was chosen for the analysis. For example, for the ecological species-based features, there were low target features (target range 10-20%), medium target features (20-40%), and high target features (40-60%). For each analysis, a point in the target range for each type of feature was used. At the bottom end of the range for the low, medium, and high target features, the targets were 10, 20, and 40, respectively. At the middle point, the targets were 15, 30, and 50, and at the high end of the target range, the targets were 20, 40, and 60. Targets were similarly varied for the C-CP features, with analyses targeting the bottom, middle, and top end of the target ranges for the highly ranked features (20-40%), very highly ranked features (40-60%), and critically ranked features (40-60%) at the bottom (10/20/40), middle (15/30/50), and top (20/40/60).

Analysis	Features Included	Ecological or C-CP Targets (target value (%) used for low/medium/high target features)	Cost Layer	Number of Runs	BLM
Target Score Classification (quartiles)	Ecological	bottom (10/20/40); middle (15/30/50); top (20/40/60)	Area	25	0.25, 2.5
Target Score Classification (thirds)	Ecological	bottom (10/20/40); middle (15/30/50); top (20/40/60)	Area	25	0.25, 2.5
Target Threshold for Coarse-filter Features	Ecological (Coarse-filter features only)	bottom (10/20/40); top (20/40/60)	Area	100	1,4,7
Targets for FNCCPs	Ecological & C-CP (version 1)	bottom (eco-10/20/40; fnccp-20/40/60); middle (eco-15/30/50; fnccp-30/50/70); top (eco-20/40/60; fnccp-40/60/80)	Area	25	0.25
Targets for FNCCPs	Ecological & C-CP (version 2)	bottom (eco-10/20/40; fnccp-20/40/40); middle (eco-15/30/50; fnccp-30/50/50); top (eco-20/40/60; fnccp-40/60/60)	Area	25	0.25
Feature Separation: Habitats and Species	Ecological (habitat features only)	bottom (10/20/40); top (20/40/60)	Area	100	0.5, 2.5

Analysis	Features Included	Ecological or C-CP Targets (target value (%) used for low/medium/high target features)	Cost Layer	Number of Runs	BLM
Feature Separation: Habitats and Species	Ecological (species features only)	bottom (10/20/40); top (20/40/60)	Area	100	0.5, 2.5
Feature Separation: Habitats and Species	Ecological (all features)	bottom (10/20/40); top (20/40/60)	Area	100	0.5, 2.5
Inclusion of Commercially-harvested Species	Ecological (no commercial species) & FNCCP	middle (eco-15/30/50; fnccp-30/50/50);	Area; Socioeconomic	100	0.25
Final MPATT Marxan* (ecological features)	Ecological	bottom (10/20/40); middle (15/30/50); top (20/40/60)	Area	100	0.25, 2.5
Final MPATT Marxan* (ecological and FNCCP features)	Ecological & C-CP	bottom (eco-10/20/40; fnccp-20/40/40); middle (eco-15/30/50; fnccp-30/50/50); top (eco-20/40/60; fnccp-40/60/60)	Area; Socioeconomic	100	0.25, 2.5

* The outputs of the final MPATT analyses were used in the following sensitivity analyses: Target Threshold for Coarse-filter Features; Incorporating Naturalness in Coarse-filter Features; Confidential data – Northern Abalone.

Appendix C: Target Levels for Coarse-filter Features

Table 25. Ecological conservation target ranges applied to the bottom patches. Targets vary inversely based on the relative area of each habitat class.

Bottom Patches	Area (km^2)	Low Target Range (%)	Medium Target Range (%)	High Target Range (%)
Hard	5,870	10.0	20.0	30.0
Mixed	8,941	8.1	16.2	24.3
Soft	10,927	7.3	14.7	22.0

Table 26. Ecological conservation target ranges applied to BC Shorezone coastal classes. Targets vary inversely based on the relative area of each habitat class.

Coastal Classes (grouped)	Length (km)	Low Target Range (%)	Medium Target Range (%)	High Target Range (%)
Channel	45	10.0	20.0	30.0
Mud Flat	111	6.4	12.7	19.1
Gravel Flat	159	5.3	10.6	15.9
Sand Beach	313	3.8	7.6	11.4
Undefined	1,021	2.1	4.2	6.3
Gravel Beach	1,047	2.1	4.1	6.2
Estuary (Organics/Fines)	1,105	2.0	4.0	6.0
Sand and Gravel Beach	1,143	2.0	4.0	5.9
Sand Flat	1,412	1.8	3.6	5.3
Sand and Gravel Flat or Fan	1,757	1.6	3.2	4.8
Rock Platform	2,976	1.2	2.5	3.7
Rock Cliff	6,000	0.9	1.7	2.6
Rock Ramp	10,389	0.7	1.3	2.0
Manmade	138	0	0	0

Table 27. Ecological conservation targets applied to BC marine ecosections. Targets vary inversely based on the relative area of each habitat class.

Marine Ecosections	Area (km^2)	Low Target Range (%)	Medium Target Range (%)	High Target Range (%)
Strait of Georgia	117	10.0	20.0	30.0
Transitional Pacific	1,643	10.0	20.0	30.0
Subarctic Pacific	2,209	10.0	20.0	30.0
Queen Charlotte Strait	2,871	10.0	20.0	30.0
Johnstone Strait	3,220	9.4	18.9	28.3
Vancouver Island Shelf	3,335	9.3	18.6	27.8
Dixon Entrance	11,309	5.0	10.1	15.1
Hecate Strait	13,571	4.6	9.2	13.8
North Coast Fjords	16,465	4.2	8.4	12.5
Continental Slope	21,750	3.6	7.3	10.9
Queen Charlotte Sound	36,626	2.8	5.6	8.4

Table 28. Ecological conservation targets applied to PMECS Biophysical Units. Targets vary inversely based on the relative area of each habitat class.

Biophysical Units (4b)	Area (km^2)	Low Target Range (%)	Medium Target Range (%)	High Target Range (%)
OtherBank	2,272	10.0	20.0	30.0
DogfishBank	7,888	5.4	10.7	16.1
Slope	16,704	3.7	7.4	11.1
Trough	19,381	3.4	6.8	10.3
Shelf	35,207	2.5	5.1	7.6

Table 29. Ecological conservation targets applied to PMECS Geomorphic Units. Targets vary inversely based on the relative area of each habitat class.

Geomorphic Units	Area (km^2)	Low Target Range (%)	Medium Target Range (%)	High Target Range (%)
Fjord, Depression floor	1,206	10.0	20.0	30.0
Fjord, Crest	1,247	9.8	19.7	29.5
Slope, Wall, sloping	1,272	9.7	19.5	29.2
Fjord, Mound	1,832	8.1	16.2	24.3
Fjord, Wall, steeply sloping	3,133	6.2	12.4	18.6
Slope, Ridge	3,318	6.0	12.1	18.1
Fjord, Depression	3,785	5.6	11.3	16.9

Geomorphic Units	Area (km^2)	Low Target Range (%)	Medium Target Range (%)	High Target Range (%)
Slope, Canyon floor	3,802	5.6	11.3	16.9
Shelf, Depression floor	5,830	4.5	9.1	13.6
Shelf, Crest	7,582	4.0	8.0	12.0
Slope, Wall, steeply sloping	11,061	3.3	6.6	9.9
Shelf, Wall, sloping	11,833	3.2	6.4	9.6
Shelf, Depression	19,176	2.5	5.0	7.5
Shelf, Mound	23,720	2.3	4.5	6.8

Table 30. Ecological conservation targets applied to Upper Ocean Subregions. Targets vary inversely based on the relative area of each habitat class.

Upper Ocean Subregions	Area (km^2)	Low Target Range (%)	Medium Target Range (%)	High Target Range (%)
Northern Strait of Georgia	280	10.0	20.0	30.0
Rose Spit Eddy	1,994	10.0	20.0	30.0
Cape St. James Tidal Mixing	2,345	9.2	18.4	27.7
Dogfish Bank Frontal Region	2,368	9.2	18.4	27.5
Johnstone Strait	2,565	8.8	17.6	26.5
Low Flow Nearshore	3,042	8.1	16.2	24.3
West Coast QCI Upwelling Region	5,237	6.2	12.3	18.5
Aristazabal Banks Upwelling	5,832	5.8	11.7	17.5
Eastern Queen Charlotte Sound	6,348	5.6	11.2	16.8
Southeast Alaska Mixing Region	6,750	5.4	10.9	16.3
Dixon Entrance Coastal Flow Region	6,853	5.4	10.8	16.2
Mainland Fjords	9,466	4.6	9.2	13.8
Cape Scott Tidal Mixing	10,506	4.4	8.7	13.1
Hecate Strait	12,032	4.1	8.1	12.2
Coastal Mixing Region	26,050	2.8	5.5	8.3

Table 31. Ecologically and Biologically Significant Areas (EBSAs). Targets vary inversely based on the relative area of each habitat class.

EBSAs	Area (km^2)	Low Target Range (%)	Medium Target Range (%)	High Target Range (%)
Learmonth Bank	232	10.0	20.0	30.0
Brooks Peninsula	966	4.9	9.8	14.7
Bella Bella Nearshore	1,371	4.1	8.2	12.3
McIntyre Bay	1,410	4.1	8.1	12.2
Haida Gwaii Nearshore	2,031	3.4	6.8	10.1
Hecate Strait	2,352	3.1	6.3	9.4
Dogfish Banks	2,397	3.1	6.2	9.3
Chatham Sound	2,688	2.9	5.9	8.8
North Island Straits	3,169	2.7	5.4	8.1
Cape St. James	3,371	2.6	5.2	7.9
Central Mainland	3,537	2.6	5.1	7.7
Scott Islands	6,976	1.8	3.6	5.5
Shelf Break	24,024	1.0	2.0	2.9

Appendix D: Ecological features assessed in sensitivity analyses focused on feature separation

Table 32. Ecological conservation priorities (E-CPs) and spatial features assessed against example Marxan analyses focused on coarse-filter features, habitat features (including both fine- and coarse-filter features), species features, and all ecological features. For overlays comparing the spatial features to analyses that targeted the bottom end of the target ranges, the target was considered achieved when the overlay resulted in the bottom end of the target range being met or exceeded. For overlays comparing the spatial features to analyses that targeted the top end of the target ranges, the spatial overlap had to meet or exceed the top end of the target range for the target to be achieved. Note that five spatial features were excluded from the assessment accidentally: sea duck key sites, sea otter modeled habitat, Steller sea lion rookeries, Steller sea lion haulouts (winter), and Steller sea lion haulouts (year-round).

Ecological Conservation Priority	Spatial Feature(s)
Ancient Murrelet	Colonies (3 relative importance classes)
Black Oystercatcher	Breeding sites
Brandt's Cormorant	Colonies
Butter Clam	Locations
Cassin's Auklet	Colonies (3 relative importance classes)
Chinook Salmon	Salmon estuaries – Chinook diversity
Chum Salmon	Salmon estuaries – Chum diversity
Cockle	Locations
Coho Salmon	Salmon estuaries – Coho diversity
Common Murre	Colonies (2 relative importance classes)
Dungeness Crab	Important Areas; Locations
Eulachon	Important Areas – spawning; Important Areas – summer
Geoduck	Locations
Giant Pacific Octopus	Locations
Great Blue Heron	Nesting sites
Green Sturgeon	Important Areas
Green Urchin	Locations
Harbour Seal	Haulouts
Herring Spawn	Spawn Habitat Index
Horned Puffin	Colonies
Horse Clam	Locations
Humpback Whale	Critical Habitat (2009-2013)
Leatherback Turtle	Important Areas
Mud or sand flat intertidal birds	Shorebird key sites
Northern Resident Orca	Critical Habitat; Habitat of Special Importance; Potential Critical Habitat
Opal Squid	Locations
Pacific Salmon	Salmon estuaries - biomass

Ecological Conservation Priority	Spatial Feature(s)
Pelagic Cormorant	Colonies (3 relative importance classes)
Pigeon Guillemot	Colonies (2 relative importance classes)
Pink Salmon	Salmon estuaries – Pink (even-year) diversity; Pink (odd-year) diversity
Razor Clam	Important Areas
Red Sea Urchin	Locations
Rhinoceros Auklet	Colonies (3 relative importance classes)
Sockeye salmon	Salmon estuaries – Sockeye diversity
Storm Petrel	Colonies (3 relative importance classes)
Sunflower Sea Star	Locations
Thick-billed Murre	Colonies
Tufted Puffin	Colonies (3 relative importance classes)
Areas of high species abundance, diversity or richness	Fish biomass hotspots (shelf); Fish diversity hotspots (nearshore and shelf)
Areas of high species abundance, diversity or richness	Invertebrate biomass hotspots (shelf); Invertebrate diversity hotspots (shelf)

Appendix E: Species and Spatial Features Removed from Sensitivity Analyses on Commercially-harvested Species

Table 33. List of 71 commercially-harvested features removed from experimental Marxan analyses to eliminate any influence of species targeted or incidentally caught in commercial fisheries.

Feature Name	Feature Type
Arrowtooth Flounder	Research catch per unit effort (CPUE)
Big Skate	Research CPUE
Bocaccio	Research CPUE
Bocaccio	Central Coast Indigenous Research Alliance (CCIRA) Research CPUE
Butter clams	records
Canary Rockfish	Research CPUE
Canary Rockfish	CCIRA Research CPUE
China Rockfish	Research CPUE
China Rockfish	CCIRA Research CPUE
Chinook Salmon	diversity hotspot
Chum Salmon	diversity hotspot
Cockles	records
Coho Salmon	diversity hotspot
Copper Rockfish	Research CPUE
Darkblotched Rockfish	Research CPUE
Deepwater Tanner Crab	Research CPUE
Dover Sole	Research CPUE
Dungeness crab	records
Dungeness crab	Important Areas
Eulachon	Important Areas - spawn
Eulachon	Important Areas - summer
Geoduck	records
Giant Pacific octopus	records
Green sea urchin	records
Green Sturgeon	Important Area
Greenstriped Rockfish	Research CPUE
Horse clam	records
Lingcod	Research CPUE
Lingcod	CCIRA Research CPUE
Longnose Skate	Research CPUE

Feature Name	Feature Type
Longspine Thornyhead	Research CPUE
Mid-lived Rockfish	CCIRA Research CPUE
Opal squid	records
Pacific Cod	Research CPUE
Pacific Hake	biomass index
Pacific Halibut	Research CPUE
Pacific Herring	spawn habitat index
Pacific Ocean Perch	Research CPUE
Pacific Salmon	biomass hotspot
Pacific Sand Lance	Research CPUE
Petrale Sole	Research CPUE
Pink and Spiny Scallops	Research CPUE
Pink Salmon (even)	diversity hotspot
Pink Salmon (odd)	diversity hotspot
Quillback Rockfish	Research CPUE
Quillback Rockfish	CCIRA Research CPUE
Razor clam	Important Areas
Red sea urchin	records
Redstripe Rockfish	Research CPUE
Rex Sole	Research CPUE
Rock Sole	Research CPUE
Rosethorn Rockfish	Research CPUE
Rougheye/Blackspotted Rockfish	Research CPUE
Roughtail Skate	Research CPUE
Sablefish	Research CPUE
Sandpaper Skate	Research CPUE
Shortraker Rockfish	Research CPUE
Shortspine Thornyhead	Research CPUE
Silvergray Rockfish	Research CPUE
Silvergray Rockfish	CCIRA Research CPUE
Sockeye Salmon	diversity hotspot
Spiny Dogfish	Research CPUE
Tiger Rockfish	Research CPUE
Tiger Rockfish	CCIRA Research CPUE

Feature Name	Feature Type
Vermillion Rockfish	Research CPUE
Walleye Pollock	Research CPUE
Widow Rockfish	Research CPUE
Yelloweye Rockfish	Research CPUE
Yelloweye Rockfish	CCIRA Research CPUE
Yellowmouth Rockfish	Research CPUE
Yellowtail Rockfish	Research CPUE