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DEFINING DISTINCT NEARSHORE MARINE BIOTOPES COASTWIDE IN BRITISH COLUMBIA, CANADA

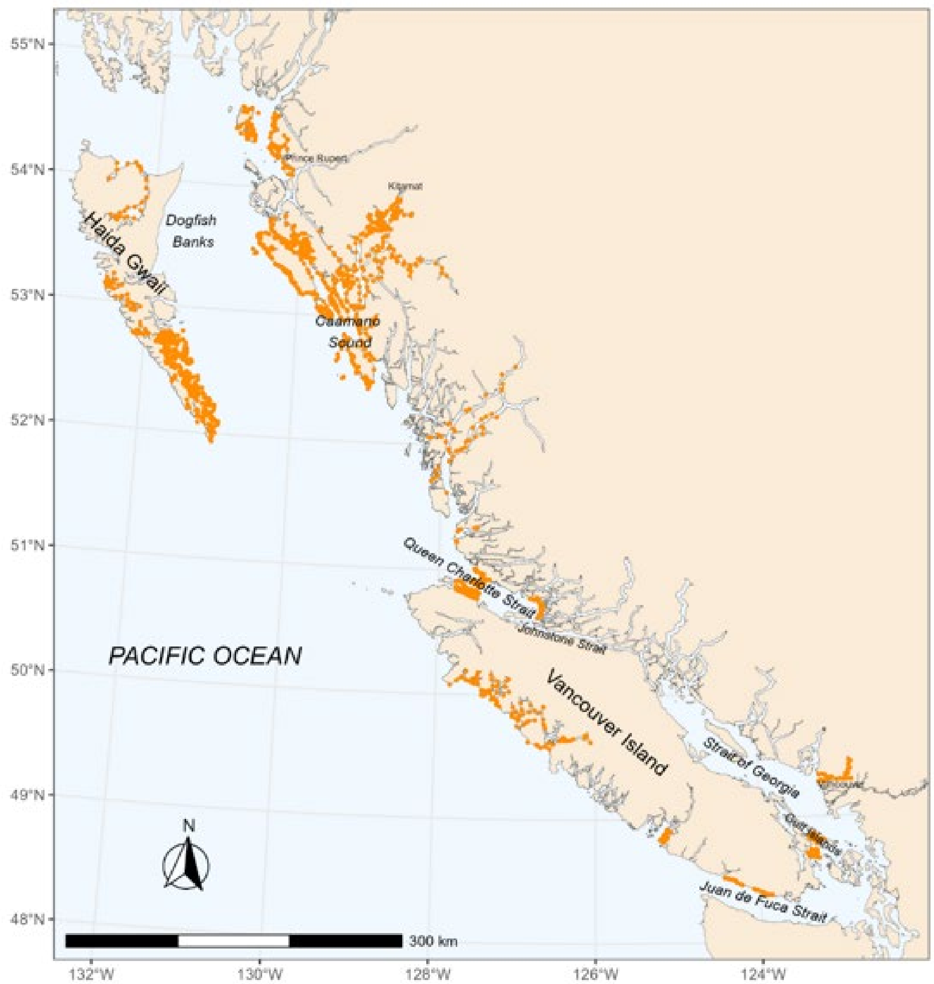

Figure 1. Location of survey transects.

CONTEXT

Fisheries and Oceans Canada (DFO) Integrated Marine Response Planning (IMRP) Program has requested that Science Branch provide tools to support environmental response.

A comprehensive understanding of marine communities and habitats is valuable to ensure informed decision-making, management, and conservation of marine ecosystems along the British Columbia (BC) coastline. Marine planning initiatives, including environmental response planning and the development of a marine protected area (MPA) network, have long been challenged by significant gaps in our knowledge of the distribution of many nearshore marine species. This lack of critical information can impede our ability to effectively manage and protect ecosystems.

We developed a set of species distribution models (single-SDMs) using data collected from ten years of benthic habitat mapping surveys. These models correlate species occurrence data with environmental variables. We used these models to make predictions of the probability of occurrence of each species across the entire nearshore BC coast. A cluster analysis of the single-SDM predictions was then used to determine biotopes, which are distinct combinations of physical and chemical water properties and associated biological communities.

This Science Advisory Report is from the regional peer review of March 3-4, 2025, Defining Distinct Nearshore Marine Biotopes Coastwide in British Columbia, Canada. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule] as they become available.

SUMMARY

- Nine nearshore epibenthic biotopes along with three physiotopes based on environmental conditions were defined and mapped for the coast of BC.
- The definition of the biotopes includes correlated species with seven environmental conditions (substrate, slope, depth, exposure, temperature, salinity, and tidal current) occurring within each biotope. Three physiotopes were defined as unique environmental areas and were not defined using species data.
- 72 Species Distribution Models (single-SDMs) were included in the analysis to define the biotopes. Many species included in the survey are widely distributed across the BC coast and may not be useful in differentiating biotopes (e.g., red sea urchin, *Mesocentrotus franciscanus,* was correlated with five biotopes) therefore indicator species were not able to be identified.
- After 10 years of conducting the benthic habitat mapping (BHM) survey, gaps in our understanding of nearshore species still remain. We lack knowledge of many nearshore species distributions, what drives their distribution, and what species they are associated with. Continued data collection could refine the species list and improve biotope classification. Additional species, including rarer species, should be considered in future surveys and data collection should focus on lower-level taxonomy (i.e., genus, species).
- There are limited environmental predictors available for the nearshore. Many predictors used in marine SDMs are derived from oceanographic models with kilometre scale resolution which only provide broad-scale species-environmental relationships. The scale disparity between the survey data and environmental covariates may limit the utility of oceanographic variables in modeling (i.e., no relationships are found) or restricts their applicability to finer scales.
- Out of the seven environmental covariates, only three (substrate, depth, and exposure), have a range of values that are not overlapping across all biotopes. Except for slope, the remaining predictors (salinity, temperature and current) are derived from oceanographic models for which the nearshore is not well resolved. This indicates that higher predictor resolution might result in better resolved relationships with species distribution, as well as better definitions of the biotopes, and\or an increase in the number of biotopes.

- While the maps provide valuable insights into biotope distribution, they should be interpreted with an understanding of their resolution limitations and the potential for finer-scale variability in nearshore environments.
- Over the course of the 10 years of this project, the team consisted of numerous biologists who were very experienced in species identification, with extensive experience working in intertidal and subtidal habitats throughout the BC coast. Their experience and knowledge were invaluable for validating the resulting biotopes in terms of species inclusion and environmental associations.
- The analysis is reliable and repeatable and, as such, the biotope outputs can be used to support management decisions, including environmental incidents and marine spatial planning initiatives, in the Pacific Region.

INTRODUCTION

The fundamental barrier contributing to our lack of knowledge of marine species distribution is the shortage of comprehensive data. Consequently, management decisions must often be made with insufficient data, before detailed surveys can be conducted. To address the need for an improved nearshore classification to support various marine planning initiatives in the Pacific Region, Fisheries and Oceans Canada (DFO) Science initiated a Benthic Habitat Mapping (BHM) survey in 2013 to document substrate types and associated algae and epibenthic marine macroinvertebrate species. Nearshore is defined here, based on the data used, as the intertidal zone, from -2 m, to a depth of 16 m below chart datum. The main objective of this research is to support development of a marine ecological classification for the nearshore waters of the BC coast and to populate the higher levels of the existing Pacific Marine Ecological Classification System (PMECS) (Rubidge et al., 2016).

This study aims to classify nearshore ‘biotopes’, which are defined in PMECS Level 6 as ‘combinations of physical and chemical water property data (sea surface temperature and salinity, dissolved oxygen, stratification) and associated biological communities’ at resolutions of <1 km^2 (Rubidge et al., 2016). The biotopes nest under Geomorphological Units (PMECS Level 5) and fill a key spatial gap in nearshore areas. The term biotope is used widely to encompass both biotic and abiotic elements (Parry 2019). This biotope classification will provide ecological classification at an appropriate scale for multiple spatial planning initiatives (DFO 2016).

The overarching goal and specific objectives of the research document were to:

Define distinct nearshore marine biotopes (combination of species communities and environmental factors) in British Columbia. Specifically:

1. Define the number of biotopes
2. Define the spatial distribution of each biotope
3. Define the species that characterize these biotopes
4. Define the environmental characteristics of each biotope
5. Quantify certainty about the distribution of each biotope
6. Recommend how to interpret, including limitations, and use this information

ASSESSMENT

We developed a set of single-SDMs using data collected from the BHM survey. These models correlate species occurrence data with environmental variables. We used these models to make predictions of the probability of occurrence of each species across the entire BC nearshore. A cluster analysis of the single-SDM predictions was then used to determine the biotopes (Fig. 2-4).

We collected from SCUBA-based research surveys spanning the BC coastline using random transects during the spring to early fall (April–October) from 2013 to 2023 (excluding 2016, 2020). These surveys assessed the presence or absence of 104 benthic invertebrates and 59 algae species or species groups. The survey protocol is detailed in Davies et al. (2018).

The distribution of benthic nearshore species was estimated using geostatistical models fit with sdmTMB (Anderson et al., 2022). This modelling package in R (sdmTMB) fits single species spatial and spatiotemporal generalized linear mixed effects models (GLMM). We excluded species with prevalence less than 0.5% and species we deemed too generic to be used in analysis (e.g., ‘Other barnacles’), resulting in 127 species included in the sdmTMB spatial analysis. Prevalence here is defined as the relative frequency a species occurs within all the quadrats sampled.

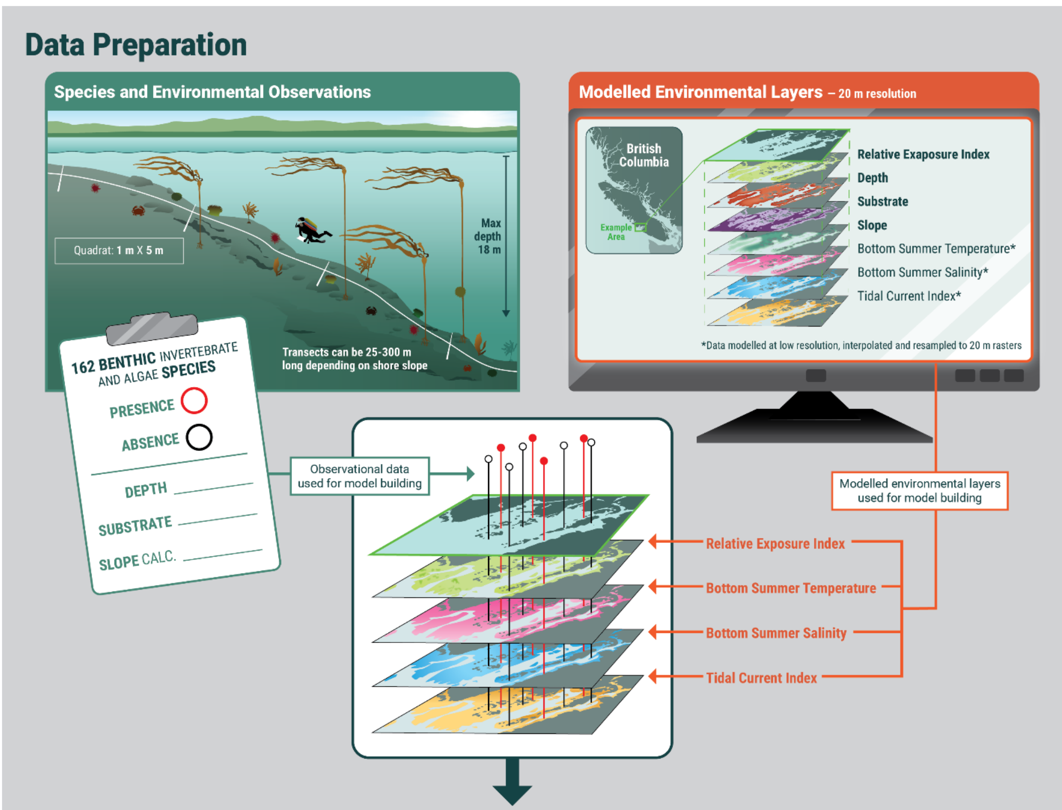

Figure 2. Data preparation process, taking observed presence and absence data for 162 recorded species, as well as the observed depth, calculated slope and substrate, and the closest values from modelled environmental layers for exposure, temperature, salinity and current. This process creates a table with locations of all the observations of a given species linked with the observed and modelled environmental conditions at these points (see Fig. 3). Generic species groups and those with prevalence value <0.5% were removed, resulting in 127 species carried forward to Model Building.

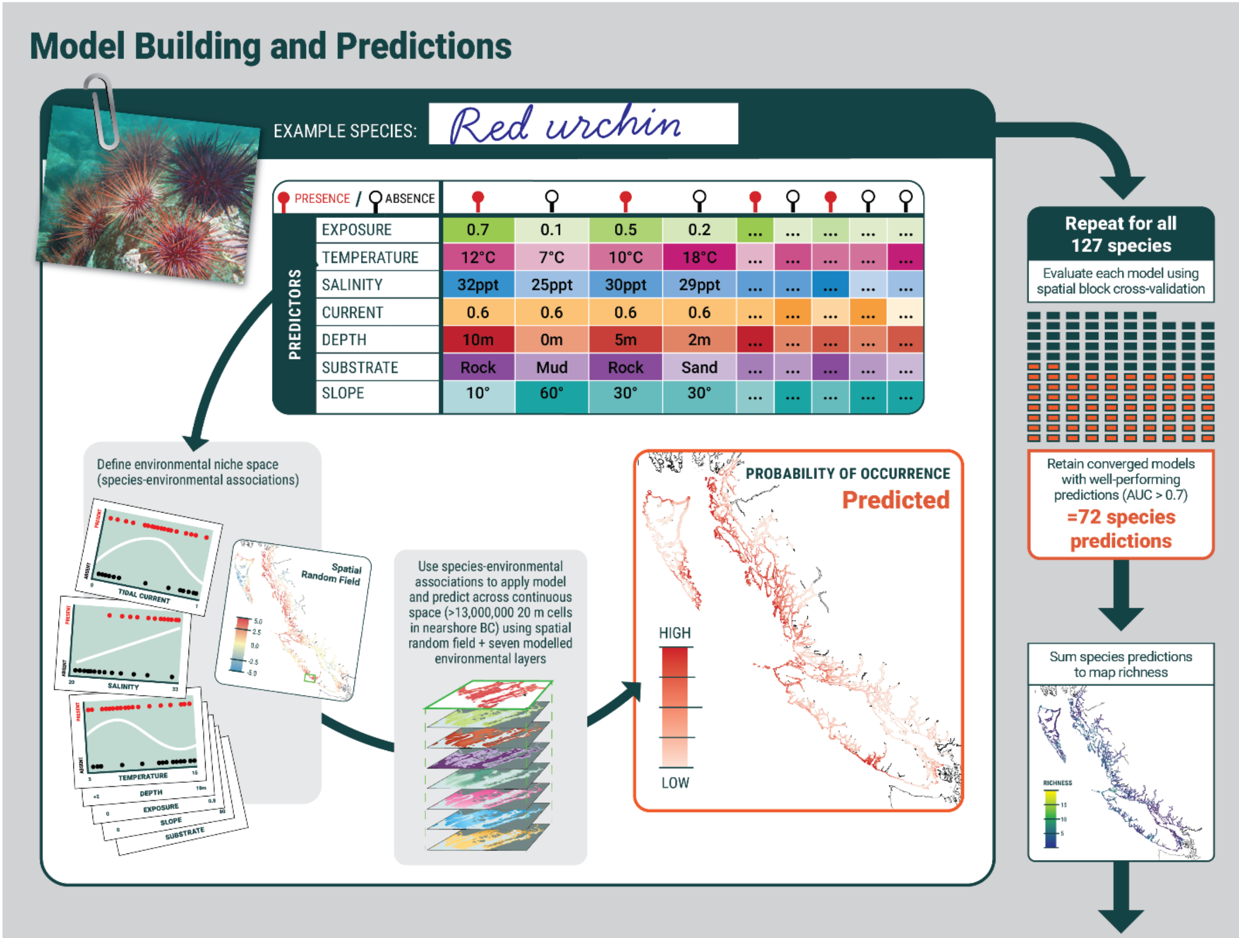

Figure 3. Overview of model building and predictions processes. Generalized Linear Mixed Models (GLMMs) are used to determine the relationships between environmental variables and species occurrence and to estimate a spatial random field. The relationships are then used to predict probability of occurrence for each species. Cross-validation is performed to determine the accuracy of the prediction (using area under the curve, AUC). These processes are repeated for each of the 127 species. 72 species with AUC > 0.7 are carried through the next steps which are summing to estimate species richness and clustering (see Fig. 4).

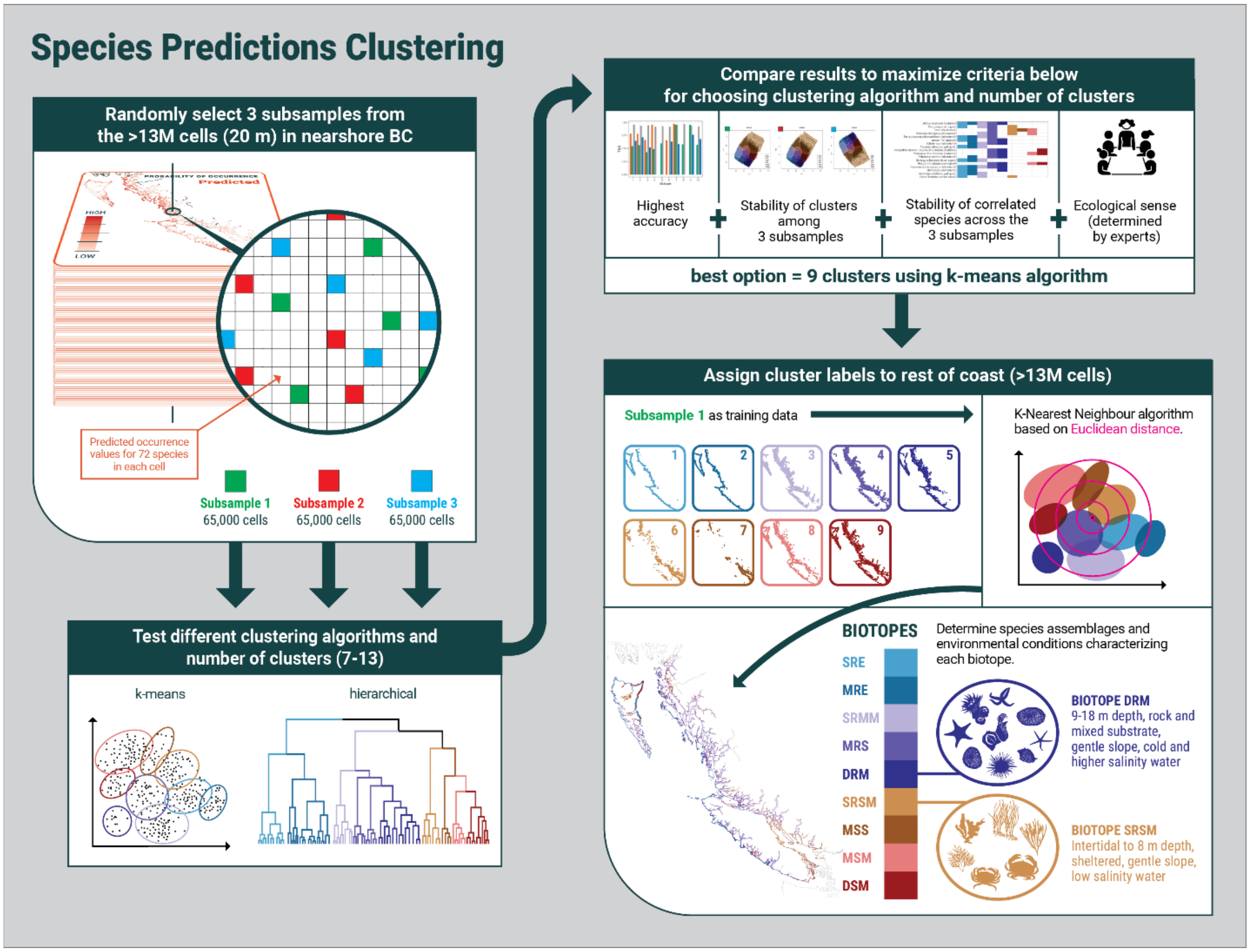

Figure 4. Overview of the clustering analysis. Predicted species occurrences were subsampled (three subsamples of 65,000 cells), and different clustering algorithms and cluster numbers (7–13) were tested. Nine clusters using k-means algorithm was selected based on accuracy, stability across subsamples, and ecological interpretability. Cluster labels were then assigned to the entire BC nearshore (>13 million cells) using a K-Nearest Neighbour classifier. Resulting biotopes represent distinct species assemblages along with the environmental conditions that defined them. The mapped outputs provided are the distribution of all biotopes.

Our selection of model environmental covariates, or predictors, was based on ecological theory, data availability, and prior knowledge of the species and region. Covariates included substrate type (classified as rock, mixed, sand, or mud) (Gregr et al., 2021), seafloor depth (Davies et al., 2019; Carignan et al. 2013; Gregr 2012), slope, relative exposure index (REI) (Fields et al., 2023), relative tidal current index (Lin & Bianucci, 2023; DFO, 2022; Soontiens et al., 2016; Soontiens & Allen, 2017; Masson and Fine, 2012; P. Thupaki, DFO, *pers. comm.*), mean summer bottom temperature (Soontiens et al., 2016; Soontiens & Allen, 2017; Masson and Fine, 2012), and mean summer bottom salinity (Soontiens et al., 2016; Soontiens & Allen, 2017; Masson and Fine, 2012). Substrate, slope, and depth data for model building were derived from direct observations during the dive surveys. The other environmental covariates (REI, salinity, temperature, tidal current) were matched from spatial layers to each quadrat by extracting values from the grid cell of the layer overlapping the midpoint of the transect (Fig. 2). The freshwater input layer was derived from the BC Freshwater Atlas (Fields et al., 2022). The sdmTMB package used to create the single-SDMs, also estimates spatial random fields that account for spatial correlation which is often due to missing covariates.

We assessed the predictive accuracy of single-SDMs using five-fold spatial block cross--validation. This involved fitting the models five times, each time withholding one of the folds of data when training the model and then assessing how well the model could predict that withheld data (Roberts et al., 2016; Hijmans, 2012). Blocks were 100 km in size, exceeding the estimated spatial autocorrelation distance in the models (determined from the spatial random fields), for most species.

Based on this cross-validation, we excluded single species models with insufficient predictive accuracy, which we define as an area under the curve (AUC) value below 0.70 (Pearce & Ferrier, 2000). An AUC of 0.5 indicates that the model does no better than random when predicting the species' occurrences in the withheld data fold during cross-validation and an AUC of 1.0 indicates perfect classification (Fawcett 2006). Nine species models were removed due to model convergence issues. Seventy-two species single-SDMs met the AUC threshold and converged. These models were then refit using the full dataset so that all observations were included in the final set of predictions.

Predictions were excluded for environmental conditions outside the model's training range (i.e., based on the BHM data), including areas with:

- high freshwater influence (>0.0008 index value),
- depths above -2 m,
- temperature outside 4.8 to 20.2°C, and,
- high exposure (>0.83 REI index value).

For the predictions of the single-SDMs, we replaced in situ (diver collected): substrate, seafloor depth, slope observations , with outputs from regional substrate and bathymetric models. This substitution assumes that in situ measurements are comparable to model outputs.

Predicted species richness in a given location was calculated as the sum of occurrence probabilities across all 72 species.

To define biotopes, cluster analyses were conducted using the 72 single-SDMs. The analyses were performed on subsamples (65,000 grid cells out of 13,863,506) because clustering the entire prediction grid was not feasible. The analyses included testing several clustering methods as well as determining the number of clusters that were statistically and ecologically meaningful. The details of these analyses are provided in the research document. Ultimately, we selected nine biotopes (Fig. 4).

To create the biotope map, we then used k-Nearest Neighbour (k-NN) to make coastwide predictions for all grid cells, using data from subsample 1 as the training data. k-NN is a non-parametric, supervised learning classifier, which uses proximity (in this case, Euclidian distance) to make classifications or predictions about which cluster an individual data point belongs to. The probability for each of the nine biotopes was calculated for every grid cell and the biotope with the highest probability was assigned to that cell.

Strictly speaking, areas without species are not biotopes since they do not include biological data. However, there were areas excluded from predictions that can be added to the biotopes map to increase its usefulness, namely the freshwater input (Fields et al., 2022), areas of very high exposure (Fields et al., 2023) and exposed sandy beaches (Howes et al., 1994). We refer to these environmentally defined areas as 'physiotopes' to distinguish them from biotopes.

To associate environmental conditions with each biotope and physiotope, we compared the distributions of each environmental variable present from all grid cells associated with each biotope and physiotope.

Species Richness

Predicted species richness across the coast ranged from 0.19 to 15.9, with a mean value of 3.4 ± 2.0 (median 3.1). Predicted species richness was generally higher near the opening to Queen Charlotte Strait, high current areas near Johnstone Strait and Discovery Passage, Caamaño Sound on the Central Coast, west and southern side of Moresby Island and Langara Island in Haida Gwaii, areas across west coast of Vancouver Island, and the southernmost Gulf Islands. Areas of low species richness were generally found in the Strait of Georgia, in inlets, and around Dogfish Banks (northeast Haida Gwaii) (Fig. 5).

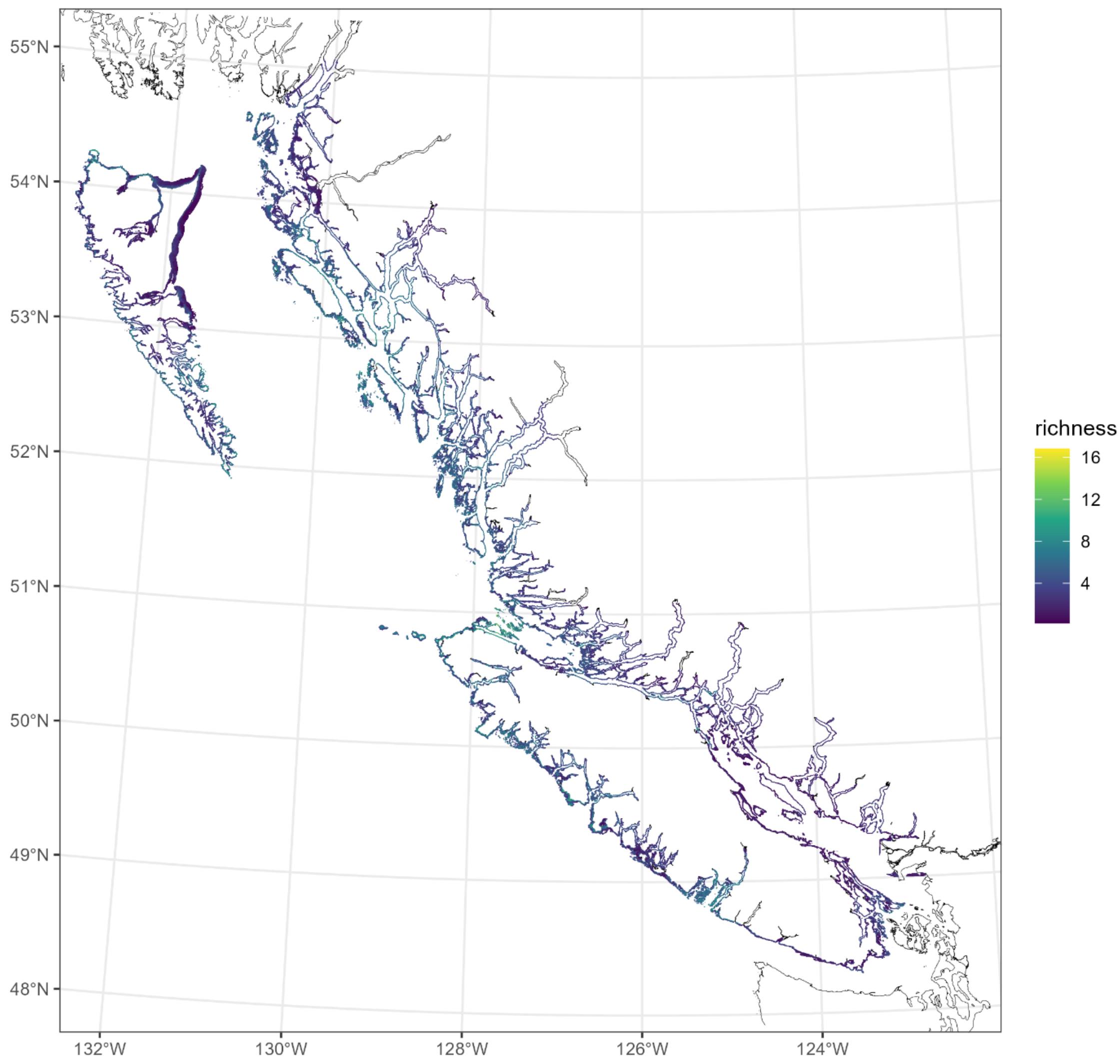

Figure 5. Predicted species richness in each grid cell, which is the sum of the predicted probability of occurrences across all 72 species.

Biotopes

The maximum probability that a grid cell was assigned to any biotope was high (mean = 0.94, median = 1) across the BC coast and ranged from 0.30 to 1. In fact, most grid cells had a probability of 1 (no uncertainty) to be assigned to a given biotope. Areas of maximum probability of less than 1 are distributed across BC on both exposed and sheltered waters indicating that there are no specific environmental conditions or regions that have more uncertainty over others in biotope assignment.

Table 1. Biotope definitions with environmental covariate means (± standard deviation), number of species correlated, and the five most correlated species based on the k-means cluster analysis. The acronym for each biotope is a combination of Depth (1st letter: Shallow = S, Mid-Depth = M, Deep = D), Substrate (middle 1-2 letter(s): Rock = R, Mixed = M, Sand = S) and Exposure (last letter: Exposed = E, Moderately Exposed (0.2-0.35) or Sheltered (0.05-0.2) = M, Sheltered = S)

Biotope	Depth (m)	Substrate (Proportion %)	Exposure (relative 0-1)	Slope (°)	Salinity (ppt)	Temperature (°C)	Current (relative 0-1)	# species	5 most correlated species (in order of correlation values)
SRE	Shallow (0.7 ± 1.6)	Rock (90)	Exposed (0.48 ± 0.13)	Low (2.0 ± 3.0)	31.9 ± 0.6	10.1 ± 1.8	0.25 ± 0.07	41	Porphyra spp, Laminaria setchelii, Acrosiphonia spp, Nereocystis luetkeana, Alaria marginata
MRE	Mid-depth (6.6 ± 2.2)	Rock (94)	Exposed (0.38 ± 0.13)	Low (2.5 ± 2.9)	31.9 ± 0.4	10.0 ± 1.5	0.25 ± 0.07	31	Urticina piscivora, Articulated coralline, Dodecaceria spp, Henricia spp, Crassadoma gigantea
SRMM	Shallow (0.9 ± 1.7)	Rock (84) \ Mixed (12)	Moderately sheltered (0.10 ± 0.09)	Moderate (7.6 ± 8.3)	31.6 ± 0.7	9.6 ± 1.3	0.19 ± 0.09	30	Green filamentous algae, Ulva spp, Cladophora spp. Fucus gardneri, Macrocystis pyrifera
MRS	Mid-depth (6.8 ± 2.4)	Rock (95)	Sheltered (0.03 ± 0.05)	Moderate (12.1 ± 10.7)	31.3 ± 0.9	9.4 ± 1.2	0.19 ± 0.09	26	Agarum fimbriatum, Apostichopus californicus, Cnemidocarpa finmarkiensis, Cucumaria miniata, Solaster spp
DRM	Deep (13.2 ± 1.6)	Rock (93)	Moderately exposed (0.25 ± 0.16)	Low - moderate (5.0 ± 7.1)	31.9 ± 0.4	9.5 ± 1.2	0.24 ± 0.07	20	Balanophyllia elegans, Mediaster aequalis\Gephyreaster swifti, Orthasterias

Biotope	Depth (m)	Substrate (Proportion %)	Exposure (relative 0-1)	Slope (°)	Salinity (ppt)	Temperature (°C)	Current (relative 0-1)	# species	5 most correlated species (in order of correlation values)
									koehleri, Henrica spp, Bryozoan Erect
SRSM	Shallow (1.1 ± 2.3)	Rock (44) \ Sand (20) \ Mixed (17)	Moderately sheltered (0.09 ± 0.08)	Low (3.2 ± 4.7)	28.9 ± 1.5	11.4 ± 1.6	0.16 ± 0.09	9	Ulva spp, Metacarcinus gracilis, Sargassum muticum, Zostera spp,
MSS	Mid-depth (10.3 ± 3.1)	Sand (60) \ Mud (28)	Sheltered (0.02 ± 0.03)	Low (3.3 ± 4.4)	28.3 ± 1.3	11.3 ± 1.3	0.15 ± 0.08	5	Metacarcinus magister, Ptilosarcus gurneyi, M. gracilis, Tresus spp, Gracilaria complex
MSM	Mid-depth (7.2 ± 2.4)	Sand (80) \ Mud (13)	Moderately sheltered (0.16 ± 0.15)	Low (2.3 ± 3.7)	31.5 ± 0.7	10.3 ± 1.4	0.23 ± 0.08	6	Tresus spp, Panopea generosa Pachycerianthus fimbriatus, Myxicola infundibulum, Gracilaria complex
DSM	Deep (13.2 ± 1.6)	Sand (60) \ Rock (20) \ Mud (17)	Moderately sheltered (0.11 ± 0.14)	Low (4.9 ± 7.8)	31.3 ± 0.9	10.3 ± 1.5	0.22 ± 0.09	7	*Ptilosarcus gurneyi, Panopea generosa, Pachycerianthus fimbriatus, Myxicola infundibulum, Chlamys* spp

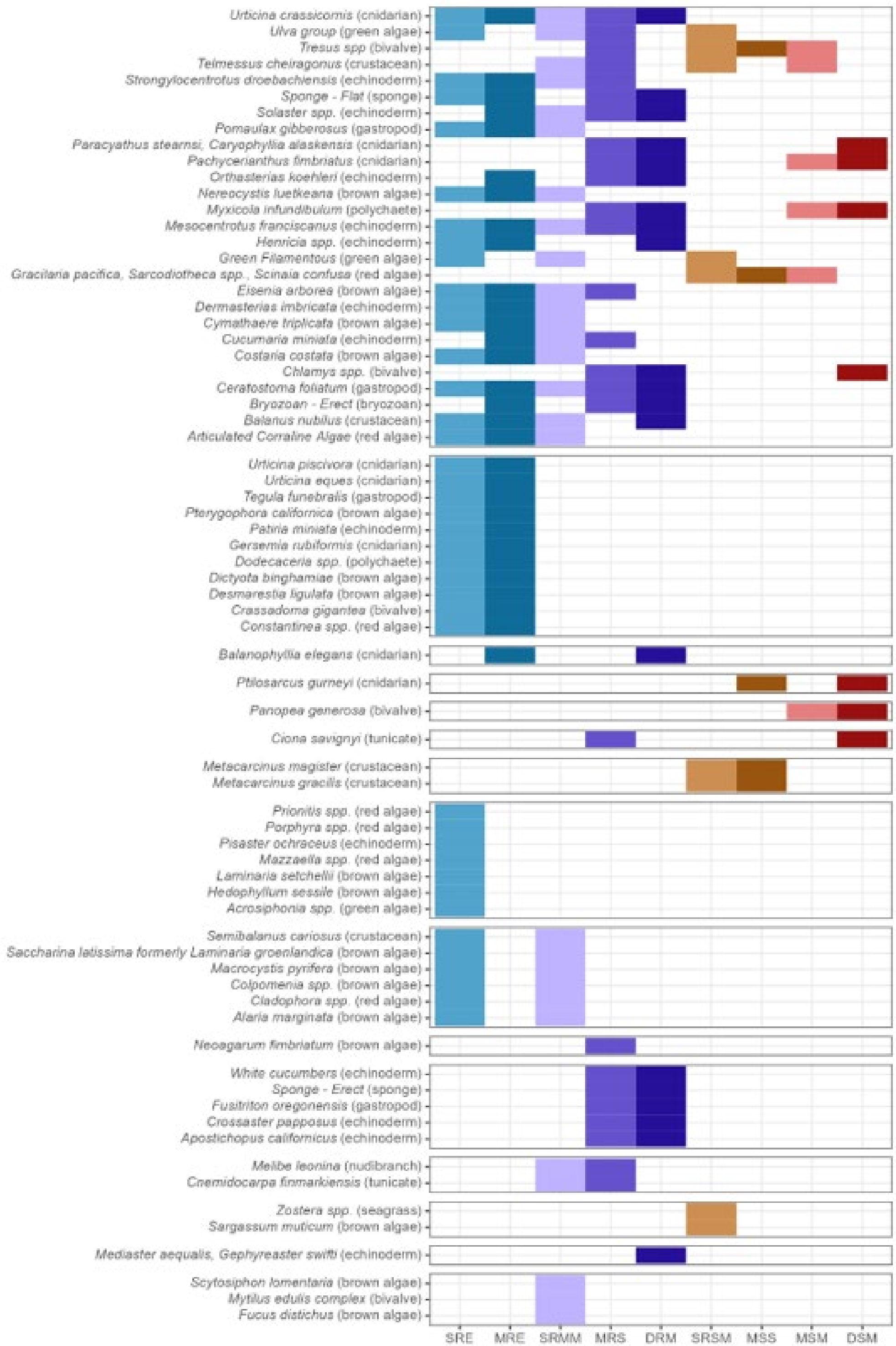

Figure 6. Species correlated with each biotope. Boxes encompassed assemblages of species correlated with categories and/or similar biotopes.

Figure 6 shows all 72 species as well as which biotopes they were correlated with. Table 1 and Figure 7 show the range of environmental covariates found at grid cells where each biotope is predicted.

Depth, salinity, and REI all produced visual patterns of distinction between biotopes (Fig. 6). With a few exceptions, biotopes were stratified across three depth ranges:

- intertidal\shallow subtidal (intertidal to 4 m depth),
- mid-subtidal depths (4-10 m), or
- deeper waters (>10 m).

Similarly, biotopes were stratified across REI values:

- exposed (>0.35),
- moderately exposed (0.2-0.35),
- moderately sheltered (0.05-0.2), and
- sheltered (<0.05).

Biotopes were primarily associated with one or two substrate types, and most were in waters above 30 PSU salinity. The two biotopes (SRSM and MSS) with lower salinity also had higher temperatures. The range of tidal current values for any given biotope overlapped with all other biotopes. Slope was the most variable covariate; all biotopes, except one, had standard variation higher than mean, which might indicate that slope is not a good predictor.

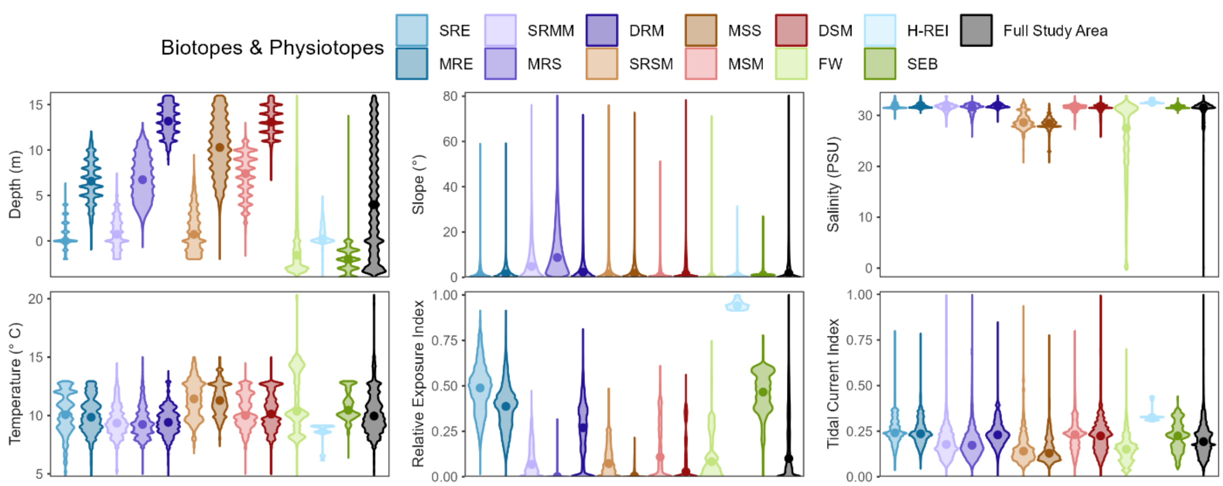

Figure 7. Distributions of environmental variables in the different biotopes, physiotopes, and full study area taken from modelled environmental layers (excluding substrate which is a factor level predictor). Points indicate the median value.

The final map has all biotopes as well as the physiotopes (FW, H-REI and SEB). The Biotopes probability spatial layers as well as the final map combining all biotopes and physiotopes will be available on [Open Government Portal](). The biotopes and physiotopes can be grouped in broad categories. They are described and shown below within these categories.

Exposed rocky biotopes (Biotopes SRE and MRE and Physiotope H-REI)

Biotopes SRE and MRE are mostly found together, restricted to exposed (REI >0.35) rocky coastlines (Fig. 7). Environmental characteristics of these biotopes include higher water motion (higher exposure and higher tidal current), that are colder and higher salinity (Table 1 and Fig. 7). The H-REI biotope is at the more extreme end of these conditions in all cases. Biotope DRM is often found deeper than these biotopes.

Many epibenthic species are correlated with Biotopes SRE and MRE (Table 1 and Fig. 6).

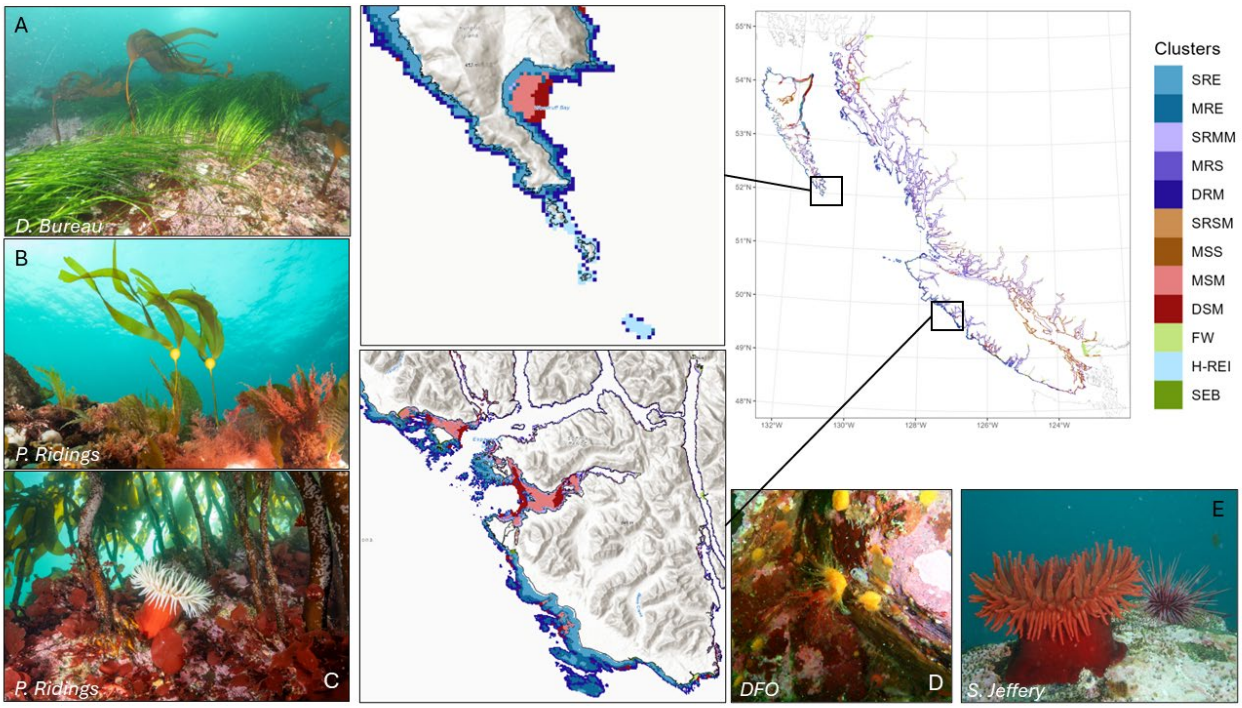

Figure 8. Map insets showing areas (Cape St. James on Haida Gwaii and Nootka Island on west coast Vancouver Island) where exposed rocky biotopes (SRE and MRE) and the H-REI physiotope are present, with images of correlated species (algae: articulated coralline algae (A-C), Laminaria setchelii (A), Nereocystis leutkeana (B), Pterygophora californica (C), Costaria costata (B); invertebrates: Urticina piscivora (C, E), Dodecaceria spp. (E), Mesocentrotus franciscanus (E), Balanophyllia elegans (D), Cucumaria miniata (D)).

Sheltered rocky biotopes (Biotopes MRS and SRMM)

Biotopes MRS and SRMM often occur together in inlets and sounds across BC, as this is where sheltered rocky areas are most common (Fig. 9). The environmental characteristics of these biotopes include waters with low motion (low exposure and low tidal currents), with higher salinity and lower temperature (Table 1 and Fig. 7). These biotopes are predominately rock with some mixed substrate. Biotope SRMM extends into the intertidal and shallow subtidal zone where slope is moderate. Biotope MRS is predicted in mid-depth areas, usually in proximity but deeper to Biotope SRMM, and occasionally Biotope SRSM in the Strait of Georgia. Often Biotope SRMM and MRS are predicted in areas shallower than Biotope DSM or DRM.

Many epibenthic species, although less than exposed rocky areas, are correlated with Biotopes MRS and SRMM (Table 1 and Fig. 6).

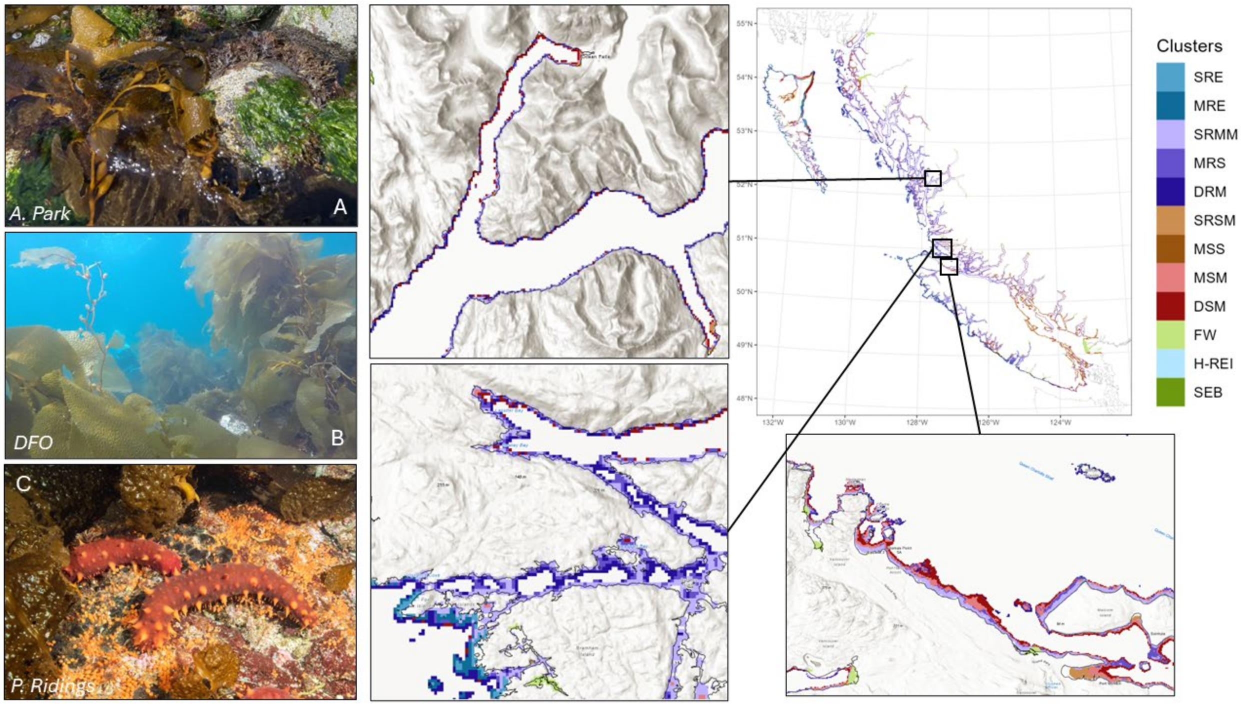

Figure 9. Map insets showing areas (Cousins Inlet and Bramham Island on the Central Coast; and between Port Hardy and Port McNeill on Vancouver Island) where sheltered rocky biotopes (MRS and SRMM) are present with images of correlated species (algae Fucus distichus (A), Ulva spp. (A), Macrocystis pyrifera (A, B), Neoagarum fimbriatum (C); invertebrates: Cnemidocarpa finmarkiensis (C), Apostichopus californicus (C)).

Deep rocky biotope (Biotope DRM)

Biotope DRM is deeper (>10 m), predominantly low slope rocky substrate, and is distributed over a wide range of exposures and higher tidal currents with higher salinity, and colder water (Table 1 and Fig. 7). Biotope DRM is often found deeper than Biotopes MRE and SRE on exposed shorelines and Biotopes MRS and SRMM in more sheltered areas (Fig. 10).

Biotope DRM has no algae species correlated with it. Many epibenthic invertebrate species, although less than shallower rocky areas, are correlated with this biotope (Table 1 and Fig. 6).

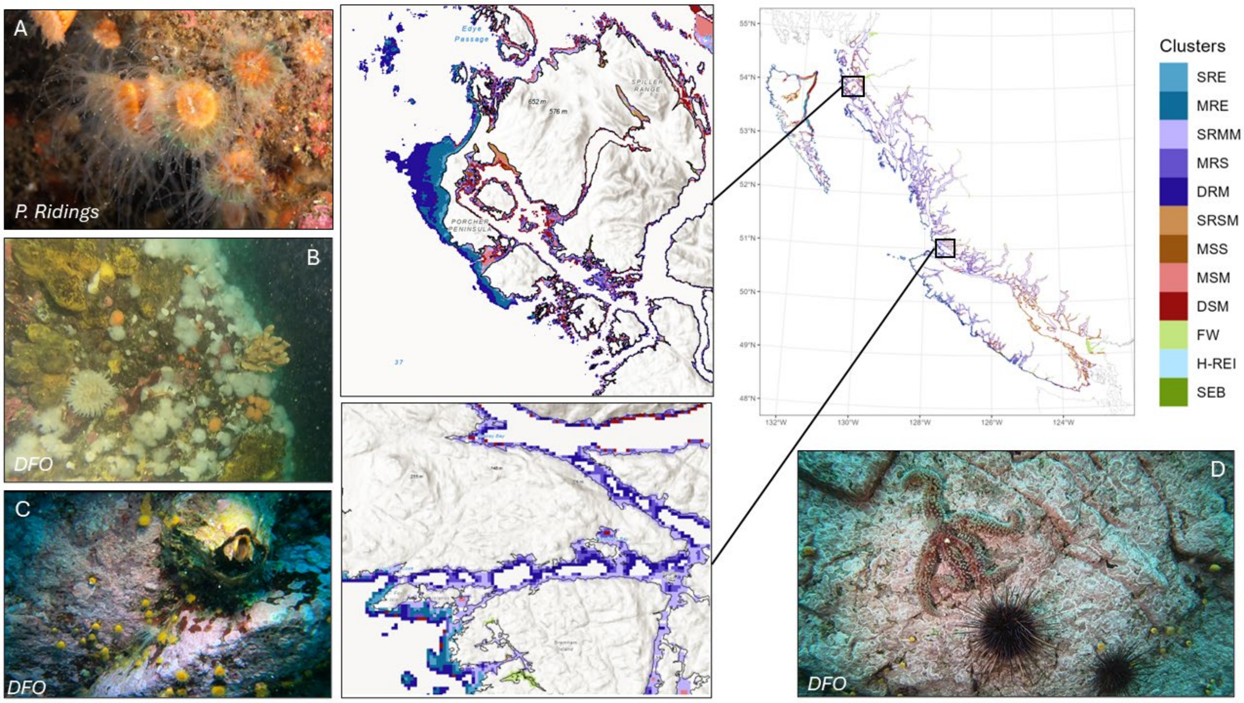

Figure 10. Map insets showing areas (Bramham Island on the Central Coast and Porcher Island on the North Coast) where the deep rocky biotope (DRM) is present with images of correlated species (invertebrates: Paracyathus stearnsi/Caryophyllia alaskensis (A), Balanophyllia elegans (C), Mesocentrotus franciscanus (D), Balanus nubilus (C), Orthasterias koehleri (D), erect and flat sponges (B)).

Sheltered lower salinity biotopes (Biotopes SRSM and MSS)

Biotopes SRSM and MSS are mainly found in areas influenced with freshwater input (salinity values are lower), and this is likely an important environmental characteristic influencing species distributions (Table 1 and Fig. 7). Other environmental characteristics of these biotopes include warmer temperatures, low water motion (low exposure and currents), and areas with low slope. Biotope SRSM characterizes a large majority of the intertidal and shallow subtidal area of the Salish Sea (Fig. 11). Biotope SRSM occurs on a variety of substrate while MSS occurs mostly on sand and\or mud. Biotope MSS is found from mid-depths to deep depths, often below Biotope SRSM.

Several epibenthic species are correlated with Biotopes SRSM and MSS (Table 1 and Fig. 6). There are multiple infauna species associated with these biotopes.

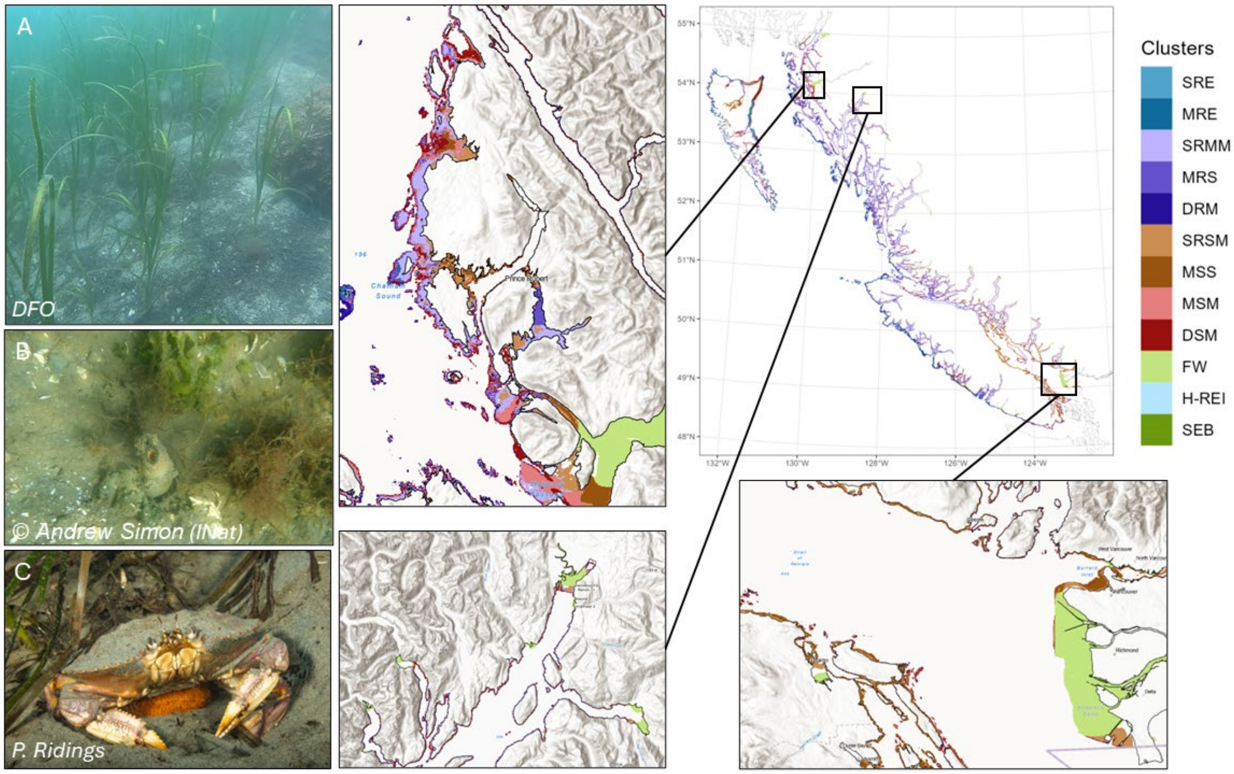

Figure 11. Map inset showing areas (Chatham Sound, Skeena River and Douglas Channel on the North Coast; Strait of Georgia on the Mainland and Vancouver Island) where the low salinity sheltered mixed biotopes (SRSM and MSS) are present as well as the FW physiotope with images of correlated species (seagrass Zostera spp. (A); algae Ulva spp. (B); invertebrates Tresus spp. (B), Metacarcinus magister (C)).

Sheltered soft sediment biotopes (Biotopes DSM and MSM)

Biotopes DSM and MSM are primarily soft substrates with low slopes in moderate tidal current areas with high salinity, colder waters (Table 1 and Fig. 7). Biotopes DSM and MSM are often found together, except in inlets and channels, where Biotope DSM is more prevalent (Fig. 12). Biotope DSM is actually ubiquitous across most coastal areas at low prevalence. These biotopes are also often predicted near Biotopes MRS and SRMM. Biotope MSM is at mid-depths, with Biotope DSM at deeper depths.

Several epibenthic species are correlated with Biotopes SRSM and MSS (Table 1 and Fig. 6). There are multiple infauna species associated with these biotopes.

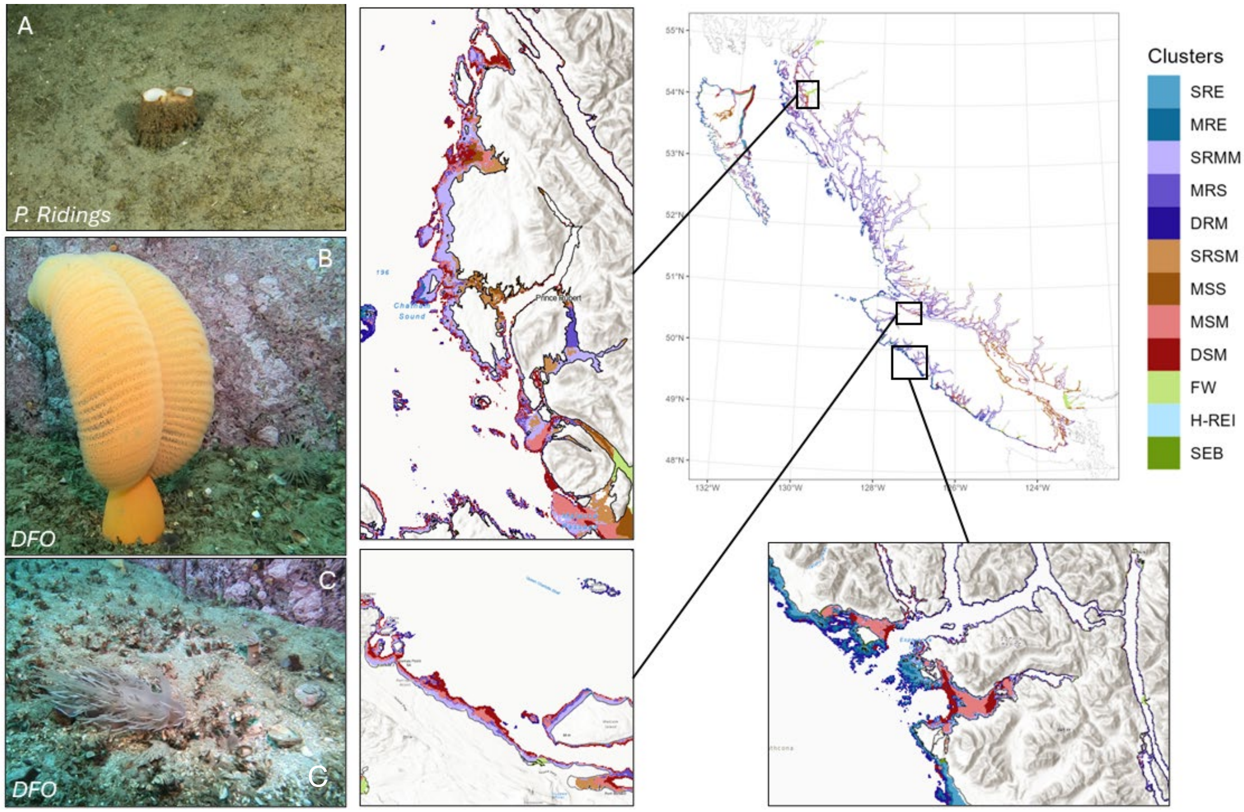

Figure 12. Map inset showing areas (Chatham Sound on the North Coast; Port Hardy to Port McNeill on Vancouver Island; and Esperanza Inlet on west coast Vancouver Island) where the sheltered soft sediment biotopes are present with images of correlated species (invertebrates: Panopea generosa (A), Ptilosarcus gurneyi (B), Pachycerianthus fimbriatus (C) with Dendronotus iris)).

Exposed sandy beach physiotope (Physiotope SEB)

The analyses did not produce a biotope for exposed sand areas probably due to lack of data because of the difficulty of diving in these areas and the survey protocol which was not designed to cover intertidal areas completely. As these areas are not distinguished with the current data, we used the BC Provincial ShoreZone dataset (Howes et al., 1994). This dataset covers the entire intertidal coast of BC. We selected shoreline segments where the shoreline type was classified as Sand Beach and exposure was classified as exposed or very exposed. This physiotope only occurs in the intertidal and is labelled SEB (Sandy Exposed Beach).

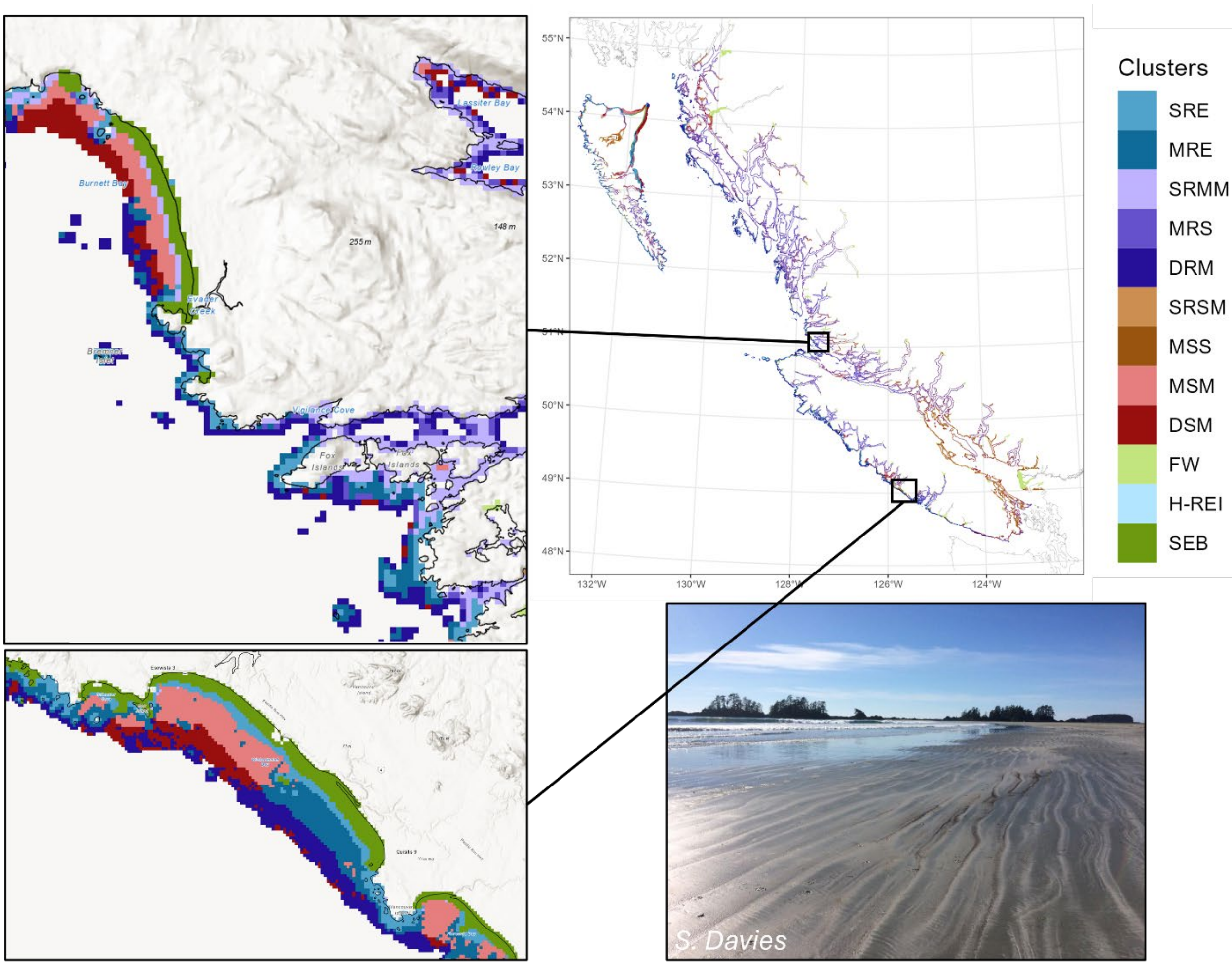

Figure 13. Map inset showing areas (Burnett Bay on the Central Coast and Long Beach on west coast Vancouver Island) where the exposed soft sediment biotope is present.

Freshwater physiotope (Physiotope FW)

The FW physiotope identifies marine areas where salinity is presumably lower due to streams and rivers freshwater output into the ocean. Smaller rivers and stream areas are often not captured in oceanographic models as can be seen by the wide range of salinity values that characterizes the biotope (Fig. 7). The FW biotope is present across BC, often at the heads of inlets or bays (Fig. 9).

Sources of Uncertainty

There are many types of uncertainty inherent in SDMs that need to be considered in the use of these results. Uncertainty includes errors in the data collected, errors contained in the predictor layers, uncertainty in the SDM models, and uncertainty in biotope assignment. Efforts have been made throughout the data collection and analysis process to minimize uncertainty where possible and communicate the uncertainty that still remains.

In terms of uncertainty in data collection, divers are trained both in classroom and underwater in survey protocol and species identification. Several measures were put in place to decrease uncertainty from the data collected. While uncertainty in the data collected can still remain, it likely contributes the least amount of uncertainty.

There is uncertainty in some of the predictor layers as they, themselves, are models. Other sources of uncertainty from predictor layers include downscaling the oceanographic models, artefacts in bathymetry, missing predictors, and predictors that are proxy for non-measured ones. Some of this uncertainty was decreased by using spatial random fields as they can account for the variability that may be due to missing covariates.

Single-SDMs were only included in the cluster analysis when they had demonstrated high predictive performance through spatial block cross-validation. Finally, we also limited the predictions to environmental conditions found at surveyed sites as extrapolating beyond the predictors' range contained within the source data can decrease accuracy (Nephin et al., 2023; Eger et al. 2017; Wenger and Olden, 2012; Elith et al. 2010).

We can quantify the assignment uncertainty of the biotopes; however, we cannot quantify the spatial certainty of the final biotope map. The high probability of biotope assignment indicates that these biotopes are stable and by extension, accurate.

CONCLUSIONS AND ADVICE

The outputs of the analyses presented here created a map of nearshore epibenthic biotopes and physiotopes for all of BC. All biotopes can be defined by a few species in conjunction with depth, exposure, and substrate. Although the biotopes have not been validated by independent data (as no appropriate dataset currently exists), we argue that the spatial layers (Figures 8-12 Open Government Portal) are authoritative and can be used for marine spatial planning initiatives because

1. the cluster analysis was based only on high accuracy single-SDMs,
2. the species assemblages are ecologically meaningful based on expert review, and
3. the environmental covariates present where biotopes are predicted are as expected based on expert review.

In other words, the lack of certainty in the distribution of the biotopes should not preclude the use of the map produced here as their spatial representation agrees with our knowledge and experience.

The biotopes can be used to replace the proxies currently used by DFO's IMRP program Environmental Incident Coordinators as a first step to identify expected substrate, expected species, and by extension potential sensitivity of coastal areas potentially impacted by marine pollution incidents.

This is the first classification of nearshore biotopes that incorporates biological data in addition to physical attributes in the Pacific region. The outputs presented here can be a valuable tool to help inform future marine spatial planning initiatives including creation of marine protected areas and environmental response along the BC coast.

ECOSYSTEM AND CLIMATE CHANGE CONSIDERATIONS

While climate change is an important factor for resource management, this project was not developed to assess impact associated with climate change. These models were designed to produce accurate predictions of species' occurrences, not to assess the causal effects of environmental covariates. Assessment of causal effects would require a different model structure that controls for how the environmental covariates are influenced by each other. Thus, it would not be appropriate to use the estimated species-temperature relationships from these models to make projections of future species and biotope distributions. However, we expect that these biotopes are relatively robust to the changes in climate that are projected over the next few decades because:

1. they are based on presence-absence occurrences which are less sensitive to changes in climatic conditions compared to abundance, and
2. they use environmental covariates for temperature and salinity that have a coarse spatial and temporal scale and so reflect regional spatial differences in conditions rather than changes in local scale environmental conditions.

INDIGENOUS KNOWLEDGE

SCUBA diving was conducted in collaboration with Indigenous partners across the coast whenever possible. This participation added to our expertise and knowledge in the field component of the BHM surveys. If additional work is proposed to augment or add to the biotope model, there could be an opportunity for additional data collection from surveys and incorporation of Indigenous knowledge. Additional users of this framework including Environment Incident Coordinators utilize local Indigenous knowledge to supplement this high-level information.

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