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Setting the stage for marine spatial planning: Ecological and social data collation and analyses in Canada's Pacific waters

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ABSTRACT

Canada's Pacific coast is one region where there is a renewed commitment to pursue marine spatial planning (MSP). The British Columbia Marine Conservation Analysis (BCMCA) project aimed to set the stage for MSP, and was designed to provide resource managers, scientists, decision-makers, and stakeholders with a new set of resources to inform coast-wide integrated marine planning and management initiatives. Geographic Information Systems and the decision support tool Marxan were used to develop two main products: (1) an atlas of known marine ecological values and human uses; and (2) analyses of areas of conservation value and human use value. 110 biophysical datasets and 78 human use datasets were collated and refined where applicable, as identified through five ecological expert workshops, one expert review of physical marine classification and representation, and guidance from the human use data working group. Ecological data richness maps and Marxan results show the importance of nearshore and continental shelf regions. Data richness maps for the six categories of human uses show that all, except shipping and transport, are also closely linked to the shoreline and continental shelf. An example ecological Marxan solution identifying areas of conservation value overlapped human use sector footprints by percentages ranging from 92% (i.e., 92% of planning units selected by Marxan also contain commercial fisheries) to 3%. The experience of the BCMCA project has the potential to provide valuable guidance to regions seeking to jump-start planning processes by collating spatial information and carrying out exploratory analyses.

1. Introduction

Declining marine resources and ecosystem services [1], and evidence that sector-based approaches to management have been inadequate at achieving sustainability [2], have led to increased global interest in marine spatial planning (MSP) [2,3]. MSP is a framework that informs the spatial distribution of marine activities to support current and future uses, and maintain delivery of ecosystem services to meet ecological, economic and social objectives [2]. Complementary literature on systematic conservation planning emphasises the importance of rigorous process, transparency and efficiency (e.g., through setting quantitative targets) throughout the planning process [4,5]. One example of combined systematic conservation planning and MSP is the rezoning of the Great Barrier Reef in Australia, which assigned six different zones, allowing a range of uses, in a region about 350,000 km^2 [6]. Many regions are following suit, instigating systematic MSP processes [e.g., Belgium, 7, California, 8, Australia, 9].

As illustrated in MSP exercises worldwide, a critical component to its efficacy is comprehensive ecological and social data to support the process [2]. Ecological data are necessary to identify areas of importance for biodiversity conservation and delivery of ecosystem services. Data on human activities are useful for identifying areas of importance to marine industries and other uses. The combination of ecological and human use data is particularly valuable in explicitly identifying overlapping interest to multiple users and/or biodiversity conservation, and investigating tradeoffs [8]. Spatial data are also necessary to use decision-support tools, such as Marxan [10,11] or Marxan with Zones [12]. Such decision-support tools can aid MSP by identifying options for areas requiring special management [e.g., marine protected areas, 6], or human use areas [e.g., designated fishing areas, 13].

Canada's Pacific coast (province of British Columbia, BC) is one region where there is a renewed commitment to carry out MSP, also referred to as "Integrated Management" in Canada [14]. In particular, the provincial government is partnering with some

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coastal First Nations to create marine plans, through what is called the Marine Planning Partnership for the North Pacific Coast (www.mappocean.org), and the federal government is working on a planning process called the Pacific North Coast Integrated Management Area. In other areas, such as the west coast of Vancouver Island, MSP has been taking place via local community, First Nations and government partnerships (i.e., West Coast Aquatic, http://westcoastaquatic.ca/plans/). While these initiatives are promising, previous discussions about MSP have been slow to get started, which has significantly impeded progress to date [15–17].

The British Columbia Marine Conservation Analysis (BCMCA) project emerged from the interest of a multitude of stakeholders to set the stage for MSP in British Columbia. The BCMCA (www.bcmca.ca) is a collaborative project designed to provide resource managers, scientists, decision-makers, and those with a vested interest in the marine environment with a new set of resources to inform coast-wide integrated marine planning and management initiatives. Furthermore, the BCMCA project set out to spatially identify marine areas of high conservation value and areas important to human use in Canada's Pacific Ocean. The BCMCA is not a planning process as it does not have the ability or mandate to implement management actions, and it does not seek to replace planning initiatives that are underway or in preparation. Rather, the results are intended to inform and help advance marine planning initiatives in BC by providing collaborative analyses based on the best available ecological and human use spatial data at scales relevant to a BC coast-wide analysis. The BCMCA project is coordinated by a Project Team, comprised of representatives from the Canadian government, BC government, First Nations (self-defined as observers), academia, marine users and environmental organisations, which is responsible for coordinating, organising and implementing the project. The BCMCA project's ecological objectives were to represent the diversity of BC's marine ecosystems across their natural range of variation, maintain viable populations of native species, sustain ecological and evolutionary processes within an acceptable range of variability, and build a conservation network that is resilient to environmental change. The history and approach of the project has been described by Ban et al. [18], and supporting documents can be found online (www.bcmca.ca).

The purpose of this paper is to report the process and results of the multi-year BCMCA effort, and discuss its relevance to BC and beyond. With increasing global popularity of MSP, the impetus for the BCMCA project, an interest by a diversity of stakeholders to set the stage for MSP is likely emerging in many regions of the world. The experience of the BCMCA project has the potential to provide valuable guidance to those regions seeking to jump-start planning processes by collating spatial information and carrying out exploratory analyses.

2. Methods

Geographic Information Systems (GIS) and the decision support tool Marxan were used to develop two main products: (1) an atlas of known marine ecological values and human uses; and (2) analyses to identify areas of high conservation value and areas important to human use. The BCMCA Project Team guided and implemented the methods, informed by ecological and human use experts who provided overarching direction and advice about the collation, use and analyses of data. All data layers were stored, mapped and documented using ArcGIS (versions 9.0–10). Key steps of the Marxan analyses, after data were collated, were to create planning units, develop targets, carry out calibration, run analyses, and draft reports explaining results.

2.1. Collation of existing data

Differing approaches were used to identify ecological and human use data to incorporate in the BCMCA project. Ecological features and datasets recommended by experts via workshops were collated and prepared for use in Marxan. Individual workshops were held for seabirds, marine plants, marine mammals, marine and anadromous fish, and marine invertebrates. Approaches used, and other details of the workshops, are described in Ban et al. [18]. A list of features and datasets to represent the physical marine environment was first proposed by the BCMCA Project Team based on a review of similar projects, then revised following expert review. Once all available datasets for a given feature were obtained, data were collated using GIS and prepared following advice given at the workshops or given by data providers. Checkplots of mapped features and supporting metadata, which documented collation and preparation methods, were reviewed by workshop participants and/or data providers in a comprehensive review process. Review questionnaires asked reviewers to (1) confirm existing target ranges or recommend new values, (2) comment on data collation and preparation methods, (3) comment on the appropriateness of older data, (4) recommend dates of expiry for use of these data in a marine planning context, and (5) make the project aware of additional data sources.

Human use datasets were first sourced by BCMCA Project Team members within each of their organisations (e.g., federally held fisheries data, provincially held recreation data). Example maps were drafted and a review of these data was sought through a two-pronged strategy of group-by-group engagement and the formation of a human use data working group to advise on the collation, mapping and analysis of human use data. Six sectors or categories of human use were identified (i.e., commercial fisheries, recreational fisheries, ocean energy, shipping and transportation, tenures, and recreation and tourism), and a nomination process was held for each sector to self-identify two representatives to participate in the working group. The working group was lead by a neutral facilitator and was designed to be broadly representative of user groups, but participants were not expected to represent a constituency in any formal capacity. The working group held thirteen meetings over almost 2 years. Two of the working group representatives – with the support of the rest of the working group – also participated on the Project Team.

Due to data limitations, it was not possible to create spatial data for some recommended features, while other datasets not specifically mentioned at workshops were developed from available data (e.g., general kelp). While the focus of the BCMCA project was to collate existing data, opportunities arose to create or update some ecological and human use datasets. Known gaps in digital datasets for four ecological features were filled by digitising data (e.g., central coast Marbled Murrelet surveys). For the purposes of the BCMCA, the existing provincial benthic classification scheme was replaced by a new benthic classification developed by Parks Canada using methods published by the Nature Conservancy (TNC) [19]. The benthic classification combined three parameters: (i) landscape features, (ii) depth, and (iii) substrate in order to identify areas of similar benthic characteristics. Human use datasets were reviewed by the appropriate sector and some were deemed outdated or inadequate for marine planning. A comprehensive local knowledge collection project, funded and overseen by the BCMCA, was undertaken through consultation with members of the Sport Fishing Advisory Board to update sport fishing data. BCMCA also undertook work which enabled access to spatial data describing commercial fisheries including Roe Herring, Sardine, and Salmon fisheries. In addition, oil and gas prospectivity data were updated, cruise ship and ferry route data were corrected, and multiple datasets were merged and/or verified with knowledgeable users to develop updated and corrected, coast wide scuba diving, campsite and marine facilities (marinas and other tourism facilities with docks) data. The BCMCA also developed a dataset illustrating areas of interest for ocean energy (wave and tidal) through a participatory exercise at a mapping workshop.

Once all features were compiled and reviewed, maps and descriptive information were combined into atlas pages, available online (www.bcmca.ca). Maps showing the number of features found in each planning unit (i.e., data richness maps) were created for each ecological group and human use sector, counting only datasets designated for use in Marxan.

2.2. Marxan analyses

Marxan (version 2.1.1) was used to identify areas of high conservation value and areas important to human use. Marxan is a free decision support tool that finds efficient solutions to the problem of selecting a set of areas that meet a suite of conservation [10,20] or human use targets [e.g., 13]. Explanations of how Marxan works have been provided in detail elsewhere and are not repeated here (e.g., see the Marxan website http://www.uq.edu.au/marxan/). An expert workshop was held in May 2009, bringing together Marxan practitioners to advise the BCMCA on its proper and robust use and make recommendations related to specific questions posed by the BCMCA (proceedings from the workshop can be found at http://www.bcmca.ca/document-library/). During the Marxan experts workshop, a new tool called Marxan with Zones [12] was recommended for running analyses incorporating human use data. At that time BCMCA decided it was not feasible to use Marxan with Zones due to the learning curve, time constraints and the unproven nature of the new tool. Instead, all the human use scenarios were designed to use Marxan to identify areas important to human use by exploring what happens to the footprint if uses were reduced.

2.2.1. Defining targets

Targets for ecological features are intended to quantify the amount required to meet ecological objectives. At the ecological workshops, experts were requested to recommend a range of targets for each feature, spanning a minimum to preferred amount (see Ban et al. [18] for details). Workshops were attended by regional species experts who drew upon their own experience and knowledge to recommend targets. Targets for physical classification and representation features were proposed by the Project Team and reviewed by experts. During data review, workshop experts and data providers were given a chance to view the collated spatial data, and were asked to review target recommendations and provide targets for any features lacking an established target range. Any targets still missing after the review were systematically assigned by the Project Team. An unanticipated result of asking experts to recommend targets through separate workshops was that values differed greatly among ecological themes (e.g., recommended seabirds targets differed from marine plant targets and invertebrate targets, etc). The BCMCA Project Team decided to illustrate solutions for three added *"What if…?"* scenarios using consistent targets for features in all ecological themes. Target ranges for these scenarios were collaboratively set by the BCMCA Project Team after consulting best practices, peer-reviewed scientific literature and the advice of the ecological experts (Fig. 1). Marxan scenarios were run using low, medium and high target values for both the expert-recommended and Project Team target ranges in order to visually display the impact that targets have on the footprint of the Marxan solutions.

To incorporate human use features, the Project Team initially suggested running Marxan for ecological features, using human uses as a 'cost', as is commonly done in Marxan analyses [21].

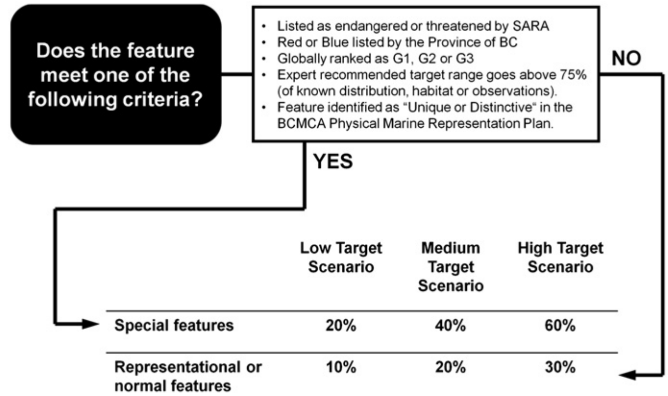

Fig. 1. Criteria used by Project Team to set ecological targets. The flowchart indicates the process used for assigning targets to ecological features (i.e., whether features are special or representational), and the corresponding percentage targets used in the three scenarios.

Alternately, an option was to set targets for human use features, which tells Marxan how much of each feature to include in the solution (i.e., to identify areas of important for all human uses, as per [13]). The human use data working group was introduced to Marxan and ultimately recommended using a range of targets, run through separate Marxan analyses for the six human use sectors: (1) commercial fisheries, (2) sport fishing, (3) ocean energy, (4) tourism and recreation, (5) tenures, and (6) shipping and transportation. The idea of running one combined analysis for all human uses did not receive support from the human use data working group, primarily because of the variation in metrics and quality among human use datasets (i.e. data varied from quantified use, to presence/absence to potential future areas of use), and for this reason was not performed.

2.2.2. Calibration

Calibration was conducted to ensure that Marxan was behaving in a robust and logical manner, following guidance from the BCMCA Marxan expert workshop and Marxan Good Practices handbook [22]. First, the influence of the boundary cost was tested in order to alleviate bias for or against external edges. This test highlighted problems inherent in using two different-sized planning units (nearshore and offshore) in the same analysis and a decision was made to use consistent 2 km by 2 km planning units throughout the study area (for a total of 120,499 planning units). The number of iterations was tested to determine how many were sufficient, such that Marxan consistently produced near optimal solutions. The Boundary Length Modifier (BLM) controls the importance of minimising the overall boundary length relative to minimising the total area of the selected planning units. Increasing the BLM encourages Marxan to select fewer, larger contiguous areas to meet its targets. This parameter was tested in order to fine-tune the degree of clumping present in the Marxan solutions. The Feature Penalty Factor parameter is a user-defined weighting which controls how much emphasis is placed on fully representing a particular input feature in the solution. This parameter was calibrated to ensure that Marxan was adequately reaching its targets for each input feature.

2.2.3. Ecological Marxan analyses

Once Marxan parameters were finalised through calibration, the BCMCA explored a range of "What if…?" scenarios designed to identify areas of high conservation value. Eighteen ecological scenarios were used: High, medium and low target scenarios for the targets set by experts during the workshops as well as those identified by the Project Team. Each of these six scenarios had three sub-scenarios with different BLMs. The best and summed solutions were mapped for all scenarios.

2.2.4. Human use Marxan analyses

Marxan was used to produce a range of solutions for the human use scenarios. In this case, the scenarios were designed to explore the most efficient reduction of footprint for each human use sector. For each of the six human use sectors, five separate scenarios were performed to explore how a range of reductions in each sector's use would affect that sector's footprint. Reduction values of 5%, 10%, 15%, 20%, and 25% were applied resulting in a range of corresponding Marxan targets (95%, 90%, 85%, 80%, and 75%) and a total of 30 unique scenarios. Various metrics were used in Marxan for characterising the human use data. Marxan runs for commercial fishing targeted total catch; ocean energy used a combination of area and relative importance; shipping and transport, and tourism and recreation, used relative intensity; and sport fishing and tenures used area. The best and summed solutions for all scenarios were mapped but are not shown here.

2.2.5. Overlap analyses

ArcGIS was used to identify the per cent of overlap between the six human use sectors and one example solution from an ecological Marxan scenario. The scenario with the Project Team medium targets and medium clump size was chosen for this overlap analysis because it illustrates a middle-of-the-road scenario. For each of the human use sectors, the combined footprint of all uses within each sector was used. Some caveats regarding the footprint data are that they only reflect the mapped footprint (which may or may not represent the most current footprint), and not the relative importance for any particular human use.

3. Results

3.1. Collation of existing data

110 biophysical datasets were collated and refined, where applicable, to create 200 features, many of which were targeted by class or region in the Marxan analyses (see Supplementary Table 1). Reports from each of the workshops were posted online (http://www.bcmca.ca/document-library/). Once the datasets were collated into the recommended features, the features were reviewed by experts. Features, and reviewer comments for each feature, can be found in the online data library (http://www.bcmca.ca/data/).

Seventy-eight human use datasets were collated and refined where applicable (see Supplementary Table 2). These datasets were identified through the process described in Section 2.1 above. Once the datasets were collated into features for each human use sector, members of the human use data working group were provided an opportunity to review relevant features. The purpose of the review was threefold; to identify deficiencies in the data, to identify missing or proprietary data, and to record concerns about use of the data. In some cases features and descriptions drafted for atlas facing pages were circulated to other experts (i.e. people who partake in those uses) for further review; in others (i.e. tenures) no review was undertaken as the data were generally considered accurate. Features, and reviewer comments for each feature or human use, can be found in the online data library (http://www.bcmca.ca/data/).

3.2. Marxan analyses

3.2.1. Targets

Low, medium and high values for ecological targets were identified from the ranges recommended at expert workshops (as described in Section 2.2.1) (see Supplementary Table 1). For the Project Team scenarios, features were split into two categories: representational (i.e., whether the feature represents an ecosystem or species) or special (i.e., higher target warranted if a species has been listed as endangered or threatened, for example, Fig. 1). Representational features were assigned low, medium and high targets of 10, 20 and 30% while special features were assigned targets of 20, 40 and 60%. The Project Team also considered using the footprint – spatial extent – of a feature to determine targets (i.e., so that features covering a large portion of the coast have smaller targets than those with small footprints), but decided not to pursue this criteria because no feature covered more than 14 per cent of the coast, and it would have raised too many additional questions (e.g., Should the % of shoreline linear features be calculated for each ecoregion? Or for the coast overall? What happens if % is high in just one region? How high is too high?).

Human use targets were set based on the human use working group recommendation of conducting analyses where the use declines by 5% for each scenario, and the metric for that use depends upon the sector. Therefore scenarios consisting of these five target values: 95%, 90%, 85%, 80% and 75% were run for each of the six human use sectors.

3.2.2. Calibration

Sensitivity tests uncovered a problem with the initial plan of using two different-sized planning units (smaller nearshore and larger offshore) in the same Marxan analysis. Marxan solutions for runs using a BLM equal to zero, area as cost, and a single feature filling all planning units equally but targeted at 30%, significantly favoured the smaller planning units (Fig. 2). The problem was resolved by using only one size of planning units, although the trade-off was increased computing time. Additional details of how the problem was discovered and solved are provided in the Marxan Good Practices Handbook, Version 2 (Box 8.1) [22].

Other calibration tests included number of iterations, boundary length modifier, and feature penalty. We determined that 750 million or 1 billion iterations effectively and efficiently produced solutions that adequately considered the solution space (Fig. 3A). The ecological runs used 1 billion iterations while the human use runs used 750 million iterations because there were more ecological features than human use features, thus warranting more iterations. The BLM for the ecological analyses was determined by calibration and visual inspection of several options and consensus decision by the Project Team (Fig. 3B). BLMs of 0, 750, and 2500 were chosen to

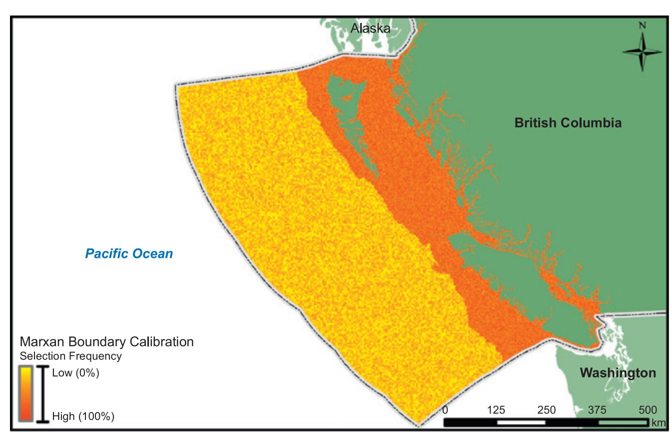

Fig. 2. Illustration of the problem of using two sizes of planning units. The effect was tested with one feature that was distributed across all planning units, with cost reflecting the size of planning units. The smaller planning units located inshore of the continental shelf, 2 km by 2 km, were selected more frequently (redder, darker colours) than the larger 4 km by 4 km planning units located offshore (yellow, lighter colours).

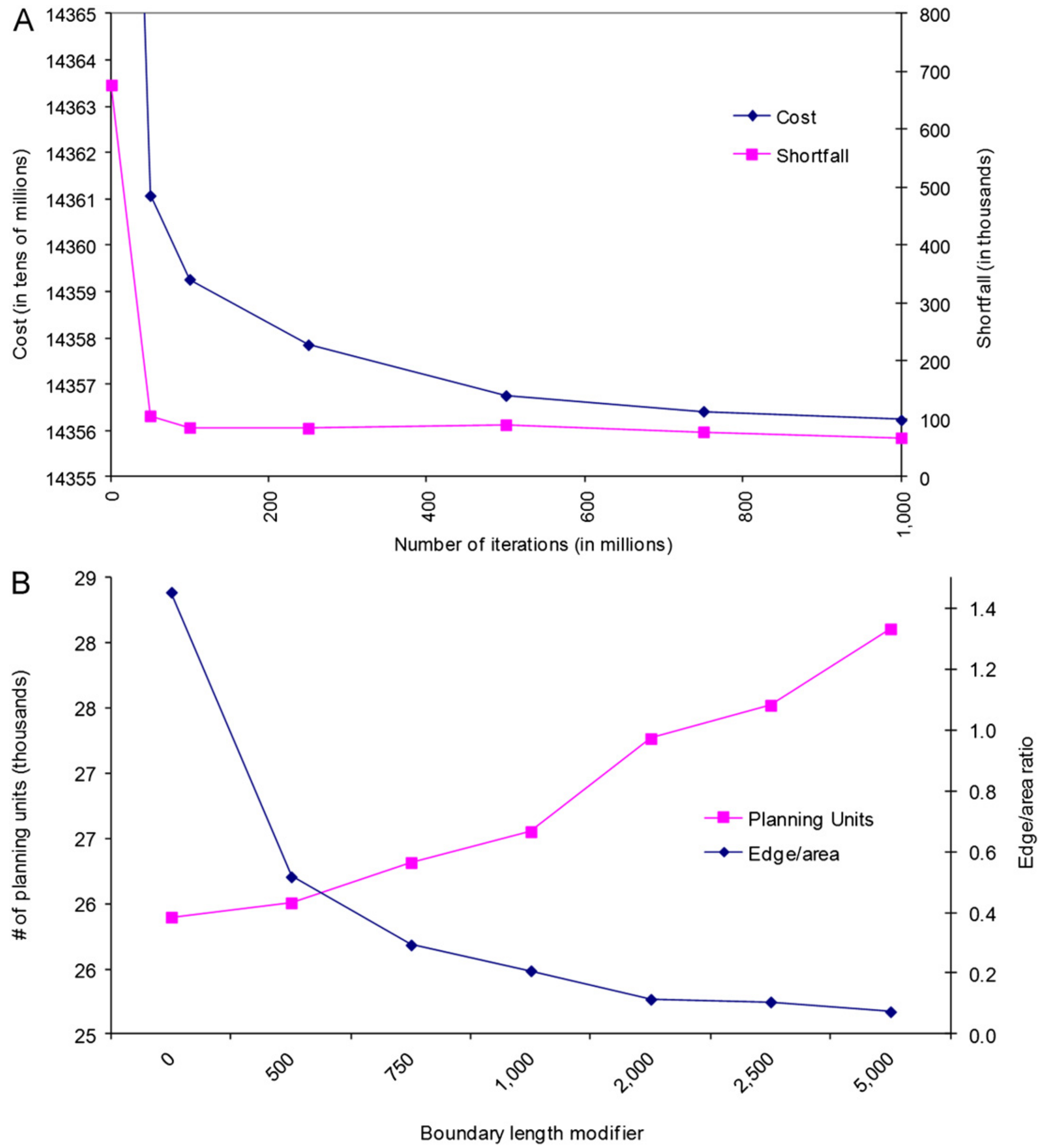

Fig. 3. Calibration used in Marxan. (A) Calibration of the number of iterations needed in Marxan to obtain efficient solutions that meet targets. Results shown are from runs using physical data only (more than 75% of the final features). (B) Calibration of the boundary length modifier (BLM).

illustrate results with no BLM and possible solutions to the range of "What if…?" scenarios that might be recommended by planners. The human use runs used a BLM of 1000, accepted by the human use data working group as the most appropriate BLM suitable for use across all six sectors. A consistent feature penalty factor of 8 was used for ecological features, and 500 for human use features.

3.2.3. Ecological Marxan analyses

Ecological data and Marxan results show the importance of nearshore and continental shelf regions. Overlaying all ecological datasets (i.e., displaying data richness, Fig. 4) shows that much of the available data hugs the shoreline, likely the result of a combination of survey effort and actual elevated biodiversity along the nearshore and on the continental shelf. The various ecological Marxan results – low, medium, and high targets (expert [Fig. 5] and Project Team derived [Fig. 6]) using medium and large clumps – highlight similar areas as being of high conservation value. The results are intuitive: lower targets depict fewer areas as being of high importance compared to

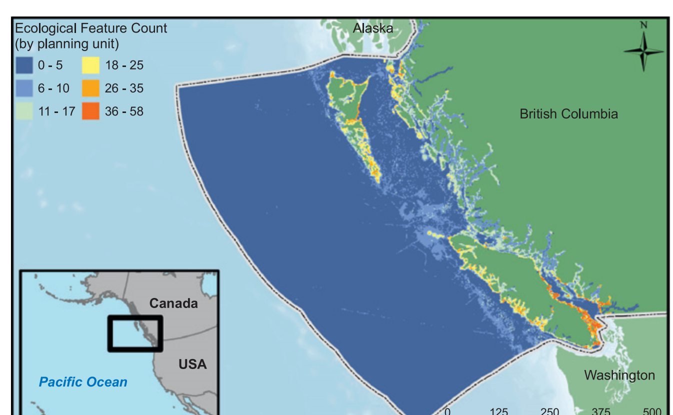

Fig. 4. Overview map and number of ecological features found in each planning unit. Blue colours indicate few ecological features, red colours many features.

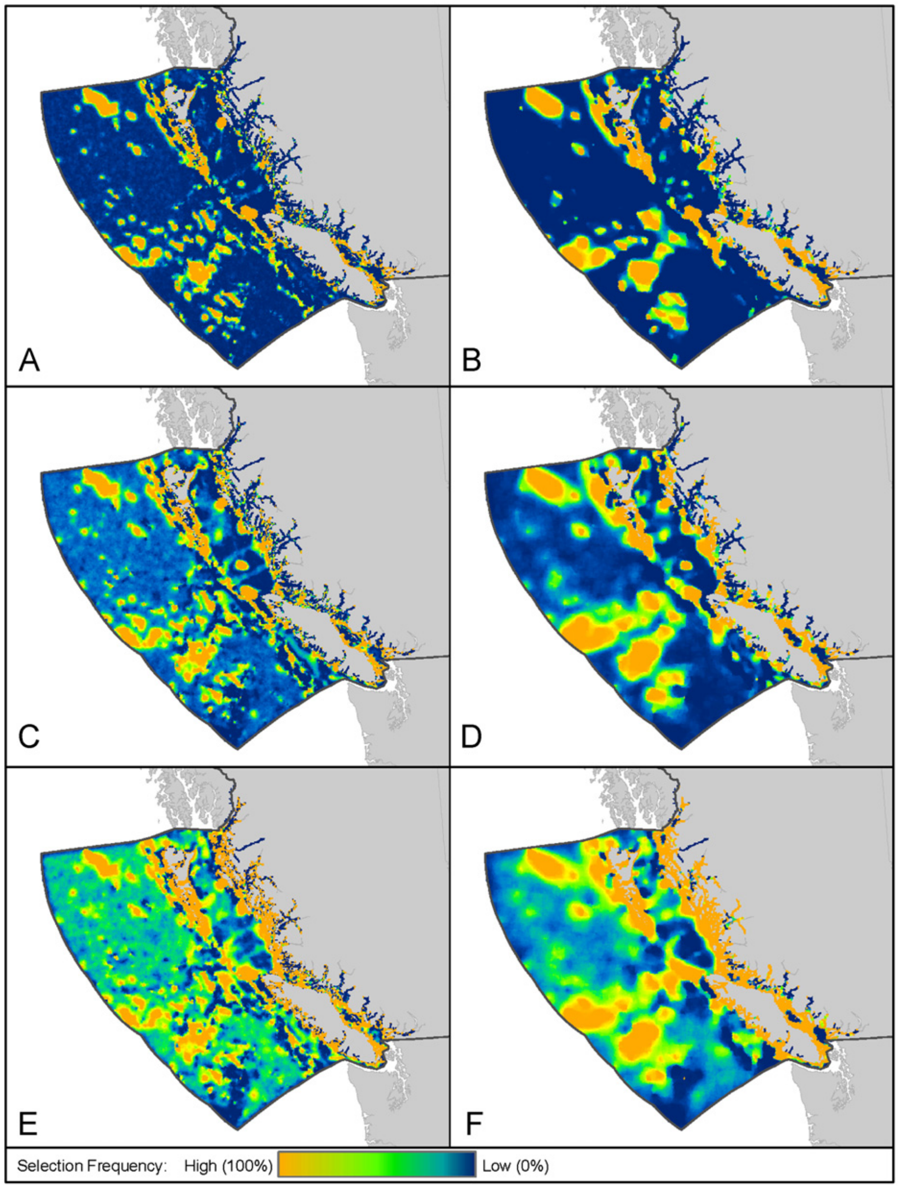

Fig. 5. Selection frequency of Marxan results from ecological runs using target ranges recommended by experts. Blue colours indicate areas selected less frequently in Marxan runs, green colours those with intermediate selection, and orange colours those selected most frequently. The panels show results for the scenarios that used: (A) Low targets, medium clump size. (B) Low targets, large clump size. (C) Medium targets, medium clump size. (D) Medium targets, large clump size. (E) High targets, medium clump size. (F) High targets, large clump size.

high targets, and medium clump size solutions shows smaller areas highlighted than those with large clump size (Figs. 5 and 6). Despite having different target ranges, the expert-set and Project Team-set target ranges (medium, high) show similar patterns and areas as being important for conservation. Targets were met 95% of the time or better. The expert recommended targets ranged up to 100%, and features targeted at this level were underrepresented more often than others.

3.2.4. Human use Marxan analyses

Data richness layers for the six categories of human uses show that all, except for shipping and transport, are closely linked to the shoreline and continental shelf (Fig. 7). As expected, the Marxan results closely mirror the data richness layers, with areas of higher data richness selected more frequently in Marxan. The human use sectors had concerns about the limitations of the input data (see discussion), and did not want the results published; hence the maps are not included.

3.2.5. Overlap analyses

Overlapping the footprint of one example solution of an ecological Marxan scenario with the footprint of each of the six human use sectors showed that all sectors utilise areas that appear in the Marxan solution as areas of high conservation value. The percentage of the Marxan solution that overlapped the sector use footprints ranged from 92% (i.e., 92% of planning units selected by Marxan also contain commercial fisheries) to 3%. Conversely, the area of each sector footprint that overlapped with the example Marxan solution ranged from 18% to 23% (Table 1).

4. Discussion

The BCMCA project's multi-year effort to collate existing data, augment existing datasets by making additional and new data available, and provide examples of Marxan analyses, has made available an impressive resource for marine planners and

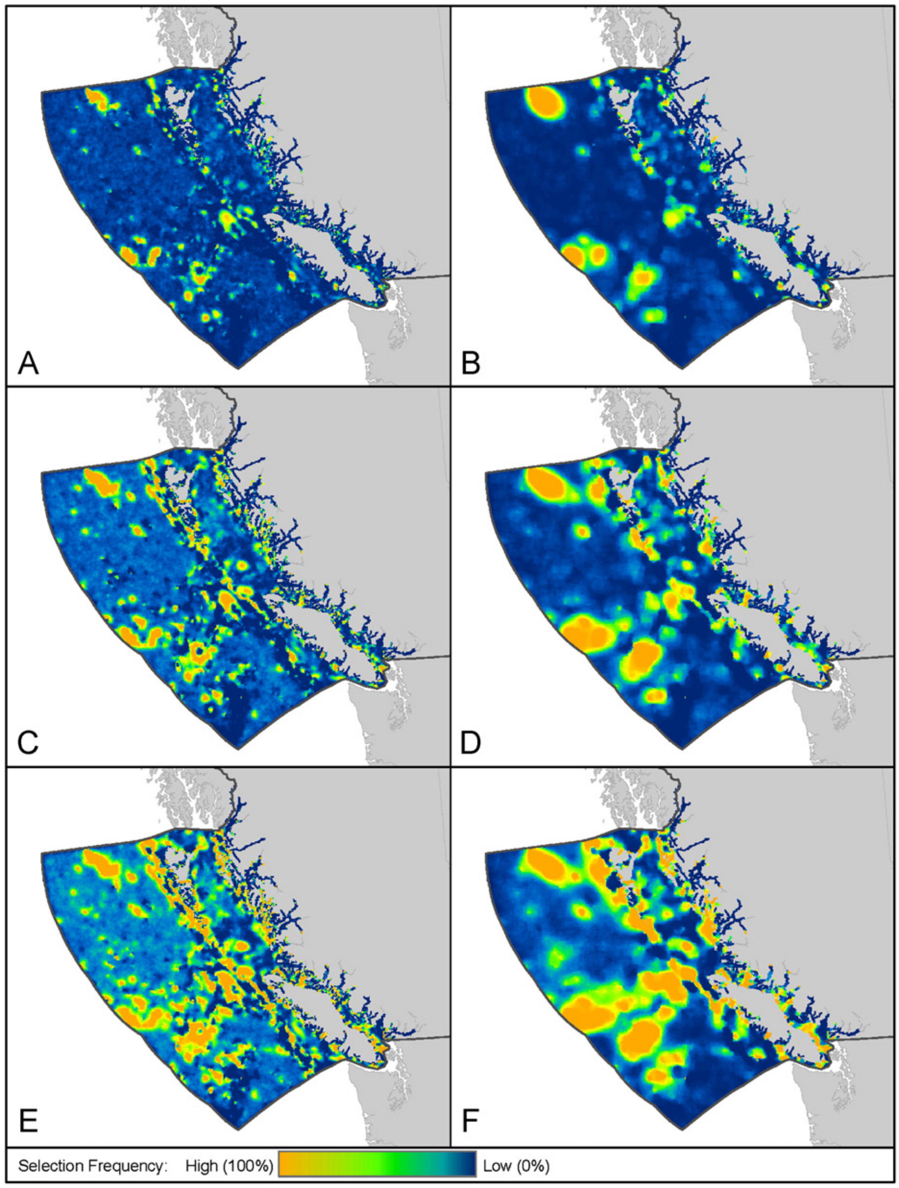

Fig. 6. Selection frequency of Marxan results from ecological runs using target ranges recommended by Project Team (see Fig. 1). Blue colours indicate areas selected less frequently in Marxan runs, green colours those with intermediate selection, and orange colours those selected most frequently. The panels show results for the scenarios that used: (A) Low targets, medium clump size. (B) Low targets, large clump size. (C) Medium targets, medium clump size. (D) Medium targets, large clump size. (E) High targets, medium clump size. (F) High targets, large clump size.

stakeholders in British Columbia and elsewhere. The project attempted to follow best practices for data analysis [22] for not only ecological conservation scenarios, but also for involving stakeholder groups and integrating human use data into analyses [23,24]. These data and supporting Marxan analyses may also have utility for habitat mangers, marine ecologists, oil spill response teams, coarse scale environmental assessments and marine protected area design—all applications beyond the project's intent to support MSP efforts. It provides a successful example of a collaborative effort to move ahead with preparatory work for marine planning without requiring the mandate to carry out the planning, a situation that likely applies to many other regions where marine planning has not been initiated.

While data collation is time-intensive, although relatively straightforward, the experience of the BCMCA project with Marxan analyses highlights several lessons that may be of interest to similar endeavours elsewhere. First, setting conservation targets is notoriously difficult [25,26] and although the BCMCA project's approach of using workshops, organised by ecological theme, provided some good input and advice, it also created several challenges. It proved difficult to get experts to recommend percentage targets for features and, for those that were provided either as specific numbers or as ranges, values differed greatly among ecological themes (e.g., recommended seabirds targets differed from marine plant targets and invertebrate targets, etc). Also, experts tended to recommend very high percentage targets, often 100% for some features, which can skew the results for features with a large spatial footprint and resulted in some feature targets not being achieved in scenario results. Follow-up sensitivity analyses with several increases to the number of iterations did not solve this problem, confirming recommendations not to use 100% target values [22]. As a way around these issues related to expert recommended targets, the BCMCA Project Team decided to illustrate solutions for three

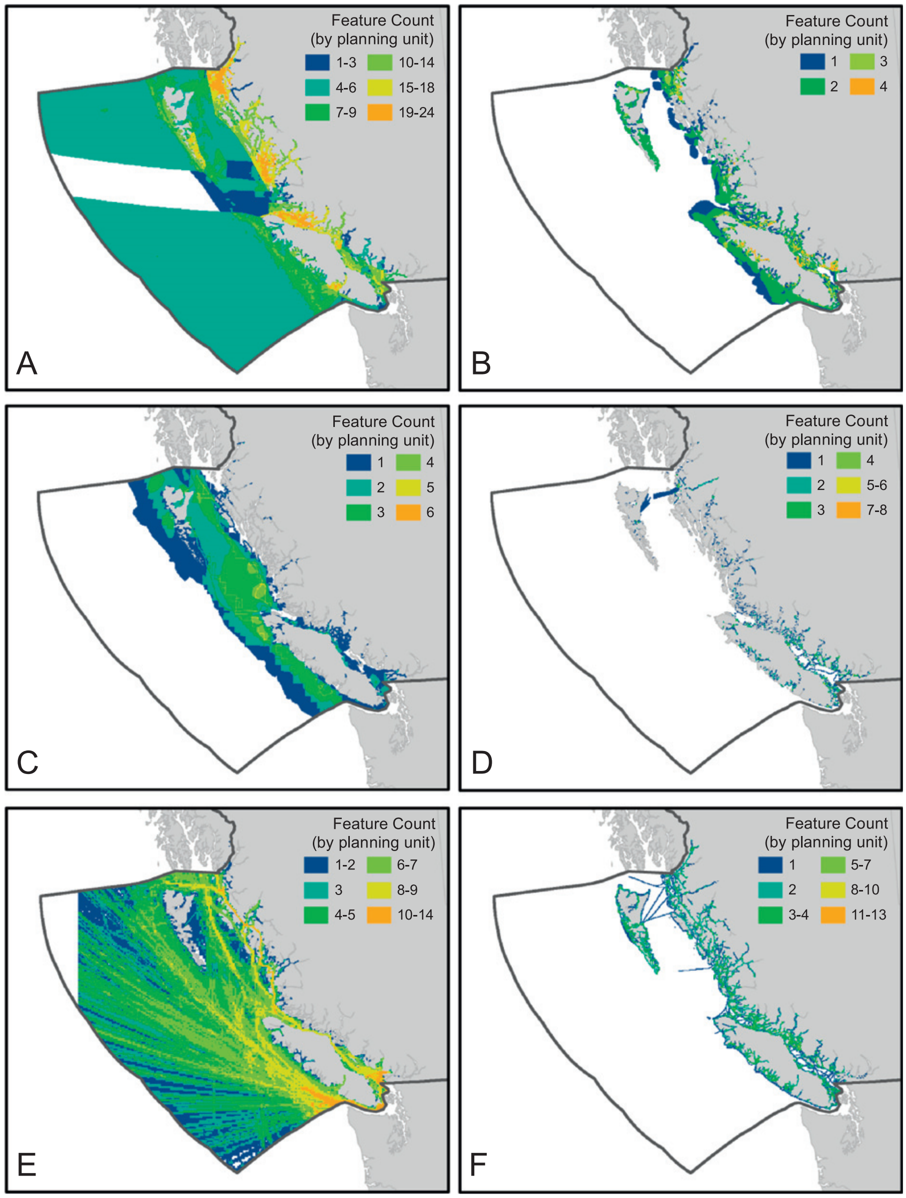

Fig. 7. Number of human use features mapped in planning units by sector. Blue colours indicate few human use features, red colours many features. The panels show feature counts for the six human use sectors: (A) Commercial fishing, (B) sport fishing, (C) ocean energy, (D) tenures, (E) shipping and transport and (F) tourism and recreation.

Table 1
Overlap between human use sector footprints and one example of an ecological Marxan solution illustrating areas of conservation value (Project Team medium target, medium clump size, which selected 22% of Pacific Canada waters).

	Per cent of ecological Marxan solution in sector footprint %	Per cent of sector footprint in ecological Marxan solution %
Commercial fishing	92.10	22.60
Energy	32.66	22.72
Shipping	92.10	22.36
Sports fishing	15.37	22.80
Tenures	2.61	17.53
Tourism and recreation	10.88	23.35

added "What if…?" scenarios using consistent targets for features in all ecological themes. This also served as a sensitivity analysis of the effect of varying the targets, and showed that the results (i.e., the patterns of areas of conservation value) were quite robust to such variations.

Second, the creation of a human use data working group was a key strength of the BCMCA project, but more could have been done to involve human users earlier and more effectively [23,24]. A common recommendation for marine planning and conservation projects is to be inclusive and transparent [2,27–29]. The BCMCA project started with a focus on identifying ecological areas of conservation importance in the marine environment in British Columbia [18], with Project Team members or observers from academia, federal and provincial governments, environmental groups, and First Nations groups (the latter self-identified as observers). It soon became apparent that the input of marine users would be crucial in identifying these areas of importance, and the human use data working group was conceived. However, because marine users were not part of the inception of the project, a fact that could not be changed, they may have felt less ownership of the project than other project team members. It also created some challenges for the desired outputs and the overall scope of the project because some marine users wanted to amend some components. In response, the project team strengthened the terms of reference and clarified terminology based on comments from marine users. Additional time was needed to build the new relationships with marine users within the Project Team. Furthermore, members of the working group had a different background than most of the Project Team, and for this reason a concerted effort was made to introduce Marxan and systematic conservation planning concepts to them. Terminology used in conservation planning did not always directly translate to the day-to-day lexicon of members of the working group, highlighting the importance of regular, two-way communication. A facilitator, independent of the process, was hired to ensure the working group process was meaningful to participants, that all participants' input was obtained, concerns recognised, addressed where possible, and documented where they could not be addressed.

Third, experts, including human use sector representatives, were crucial to identifying the limitations of existing human use data for use in Marxan, and data gaps. Challenges are similar for ecological and human use data. For example, some species distributions and human uses are seasonal, and where spatially explicit seasonality data are missing, Marxan results do not capture such nuanced information. Similarly, some areas may be particularly important for some species or human uses (e.g., spawning grounds, shipping traffic to small communities, fishing areas close to communities), but this level of detail may not be represented in available data. Thus, although analyses were designed to identify areas important to ecosystems and human users, with little or no relative value information in the data sets, Marxan uses data density to determine areas of importance. Another data limitation is that the time period over which data were originally collected was not consistent. Some data are older, even though they may be the best-available data, and data sets for different features used in a single analysis may have been compiled for different time periods. Furthermore, data illustrated for some features may not reflect current or future reality in terms of the various measures of relative importance. Both ecological and human use features shift spatially over time due to ongoing changes in the environment and management. Thus feedback from the human use sectors was that the Marxan results for human uses were of limited value, and may not represent actual areas of importance.

Fourth, as highlighted in the Marxan Good Practices Handbook [22], the BCMCA project found that calibrating parameters in Marxan and documenting and communicating data limitations was crucial. Calibration uncovered problems with the external edges and the use of two sizes of planning units. Without careful calibration, the analyses would not be robust, and the results might not have represented areas of conservation value. Similarly, because such a project involves a vast amount of data and numerous data providers, clear and transparent documentation of the limitations of each dataset is very important. Without this, the integrity of the project and its results could be compromised. One of the particular strengths of the BCMCA project's atlas is that it pairs each map with a facing page that documents details of the data sources, limitations, and any other comments noted as important by peer reviewers of the dataset(s) illustrated on the map.

Fifth, unfamiliarity with Marxan was an obstacle, but a surmountable one. Education about Marxan, how it works, what it does, and what it is used for, was necessary with most participants—e.g., ecological experts, data providers, government employees, non-profit groups and marine users. Much effort was put into educating participants about this tool and its potential uses and limitations. An ancillary benefit to the marine based community in British Columbia is a better understanding of Marxan, both its strengths and limitations. This may prove useful for marine planning processes in the future.

Finally, while the BCMCA project was made possible in part because of the commitment and dedication of many people who volunteered their time, having adequate funding ultimately made the project possible. Some groups needed funding to participate, workshops cost money, GIS contractors were needed for preparation of the many datasets, and so on. Thus, while volunteer efforts can go a long way to instigating a data collation and analysis project, to realise its full potential, the BCMCA required financial resources to be completed.

Ultimately, one of the most important benefits of a project such as the BCMCA is the development and maintenance of working relationships among stakeholder groups. As shown by the exploratory overlap analyses, marine areas of conservation value in the Canadian Pacific are also important to a variety of stakeholders. The process that the BCMCA project developed – including development of a Project Team, human use working group, user group outreach, presentations to planners – served to get parties to work together, strengthen relationships, raise awareness about the need for data collation and analysis, and educate marine users and others on the value of quality data and Marxan analyses. Communication with collaborators was a part of the project throughout. Such benefits are difficult to substantiate, yet anecdotal feedback from participants indicates that communication and collaboration among stakeholders has improved because of the project, and that the BCMCA's data products are in high demand.

This project affirmed the importance of several issues discussed in the marine spatial planning and conservation planning literatures. Involving stakeholders early in the process is important for their support for the project [23,24], but it is also difficult to conceive a project with all stakeholders involved—a conundrum that most planning processes are faced with [7,9,15,30]. Having good data is important for achieving quality analyses, but much more emphasis exists in the literature on how to incorporate ecological than social data [2,3,23]. Ultimately, the acceptance of any project's analyses – and the BCMCA's in particular because the project itself does not have an implementation mandate – depends upon acceptance by stakeholders, which is partly influenced by the process followed and the quality of the data and analyses.

5. Conclusion

The BCMCA project has been invaluable in supporting MSP initiatives in British Columbia. The BCMCA project has received additional funding for a period ending May 2013 for product support, updates to select datasets, and support (if requested) to marine planning processes that are now underway. Additional communication and outreach are also planned to help people understand and build trust in the data products and supporting analyses. Furthermore, the Project Team is interested in exploring tradeoffs and win-win solutions for human uses and conservation. The simple overlap analyses reported here were illustrative only; more sophisticated and informative analyses would be useful. For example, possible use of a sister tool of Marxan, Marxan with Zones [12], to develop trade-off curves between different human uses and ecological features, is under discussion. This is one way to explore analysing and visualising overlap amongst users and between human uses and biodiversity hotspots.

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Appendix A. Supplementary Information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.marpol.2012.10.017.

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