Final Report

BC Marine Conservation Analysis (BCMCA)

Pacific Marine Analysis and Research Association (PacMARA)

Marxan Workshop

Workshop Proceedings Report

May 26, 27th, 2009
University of British Columbia
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1 Introduction

1.1 Marxan Workshop Overview and Objectives

The BC Marine Conservation Analysis (BCMCA) is assembling the best available information regarding Marxan analyses as it relates to the BCMCA project. To support this work, the BCMCA and the Pacific Marine Analysis and Research Association (PacMARA) jointly hosted a Marxan workshop May 26-27 2009 at the University of British Columbia, Vancouver B.C.

The workshop was attended by 29 invited experts and observers from Australia, Alaska, California, Oregon, Washington, Colorado, Washington DC, Victoria and Vancouver. The attendees included government staff, university researchers, graduate students, NGO staff, Marxan consultants, professional economists and climate change scientists. Attendees participated in one of three workshop sub-groups (robust analysis, human use, climate change) and periodically reported back on their progress during plenary sessions.

The intent of the workshop was to draw on the knowledge and experience of Marxan experts representing a broad spectrum of application users and researchers. More specifically, the workshop had five objectives:

1. Assess and report on the applicability of the Marxan Good Practices Handbook (MGPH) for the BCMCA project.
2. Encourage the use of good Marxan practices in BC in order to support ecosystem-based management and an integrated management approach.
3. Discuss and develop guidance on sections of the MGPH that currently do not provide sufficient or clear guidance.
4. Obtain expert guidance on proper and robust use of Marxan, specifically for the BCMCA project.
5. Obtain guidance on the robust development of cost layers (e.g., human uses) and how to best use Marxan's cost function to achieve BCMCA's scenario objectives.

Expected products from the workshop were:

1. A workshop report (this document). The report details expert recommended Marxan-related advice for the BCMCA to consider in conducting Marxan analysis. Content is organized according to the three break-out groups from the workshop: climate change, human use, and robust analysis. The report also contains feedback and advice on gaps in and improvements for the MGPH, which PacMARA will consider when updating the handbook.
2. Information and material from which members of the BCMCA Project Team will document how the MGPH contributed to the BCMCA use of Marxan. This material will contribute to documentation of the BCMCA as a Marxan Good Practices case study.

The anticipated audience for the workshop report are those who are familiar with the use of Marxan and conservation planning theory and who wish to explore good practices around employing robust Marxan analysis or incorporating human use and socio-economic data in a Marxan analysis. Those interested in proposed ways to take the uncertainties related to climate change into account in Marxan analysis may also find value in this report. Some of the recommendations found in this report will be tested and applied during the BCMCA analysis, which will act as a case study for good practices in the use of Marxan.

1.2 BCMCA Project Background

The BC Marine Conservation Analysis (BCMCA) is a collaborative, BC coast-wide project that is assembling and analysing map-based data that can support marine planning initiatives in BC, without advocating any particular planning outcomes. The overall goal of the BCMCA is to identify marine areas of high conservation value and marine areas important to human use.

There are several marine planning initiatives underway or in preparatory stages in BC. The BCMCA project does not seek to replace these processes. Rather, the BCMCA will develop products that illustrate the spatial distribution of biological, ecological, oceanographic and human use values in BC's marine environment in order to inform discussions and decisions made within these planning initiatives.

The data assembled by the BCMCA will be used to create two products:

- An atlas that illustrates known biophysical values and human uses in Canada's Pacific Ocean. This atlas will be created from existing best available mapped data. Its purpose is to illustrate aspects of marine biology, ecology, oceanography, and human use relevant to a coast-wide scale.
- A set of results from analyses using the Marxan[1] decision support tool. Results will be documented from a range of scenarios, each with different sets of explicit objectives which inform the values put into Marxan parameters. Broadly, the analyses will apply marine reserve theory to identify areas that would help represent BC's marine biodiversity while minimising overlap with areas important for human use.

Biophysical maps will illustrate the distributions of marine invertebrate, fish, mammal, plant, and bird species, as well as physical marine and oceanographic features. The human use maps will include marine areas important for commercial fishing, recreational fishing, shipping and marine transportation, energy exploration and development, recreation and tourism, and marine tenures such as aquaculture or log handling sites. Data will be gathered from existing sources and reviewed by experts and, for human use data, those whose interests it represents. The data will then be analysed and shared to the extent permitted by data sharing agreements with data providers.

Beginning in the fall of 2006, the BCMCA held a series of workshops in order to assemble the best available biological, ecological, and oceanographic data for the coast. Scientific experts were invited to the workshops to identify these data and make recommendations on the parameters for Marxan analyses. The BCMCA is now collecting and processing those data, preparing features that will inform the atlas and spatial analyses. Reports summarising experts'

[1] www.uq.edu.au/marxan/

feedback are available at the BCMCA website (www.bcmca.ca). All reports undergo the experts' review before finalisation.

The BCMCA is also assembling human use data and considering how best to incorporate the input and needs of different user groups into the BCMCA process. To help ensure user groups' input is addressed, the BCMCA has met with representative organisations and advisory boards.

1.3 PacMARA Background

The Pacific Marine Analysis and Research Association (PacMARA) acts as a catalyst for collaborative research and analysis, informing marine policy based on impartial evidence from the marine community. The organization takes an impartial, non-advocacy approach to ocean and marine planning because access to data, good science, and clear results are the heart of sustainable oceans management. PacMARA hosts international workshops on policy, management practice, marine science and the use of planning tools based on case studies. PacMARA facilitates interaction and collaboration between neighbouring and overlapping jurisdictions, and assists in the planning and implementation of an Ocean Information Management System, within the auspices of the Canada BC Ocean Coordination Committee (OCC) working group. PacMARA aims to create relationships within the marine planning community.

PacMARA also provides training and support in the use of marine spatial planning tools and best practices for ecosystem-based management (EBM) to address challenges in coastal environment management. PacMARA's goal is to develop, facilitate and encourage multi-disciplinary marine science grounded in ecosystem-based decision-making. The organization works for British Columbia's marine community of practice by addressing common issues and leveraging shared opportunities.

PacMARA represents the marine community through its dynamic and inclusive Board of Directors, with directors who work for the Government of Canada, Province of British Columbia, academia and non-governmental environmental groups. PacMARA has over 150 members from government, First Nations, academia, environmental non-governmental organizations and the consulting community.

Since its inception in 2003, PacMARA has completed a number of highly successful workshops and projects, detailed at www.PacMARA.org. PacMARA's recent focus has been on the development of good practices in the use of marine planning tools. PacMARA hosted an international four-day workshop, attended by over 100 delegates to discuss issues common to such tools, which resulted in PacMARA leading the writing of a Good Practices Handbook for Marxan - the most commonly used marine spatial planning tool – and a fully revised Marxan User Manual (in English and Spanish) jointly published with the University of Queensland Ecology Centre (Australia). This workshop is a continuation of PacMARA's support of good marine spatial planning practices.

2 Robust Analysis Breakout Group

2.1 Participants and Observers

Participants

Dave Nicolson: Moderator	BCMCA - Plenary lead	BCMCA Project Manager
Jason Thomson: Note taker	BCMCA - Workshop logistics	BCMCA Project Assistant
Charles Steinback	Ecotrust	Director of Marine Planning
Dan Dorfman	Intelligent Marine Planning	Consultant
Dan Kelly	The Nature Conservancy, Oregon field office	GIS analyst
Grant Humphries	University of Alaska	Graduate Student
Jeff Ardron	Marine Conservation Biology Institute	Conservation Oceanographer, High Seas Program Director

Observers in attendance

Greg MacMillan	Parks Canada - BCMCA Project Team
Karin Bodtker	Living Oceans Society - BCMCA Project Team (co-chair)
Krista Royle (1/2 day Tuesday)	Parks Canada - BCMCA Project Team

2.2 Goals and Overview

The goal of this group was to help ensure that the BCMCA Marxan results are as defensible as possible and will stand up to a peer review process.

2.3 Breakout Group Discussion Points

1. Review plan of sensitivity testing based on the MGPH recommendations. Are any sensitivity tests missing? Are any unnecessary?
2. Review preliminary sensitivity testing results and preliminary decisions about final parameters.
3. Discuss how to address data gaps and presence-only data.
4. Discuss how to deal with missing features or partial coverage of features.

In general, the Robust Analysis breakout group felt that the MGPH covers the topic of sensitivity and robust analyses relatively well. To be more effective, it could explore the topics of collection, collation, and pre-processing data for use in Marxan, and elaborate on calibration techniques. In addition, the handbook should acknowledge the reality that there are often multiple approaches or methods for each calibration test. Based on the above stated goal and discussion points, the Robust Analysis breakout group recommended improvements to the MGPH and advice to the BCMCA on a number of topics outlined below.

2.4 Recommendations related to Planning Units

<u>BCMCA planned approach:</u> The BCMCA has committed to using two different sized planning units (PUs) in the same Marxan analysis. Nearshore PUs will be 2x2 km and offshore PUs will be

4x4 km. The division between the two different sized PUs is the toe of the continental slope. The baseline scenario uses area for cost. There is little data representing conservation features in the 4x4 PUs. To ensure the Marxan output is stratified across the entire study area, one of the features is a percent of the 12 ecosections that constitute Canada's Pacific Waters. The combined total number of PUs is over 61,000.

The MGPH (Section 7.8) suggests "Planning units should generally be of a consistent range of sizes to avoid variable unit problem biases." The Robust Analysis break-out group provided the following comments on the pros and cons of the BCMCA approach:

- To date, there are a limited number of documented projects that have used two uniform sized PUs in the same Marxan analysis.
- Marxan was not designed to handle two different sized PUs in the same analysis.
- Two different sizes of PUs can create biased results because of the way Marxan treats planning unit and boundary cost. One PU size may be preferentially selected.[2]
- The differences between the two PU sizes can be addressed by varying the base cost (e.g., area) and/or the boundary cost. Marxan must be calibrated and costs (PU and boundary) normalized to ensure that the larger and smaller PUs are treated equally. Recalibration (e.g., determining optimum values for BLM, external boundary, etc) is required every time there is a change to one of the input parameters and this recalibration is more complex with 2 or more PUs.
- It is critical to understand what data sets (conservation features) straddle different PU sizes. There may be more Marxan output issues associated with species distribution data (e.g., bird forging habitat) than with representative data (e.g., benthic classes). If the features do not straddle the different sized PUs it may be better to conduct two separate analyses and then combine the results. Marxan technicians could combine the results internally as part of the analysis process before presenting to a broader group.
- If there is a distinct boundary between the input features, it may be best to modify the PUs so the large and small units follow the natural boundaries of the input data, rather than the current division (the toe of the continental slope). Boundaries of existing planning initiatives (e.g., PNCIMA) could also be considered as dividing lines for different sized PUs.
- By working with the boundary cost (altering the boundary lengths between the large and small PUs), it may be possible to get a seamless interface between the large and small PUs in the Marxan analysis outputs.
- The boundary length cost and/or PU cost needs to be proportionately reduced in order to obtain a seamless interface between the two PUs. The BLM works best when there is a consistent area to perimeter ratio among the different sized PUs.
- Can the data support using a 2x2 km grid throughout the study area? This may result in oversampling some data and create computational challenges due to the number of PUs required to cover the BCMCA study area.

[2] In calibration tests for the BCMCA, smaller PUs were consistently selected where each PU contains the same feature. This bias was encountered both with and without an assigned boundary cost.

- If the BCMCA wishes to use two different sized PUs, they need to document the break-point between the two sizes. One recommendation was that the change in PU size occur at the point of the greatest rate of slope change at the edge of the continental shelf.
- There was a clear preference among the group to conduct the analysis using a single size of planning unit, unless there were computational reasons or clear data benefits to using multiple sized planning units in one analysis.

<u>BCMCA question on planning units at the edge of the study area:</u> The BCMCA PUs are grid cells. As such they partly fall on land and water along the coast, and also cross the 200 nautical mile study area extent. Spatial data informing the conservation features follows several different versions of the coastline but does not extend beyond the 200NM limit. Should the BCMCA clip the PUs to a coastline and/or the 200 NM limit? Not clipping the PU would mean these PUs contain relatively smaller amounts of a feature and have a higher cost than other nearby PUs fully inside the study area, thereby predisposing them to be excluded from solutions (assuming features are quantified into PU in terms of areal extents rather than presence/absence).

Options presented by the Robust Analysis break-out group included:

- Leave the PUs intact – do not clip to the coastline, particularly if several coastlines were used to compile features.
- Erase all PUs that extend beyond the edge of the study area.
- Populate the entire "edge" cells with the feature(s) that are recorded in parts of cells included in the study area (if features are quantified into PU in terms of areal extents).
- Populate the feature with data from adjacent jurisdictions (Washington State and Alaska).
- Apply a formula to balance the abundance of features within the PU according to how many could have been there – the square root of density times abundance, for example.[3, 4] For presence / absence data:

$$\text{HexScore}_{f(\text{presence})} = \sqrt{((\sum f)^2 / (2\,N_f))}$$

  - Where f is the feature occurrence (presence = 1, absence = 0); thus $\sum f$ is the sum of all feature cells;
  - And N_f is the total number of possible feature cells –which is usually the same as the total number of water cells.

Another way to state this is: $\text{HexScore}_{f(\text{presence})} = \sqrt{(\Sigma f * f_{mean})}/2$

  - Where f_{mean} is the mean value of that feature, wherever there is water. For presence data, this is the same as density as discussed above.

[3] This was done in an analysis by the Living Oceans Society for the Coast Information Team in 2003: http://livingoceans.org/_pvwC21CD930/files/PDF/mpa/CUA_05a.pdf.

[4] See Ardron, J.A. 2008. Modelling Marine Protected Areas (MPAs) in British Columbia. Proceedings of the Fourth World Fisheries Congress: Reconciling Fisheries with Conservation. American Fisheries Society.

2.5 Recommendations related to specific aspects of the calibration / sensitivity testing

The following questions were posed to the Robust Analysis sub-group: What should be tested first – BLM, SPF or # of iterations? After a value has been set for one of those variables, do they need to be re-tested when the next variable is selected? Are there sensitivity tests beyond MGPH Ch 8 that can be recommended? Their responses, organized by issue/question/topic are found below. Advice is intended to inform the BCMCA analysis and improve the MGPH.

Issue/Question	Discussion points and recommendations
Number of Iterations	• The MGPH is not clear on how to identify the optimal number of iterations. • Two steps for iterations: 1. rough calibration to ball-park number of iterations for testing other settings, then; 2. fine tune the number of iterations when other settings are finalized. • Optimal number of iterations will depend on number of PUs, number of features, distribution of features (widely distributed or rare). • For BCMCA recommended starting testing at 50 million iterations. • Use of Marxan's verbose mode will allow the operator to identify where the score is constant (point of no change in cost) – that is the point where the number of iterations is adequate. • It is better to show the point of no change graphically. Plot the number of iterations against score/cost on a graph (XLS). Zonae Cogito has a tab to assist in testing for calibration (although not for testing the number of iterations). • Although having more iterations than necessary will require extra computer processing time it is better to have more iterations than the minimum point where cost is constant. In terms of the dollar cost to conduct a Marxan analysis, the cost of computer time is minor compared to the cost of gathering data for analysis.
Boundary Length Cost / External Boundaries	• It was recognized that the ability to adjust boundary length cost is underutilized in many Marxan analyses. Practitioners most often adjust the PU costs as a way to compensate for the differences with PUs close to a shoreline (compared to other PU) but adjusting boundary length cost is another method. • May be necessary to treat the external boundary on the terrestrial edge of the study area differently than the external boundary at the seaward edge (200 NM limit) when calibrating to minimize the edge effect (Marxan being drawn to or avoiding the edge of the study area). No techniques were offered on how to treat these two external boundaries differently. • Adjust external boundary length cost to eliminate edge effects. Some reviewers disagreed that an edge effect would be observed along a coastline as there are many other factors in the objective function impacting the outcome of an analysis. The effect may be noticeable with one or two features but "wash out" when many features are used.

Issue/Question	Discussion points and recommendations
	• In work conducted on the BC Coast[5], Natalie Ban encountered results that were biased towards or away from PUs on the outer boundary of her study area (PUs not adjoined by other PUs on all sides). The problem was particularly noticeable in complex study areas where the perimeter is large compared to the area (e.g., coastlines with fjords) or where there is an absence of features in PUs on the outer edges of the study area. Ban recommended conducting a test with one feature uniformly distributed in the study area. Check to see that a random selection of PUs across the study area are selected for inclusion in the Marxan results; adjust the external boundary costs until this criteria is met. • Ardron documented a method for the CUA (http://livingoceans.org/_pvwC21CD930/files/PDF/mpa/CUA_05a.pdf). This technique employs a non-parametric relative method whereby PUs in different areas (e.g., inlets vs. passages vs. open ocean) have different boundary costs, with the passage boundary cost being the standard. This creates different sized clumps in different areas in one Marxan result, while using one BLM value. This concept has also been documented in a Master's thesis by Munro (http://circle.library.ubc.ca/handle/2429/17789).
Species Penalty Factor	• It was recommended that the BCMCA start out using a consistent SPF for all features, calibrated to be in the same order of magnitude as PU costs. • It is possible to use the SPF to make Marxan more efficient (e.g., "tweaking" to achieve more efficient solutions that better meet all objectives). • Adjust the SPF to get a balance of target achievement that is desired and to balance the amount of data (number of features) relative to each ecological group. It may be very 'costly' to achieve the final 10-15% of the targets. BCMCA could run tests to determine how much of the cost of a Marxan solution comes from achieving the last 15% of targets and use the SPF to tweak the Marxan output. • BCMCA representatives present indicated they would prefer not to adjust the SPF for individual features out of concerns that this would in effect be weighting features – a surrogate for importance. However others noted that weighting had been applied through setting targets and a higher SPF for features with high targets may be considered. This is recommended in the MGPH (Section 5.6). • Rule of thumb for assigning the initial flat "all-PUs-are-equal" SPF: use a value approximately that of the mean numeric value of the PU cost. Mathematically what Marxan requires are numbers in the same general range.

[5] See Ban, N. 2009. Minimum data requirements for designing a set of marine protected areas, using commonly available abiotic and biotic datasets. Biodivers Conserv (2009) 18:1829–1845.

<table>
<tr><th>Issue/Question</th><th>Discussion points and recommendations</th></tr>
<tr><td>Planning Unit Cost[6]</td><td>Calibration of PU cost was not discussed but the following information was offered relating to PU cost:
Distance from port can be incorporated into PU cost when considering marine use – farther from port has a higher cost for human use and may be therefore of lower cost for conservation.
Generally coastal areas have a higher cost of conservation than non-coastal areas because of the number of activities.
Length of shoreline and/or some sort of rugosity measure (e.g., fractals) can be used to create a cost for coastal PUs.
Rule of thumb for assigning PU cost that is not based on area: equal to a value between the area of the PU and 5 times area.
Zonae Cogito has some tools to help calibrate PU cost.</td></tr>
<tr><td>Order of Calibration</td><td>There is no unanimously recommended order for calibration; each expert user of Marxan seems to have developed a method that works for them.
Participants agreed the following order would provide suitable calibration:
1. Iterations (1st time-rough),
2. BLM,
3. Species penalty factors (SPF), and
4. Iterations (2nd time – considering the BLM and SPF that have been set)
For recalibration, tweak in reverse order.</td></tr>
<tr><td>Need to recalibrate</td><td>When you change the number of species or features in an analysis do you need to recalibrate?
Depends… need to at least do the fine scale calibration – look at targets achieved and adjust SPF until you reach the desired balance of targets achieved vs. total cost. (May need to increase iterations to achieve this.)
If the PU cost is changed, recalibration will usually be required, though it often can be fairly quickly done.
If more features are added, more extensive recalibration will be required.</td></tr>
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2.6 Recommendations for data normalization

The MGPH would benefit from a discussion on the benefits of, and transformation techniques for, data normalization. There are multiple approaches, although not all participants agreed that each method discussed was necessary or effective. In the MGPH, transformation techniques could be discussed in a broader section on methods for turning collated datasets into Marxan files. Although data collation is discussed in the MGPH, how collated data sets get quantified into PUs and represented in Marxan input files is not well documented. The use and application of normalizations/transformations is dependent on what conservation question one is trying to

[6] Many Marxan practitioners use socio-economic considerations to determine cost – see Section 3 of this report. Other information on PU Cost has been included with other issue/question topics.

answer. Marxan analysis conducted by Ecotrust in California addresses scientific guidelines for data collation and normalization within current policy.[7]

There may be advantages to normalizing data when working with issues of scale (e.g., differences between large and small estuaries). Normalizations will occur at the data preparation and pre-processing stage, when features are quantified into PUs.

A number of methods can be employed. Reviewing histograms and the distribution of the data will help inform which method is most appropriate (e.g., square root, standard deviation, log transformations, or natural breaks).

Discussions around adjusting the external boundary costs (see pp7-8 above) led to a discussion on fitting coastal data to PUs. A data normalization technique was presented that can be used even if different coastlines were used to map different datasets. The benefit of this normalization is that the noise of different coastlines is removed. In the example given at the workshop, a feature measure is quantified as the ratio of the actual amount of the feature in the PU versus the total amount that *could be* in the PU (e.g., amount of shoreline or marine waters contained in the PU). It was noted that most Marxan analyses use the actual value or areal extents of a feature rather than a proportional value.

Another topic not addressed in the MGPH was interaction at the land-sea interface. Should you conduct Marxan analyses using terrestrial and marine data in the same analysis? Do the results naturally bias towards the intersection of marine and terrestrial data? The group felt that it would be beneficial for the MGPH or a research paper to delve deeper into the discussion of how to address the land-sea interface. Because this topic was out of scope for the BCMCA, it was acknowledged but not discussed further at the workshop.

2.7 Recommendations for targets and features

Question	Responses
Chapter 4 of the MGPH discusses setting targets based on ecological objectives. The BCMCA has set some broad ecological objectives, but for many conservation features there is no consensus among the experts on a target or even a range of targets. And even for those features with targets, the targets may be based mostly on best guesses. Aside from running a number of analyses for each scenario	• Experts not providing a target range is not the same as experts saying not to set a target for a feature. • MGPH recommends setting targets in a relative manner for those features without expert-recommended targets. Compare features without recommended targets to those that have recommended targets and look for similarities to assign targets. • Hugh Possingham and others have spoken out against using an additive scoring system to set targets for features, since five 1s is seldom the same as a single score of "5."

[7] See for example
http://www.uq.edu.au/spatialecology/docs/Publications/2008_Klein_etal_EffectivenessOfMarine.pdf; http://www.ecotrust.org/mlpa; http://www.dfg.ca.gov/mlpa; http://www.hd.gov/HDdotGov/detail.jsp?ContentID=255

Question	Responses
with a range of targets are there any other recommendations on best practices/options for dealing with the reality that ***for many of our conservation features, no targets have been recommended***?	• If data quality is low, one could turn down the SPF rather than set a lower target. • Set targets for coarse scale features proportional to the area of that feature overall. (Higher targets for classes/features that are more rare.) Use transformation and normalise the data (See Box 4.1 of the MGPH). • It was noted that targets of 40% for all BCMCA physical features (which are the coarse filter features for the project) may 'overwhelm' the analysis resulting in the most common and widespread features being predominant in the Marxan output – a counter-intuitive result for conservation planning.
Some ecological experts from different workshops recommended the inclusion of the same feature (e.g., eelgrass as a plant feature, and eelgrass as a surrogate/habitat for juvenile fish nursery areas). ***Should these features be weighted or included as 2 different features?***	• Only include as one feature but can take the higher of the recommended targets. Document why the higher target has been selected. • Do not include the feature twice as that would result in doubling the SPF for that feature.
Many of the BCMCA features are informed by incomplete datasets or data that came without proper metadata. The BCMCA has spent considerable effort documenting this to meet our principle of transparency and to follow Section 7 of the MGPH. ***If a data set is incomplete or of low quality,*** should it be included in the analysis as per other datasets, have a lower or null target assigned to "track" what is included in a reserve design or have a lower SPF? Is there a way to operationalize this statement: "for each dataset that is under consideration for inclusion in the analysis it is appropriate to ask what that dataset and the associated metric represents and if it meets the specific objectives and site selection criteria for the analysis."	• Some organizations consider the data collection methods and may reject certain datasets if they do not meet a pre-determined standard. • There are different types of "bad" data. For example false presence (e.g., old data indicating a species is present when it is no longer) and gaps in coverage. • Point data could be converted to a probability surface. • Run the scenarios, obtain solutions, remove questionable data sets and re-run analysis, then compare results statistically to see if the solutions with and without the questionable data are significantly different.[8] • May be able to use a surrogate that better represents the feature(s) as a substitute for poor quality data. • Define data regions based on data confidence and data collection zones and include the regions as features. • Include the features in the analysis, but do not assign targets and/or set lower (or no) SPF. Use the Marxan accounting function to see if an adequate amount of the feature was captured in the solution to meet conservation objectives.

[8] See Ban, N. 2009. Minimum data requirements for designing a set of marine protected areas, using commonly available abiotic and biotic datasets. Biodivers Conserv (2009) 18:1829–1845.

Question	Responses
How can the BCMCA ensure equitable treatment among taxa groups when some groups have multiple features while others are represented by few features. There is an ***unequal abundance of data.***	• If one taxon appears to be skewing the results of the analysis (solutions are dominated by the location of certain taxa), SPF can be adjusted. • One method to try: Weight by setting a value for the total SPF and divide by the number of ecological groups. This allows the SFP to be distributed evenly across the groups. For example there may be 5 taxa groups, each of which would be assigned 1000 SFP “points” - the formula for assigning the SPF for each feature within the taxa would be [feature1/all feature in taxa]*1000[9]. • Recommend keeping the SPF uniform at the start of the analysis and apply above technique if feature groups / taxa appear to be unduly influencing the Marxan solutions.
One of our group of features are ***ecosections*** (12) – they form a proxy for all biodiversity in the study area (each ecosection contains unique habitats). By targeting a certain percent of each ecosection, the Marxan solutions should contain broad geographic distribution of all features that are distributed throughout the study area. However we do not want this feature group to dominate or dictate the size of the reserve solution. Thoughts on appropriate target setting for this group of overarching features or on how to reduce the potential of ***broad data features dominating the analysis?***	• Select generally lower targets for the broad data (coarse filter) – consider what the objective of the analysis is (e.g., is 20% of abysmal plain needed for achieving a conservation objective?). • As a way to monitor the influence of these broad data features, conduct a series of Marxan runs where targets are set for one additional broad feature on each run and compare the results of the analysis.
Is it advisable to ***target benthic classes*** and other physical, coarse scale features ***by ecosection***? Box 4.1 of the MGPH suggests one alternative approach. Thoughts on appropriate target setting for this group of overarching features or on how to reduce the potential of ***broad data features dominating the analysis?***	• Most participants agreed that the data should ‘speak for itself’ and naturally cluster unless there is an ecological reason to assign targets for features by ecological region. • On the other hand, significantly different survey densities could provide a rationale for targeting by survey regions. • Using ecosections to stratify the features has the advantage of ensuring a broadly distributed Marxan solution. However, large features that range across a broad spectrum, could bias the analysis towards common features away from features that need conservation.

[9] This is a method that will not be found in the Marxan Good Practices Handbook. One participant was doubtful this method would work as SPF is not additive across different spaces.

Question	Responses
	• If stratifying features by biogeographic classifications (e.g., ecosections), especially ones with many classes, some of which are small, features need to be thoroughly reviewed for data artefacts (slivers). It may be necessary to adjust ecosection boundaries (for the purposes of running the Marxan analysis) to minimize slivers. This would reduce "noise" of artificial classes made up of combinations of ecosection and benthic classification. • In general terms, stratifying features according to broad ecosections was seen as an appropriate practice, but using more detailed "ecounits" to stratify features was seen as problematic and not recommended (more detail can bring more introduced noise and error due to slivers). If more detailed ecological units are desired as features they should be treated as a separate layer. • Caution was urged not to combine multiple classes. • Recommendation to identify slivers: use of a histogram to identify natural breaks. • There is no need to use just one biogeographic classification system; each have their own strengths and weaknesses. A good practice would be to include multiple biogeographical classification systems on their own without trying to fit other data within them. Each grouping of features – fish, invert, etc- can use its own classification system.
One of the BCMCA Features (benthic substrate) has data for all but 1300 of 61,000 PUs. These PUs fall primarily in narrow inlets or along shoreline. ***Should the BCMCA target a percentage of the area where there is no data coverage for a feature class***?	• There was no agreement on whether the BCMCA should set a target for areas of no data. • One recommendation was to look at the no-data areas and see if a sensible classification could be created – for the example given in the question, add an inlet category to the benthic classification. • Another recommendation was to look to see if there is a proxy that can be substituted for areas that have no data for a feature (e.g., use shorezone or estuary as a proxy for some feature where data coverage is not complete).
The ecological experts have identified some features for which they have ***recommended targets of 100%*** of the feature. In our preliminary analysis some of those targets are being met while others are not. Does the group recommend locking in the PUs where features for these 100% targets are found? Is it acceptable for solutions to	• Any feature targeted 100% (so long as it has a SPF >0) will act as a seed in Marxan whether it is locked in or not and therefore will bias the analysis toward these areas. • Setting the boundary length cost to zero on the PUs with features that have been targeted 100% will reduce the seed effect, as would reducing the SPF to 0. • Go back to ecological objectives and ask; "Is an area-based approach going to meet your management objectives for these features?"

Question	Responses
achieve less than their target for features?	• Consensus that the BCMCA should not lock in the PUs where there are features that have 100% targets. The BCMCA could leave very rare or unique features with targets of 100% out of the analysis, but display as occurrences of rare species on top of the analysis results. • The feature could be left in the analysis and tracked to see how much was included in the solution. PUs not selected by Marxan where the feature occurs could be added manually to the solution set after the analysis is complete, thereby ensuring 100% of the feature was included in the solution but avoiding the seed effect.
Should ***limited extent features*** – features where the data covers only a portion of the known extent of the feature - be included in the analysis (e.g., where there is data for just one bay, but the feature range is several bays)?	• Generally features whose data is limited to a subset of the overall known extent, should be removed from the analysis or tracked but not targeted in the analysis. • If there is a feature for which there is coast-wide data, but additional data for a portion of the feature range, it may be appropriate to assign targets for both datasets separately. • Testing should be conducted to determine if including a partial dataset influences the Marxan solutions.
Should ***surrogate/proxy datasets*** (MGPH section 7.4) have the same "weight" as "defined" features? How to weight?	• It depends on the confidence in the surrogate/proxy dataset. • Generally whatever the surrogate/proxy represents must be important enough to use a substitute dataset to represent the feature. Therefore use same weighting for proxy as for the actual feature.
Is it appropriate to use a classification system that has ***not been validated or ground-truthed*** as a proxy? Page 62 of the MGPH suggests documenting and reporting on surrogate parameters etc, however most people just look at the output of the Marxan analysis (maps, tables). Are there techniques for the BCMCA to ensure the documentation is read/understood? Where should this reporting occur?	• Validation should occur through review of the datasets representing the feature. • Document that the data being used is the best available and provide references for the data in a report on the features used in the analysis. • Include information on the context of the data, including the scale and intended resolution of use. • It was noted that very few classification systems anywhere in the world have been ground-truthed.
Most of the BCMCA data is not ***presence/absence***, but rather presence only. Where we have absence we plan to include it as a feature but not assign a target. What are some ways to follow this advice	• Bin the data and document how much survey time has been spent in each "bin". To do so one would need to know ship speed and survey duration. • Test the analysis with and without the features to see the impact of their inclusion. • One participant recommended setting a lower SPF for data

Question	Responses
from the MGPH: "data should be corrected for equal search effort in space and time"? In almost all cases we have no indication of the level of effort that went into data collection. We have good indication for level of effort for commercial fisheries data.	with suspected low comprehensiveness or reliability, so as not to "drive" the analysis.
BCMCA is using ***data aggregated over many years***, both for ecological features and human use (e.g., fisheries). This was in an attempt to address the issue of use areas changing from year-to-year (an area may be important one year, then not again for another 4 years). However the human use working group has suggested past patterns are poor indicators of future use patterns. This is touched on but not addressed in any great detail in the MGPH (e.g., Section 7.6, Table 7.3). Suggestions?	• Agree that past/current data may not reflect future potential use patterns. Environment, management and policy decisions may impact future use. • Use as close to current time period (<5 yrs) for human impact models. If only old data is available, ensure that it is the best available data. • Could weight older data differently than newer data. • Marxan is not a predictive tool – different tools should be used for predictive analysis. Outputs of the Marxan analysis can be used as input to the predictive tools. See for example work done by Chris Costello (University of California, Santa Barbara) or bioeconomic models such as EcoPath. • Consult users to identify "core" areas (see Section 3, below).
BCMCA was considering scenarios with human use as a cost. Human users have told us there maybe ***seasonal incompatibilities*** between some conservation features and human uses, but that incompatibility is typically addressed through management practices (e.g., seasonal closures). Are there ways to address this in Marxan, short of running the same scenario using different cost layers for each season and/or providing comment on the dialog being distributed with the results of the Marxan analysis?	• Record the seasonal incompatibilities where they are known. • Marxan with Zones may be useful to address seasonal incompatibilities – there could be different zones applied for different seasons.
Some of the BCMCA conservation features are ***seasonal or migratory***. In some cases they migrate outside of the study area. Comments on how to address this in a Marxan analysis?	• Seasonality needs to be considered if the features vary a significant amount between seasons or if the data will be used to make decisions based on seasonality. Separate features may be required for each season. • MGPH states for a feature that does not have annual seasonality but shows shifts over several years, it may be

Question	Responses
	appropriate to use non-aggregated data from several years (tracked as separate features) to account for the full range of historical and present distributions. • Need to consider how much change there is and persistence overtime. • If the conservation features are highly migratory and migrate outside of the study areas, include notes with the results of the analysis regarding feature distribution at different times of year. • If seasonal or migratory features are to be included in the Marxan analysis, ensure that spatial and temporal bottlenecks are reflected in the data and associated Marxan targets. A bottleneck is an area used intensively by a migratory species, perhaps in a particular life history stage. They are species specific and can include feeding grounds, staging grounds, breeding grounds and physically constrained geography.
Many BCMCA features are ***ranked*** for importance among the features. In some cases the ranking is relative (groups of high, moderate and low importance). In other cases the features contain density or abundance information, with the areas of higher density or abundance being more important than areas of lower abundance. Are there recommendations to ensure the more important features are ***preferentially selected***?	• Have different features for high and low abundance with higher targets for high abundance and lower targets for low abundance features. • To ensure the more important instances of a feature will be preferentially selected: 1. Use standard deviations to calculate what is high abundance vs. low abundance; OR 2. Use the relative measure as a multiplier (weighting) where the relative measure is based on densities.
Some BCMCA features, for example bird colonies, are points that have been buffered to capture an area of importance around the bird colony. When buffered the feature extends beyond a single planning unit. All area within the colony (buffered point) is considered important to each site, and targets are recommended by sites. ***How do we ensure Marxan captures entire sites (colony plus buffer) when achieving its targets and not just a***	• Could use minimum clump size, but that really slows down Marxan. • Initially do not put any constraints on the analysis and see if the Marxan results fall out naturally (if all PU which contain a colony are included in the solution). • Larger colonies should be more “important” than the smaller colonies within the analysis (have a higher target assigned because they are likely to be more persistent over time). Set up a density analysis of distribution of “colonies.” Clumps of colonies may be separated by distances that are not significant for a given species (e.g.,

Question	Responses
portion of several different sites?	with less than 5 km separation) and could be counted as one[10]. • One method to ensure an entire colony is included in a Marxan solution: increase the boundary length between the edges of the PUs internal to the colony. Noted that such action would be very labour intensive and may be difficult to explain to those not familiar with Marxan. It was also noted that if the BLM is being used, and has been properly calibrated, Marxan results 'clump' naturally and the above boundary length adjustments are probably not necessary. • Comment that nesting areas and feeding areas may be ecologically adjacent not spatially (geographically) adjacent, so buffers around the colony may not be appropriate (check with experts). If the nesting and feeding areas are not adjacent, and it is important to include both in a Marxan solution, then the boundary length between the PUs that have the areas should be manually adjusted (increased) to encourage preferential selection (if one is selected, Marxan would be more efficient if the other was selected as well). • Circuitscape (www.circuitscape.org) was recommended as software that can be can be used to map the corridor between the nesting and feeding area[11].
Should ***coastal eagle/peregrine falcon nests*** be included in the analysis given that only a subset of the total number of nests would be located in coastal planning units (with the rest perhaps near the coast but outside of the extent of the PUs)?	• Because the distribution of nests extends beyond the breadth of the PUs it was recommended not to include these features in the analysis. • Question as to why falcon and eagle nests (terrestrial features) are features in a marine conservation analysis? Having experts develop maps of falcon/eagle marine use areas would be more relevant to this work. Suggest going back to marine bird experts and confirming.
Marine Mammals features are currently data poor. Are there any recommendations to improve this dataset?	• TNC has had experts review the use of chlorophyll A and upwellings (based on sea surface temperature differentials) as a proxy for marine mammals. Experts (including Barbara Hickey, an oceanographer with the University of Washington), recommended using chlorophyll A but not upwellings to identify highly productive areas more likely to be frequented by marine mammals.

[10] This was done in an analysis by the Living Oceans Society for the Coast Information Team in 2003: http://livingoceans.org/_pvwC21CD930/files/PDF/mpa/CUA_05a.pdf.

[11] Note: Circuitscape is not related to Marxan.

Question	Responses
	• Sea surface temperature (SST) fronts are very dynamic and not a good proxy. • If improvements cannot be made, the data gap should be noted in the project's documentation, as well as the reasons why the data were not available or why the data is considered to be poor.
Seaweed/Kelp: comments on seaweed and kelp recorded during the review of available data.	• This data can be ephemeral and may not exist where the maps portray it if the data is old. Are there time series that would allow the identification of persistent kelp? *Response:* No • Larger kelp beds are much more likely to be persistent than small ones. Likewise, dense aggregations of many beds are likely to be more persistent than sparse singular ones. Therefore, if size/density is taken into account when loading the feature into PUs, then Marxan would be more likely to select the larger, denser, and probably more persistent areas. • There may be problems with rare/unique species point data. (See above regarding 100% targets for rare and unique features.)
Other features: general feature comments recorded during the review of available data	• With regards to bird features, Grant Humphries is conducting research that suggests birds (specifically storm petrels) are attracted to dimethyl sulphide (DMS). There is mapping of DMS using a 1x1 degree grid. • In the review of all ecological features BCMCA had compiled, a recommendation was made on how to decide whether to include a feature when there is some question on if that feature should be included. Recommended to conduct Marxan analysis with and without the feature and evaluate the differences in results (if any). • *Question:* why hydrothermal vents were included as a feature in a conservation analysis (e.g., what human activity is threatening them). *Response:* They were identified as a unique feature with a unique assemblage of biota. • *Question:* Is there a proposed method to create a feature to represent gyres/eddies? Possible to use SST fronts. • *Question:* How is the seaward end of estuaries defined? *Response:* Used the definition from federal/provincial datasets.

3 Human use breakout group

3.1 Participants and Observers

Participants

Natalie Ban: Moderator	James Cook University BCMCA Project Team	Postdoctoral Research Fellow
Tanya Bryan: Note taker	Nature Conservancy of Canada – BC Region BCMCA Project Team	Marine Ecologist
Dan Segan	University of Queensland, Applied Environmental Decision Analysis Centre	Research Assistant
Edwin Blewett (Tues only)	Counterpoint Consulting Inc.	Consulting Economist
Patrick Mahaux (Tues only)	DFO, Policy Branch	Manager, Economics & Analysis
Rosaline Canessa (Wed only)	University of Victoria, Department of Geography	Assistant Professor
Sarah Klain	University of British Columbia	Graduate Student

Observers in attendance

Bruce Turris	BC Seafood Alliance - BCMCA Project Team
Carrie Robb	Living Oceans Society - BCMCA Data Manager
Chris Bos (Tues only)	Sport Fish Advisory Board -BCMCA Project Team
Rick Page	BCMCA Human Use Coordinator

* see Appendix 4.2 for contact information and an additional list of observers present at the workshop

3.2 Goals and Overview

The goal of this breakout group was to determine the best methodology for incorporating human use data into the Marxan analysis, in the context of the BCMCA, as well as to identify gaps in the Marxan Good Practices Handbook.

3.3 Breakout Group Discussion Points

1. Utility of the socio-economic chapter of Marxan Good Practices Handbook
2. Scenarios that use human use data as features to be targeted
3. Analyse and compare the results of using each human use layer as a cost in separate scenarios
4. Generic cost scenarios and ways of combining costs and related sensitivity analyses
5. Recommendations for dollar values associated with the human use data
6. Current versus future human uses of the marine environment

Based on the above stated goal and discussion points, the Human Use breakout group made these observations and recommendations regarding incorporating human use data into the

BCMCA Marxan analysis and for improvements to the MGPH.

3.4 Marxan Good Practice Handbook

The MGPH needs more specific guidelines around the incorporation of human use data in the Marxan analyses.

3.5 Incorporating Human Use into Marxan

Some general recommendations and observations that were discussed by the breakout group include the following:

- A richness map of human uses would be more valuable than a human-use only (e.g., targeting human uses) Marxan scenario.
- When using human use features as cost, it needs to be acknowledged that different human uses (e.g., the harvest of a transient species like halibut vs. a non-mobile species like geoduck) are affected in different ways by conservation measures.
- Decisions on how human use of the marine environment (as reflected by the human use data sets) is incorporated into a Marxan analysis may be more suited to a mandated/government-led planning process rather than the BCMCA process.
- If data is available for future uses, it needs to be incorporated into a sensitivity analysis to determine if it alters the results. There are currently only a small number of human use groups that have future use maps. Within the analysis, present-day uses should get priority over future uses.
- If possible, determine relative economic values associated with each of the human uses. This data can then used be used as a cost layer when targeting ecological values (see EcoTrust's work on the California Marine Life Protection Act Initiative (MLPA)[12]). The data could then be normalized to produce an equitable distribution of cost. It is not necessarily straight forward as some fish stocks (for example) could have high volume but low value. But a good alternative is to generate trade-off curves (e.g., Klein, C., C. Steinback, M. Watts, A. Scholz, and H. Possingham. 2009. *Spatial marine zoning for fisheries and conservation.* Frontiers in Ecology and the Environment doi:10.1890/090047[13]).
- It is important to at least note the temporal aspect of fisheries. From year to year, many fisheries, such as hake, sardines, and anchovies are quite variable and are usually only targeted in any one location for part of a year. Although there may not be data to show this, it needs to be noted as a limitation.

[12] http://www.uq.edu.au/spatialecology/docs/Publications/2008_Klein_etal_EffectivenessOfMarine.pdf; http://www.ecotrust.org/mlpa; http://www.dfg.ca.gov/mlpa; http://www.hd.gov/HDdotGov/detail.jsp?ContentID=255

[13] http://www.uq.edu.au/marxan/docs/Klein_etal_2009_Spatial_marine_zoning_for_fisheries_and_conservation

3.6 Marxan with Zones

- It was recommended that the BCMCA examine the pros/cons of using Marxan with Zones. If suitable within the confines of the project, the breakout group recommends that the BCMCA use Marxan with Zones.
- Marxan with Zones makes it possible to run scenarios with both ecological features and human uses as both targets and costs.
- Generate trade-off curves to help to visually represent what happens at different target levels for ecological and human use features and how they interact.
- By developing these types of curves, the BCMCA can clearly show what happens to the level of protection when costs increase or decrease and if there is a 'tipping point' in terms of cost vs. conservation. This will help develop rationale for the chosen target amount.
- The BCMCA feels it should not be identifying specific zones (e.g., no take, long line only, etc) as that is outside of the scope of the project agreed to by the project participants. Different government agencies have the mandate to assign marine use zoning and it will be these agencies that determine the zone use. The BCMCA is merely trying to provide options on how the management agencies could move forward[14].
- Given the above statement, it was recommended that the BCMCA use a 2 zones focus – a use zone and a protected area/conservation zone.
- It was acknowledged that one of the disadvantages of Marxan with Zones was the amount of time that would be needed to learn and use this new software.
- It was expressed that specific training on Marxan with Zones would be beneficial for the marine planning community.

[14] This is a BCMCA decision based on the scope of work agreed to by the project participants, and not a "good practice" per se. Other initiatives have used decision support software to assist in multiple use zoning, most notably the use of Marxan to assist in rezoning the Great Barrier Reef, the single biggest implemented systematic conservation plan in the world.

4 Climate Change Breakout Group

4.1 Participants and Observers

Participants

Dusan Markovic: Moderator	Contractor	
Sarah Loos: Note taker	Nature Conservancy of Canada – BC Region	Conservation Planner
Eddie Game	The Nature Conservancy, Indo-Pacific Resource Centre	Conservation Planning Specialist, Conservation Methods and Tools
Hussein Alidina	WWF Canada – Pacific Region	Conservation Planner and Policy Analyst
Marlow Pellatt	Parks Canada, Resource Conservation	Coastal Ecologist
Thomas Okey	West Coast Vancouver Island Aquatic Management Board	Science Director
Zach Ferdaña	The Nature Conservancy, Global Marine Initiative	Senior Marine Planner

Observers in attendance

Karin Bodtker (Tues afternoon only)	Living Oceans Society, BCMCA Project Team (Co-chair)

4.2 Goals and Overview

The goal of this breakout group was to make recommendations on how best to calibrate Marxan to anticipate climate change and identify options for explicitly considering the effects of climate change (and other temporal aspects) in Marxan analyses, in the context of systematic reserve design. The group's focus was not specific to the BCMCA data and analysis. The discussion and recommendations are made with the caveat that the BCMCA does not expect to have the resources to commit to acquiring additional datasets or analysis needed to implement all the recommendations, but that these ideas which require a greater investment of effort should be considered in analyses that build upon the BCMCA, as better climate data become available.

4.3 Breakout Group Discussion Points

1. Discuss methods and/or concepts, applicable to Marxan, which enable the design of MPAs and conservation networks to anticipate and accommodate the risks posed by climate change.
2. Consider how to calibrate Marxan to choose sites that are more likely to be resilient or are resilient to global environmental change. Are there known habitat characteristics that increase/indicate resilience?

3. Discuss the concept of minimize-risk vs. minimize-cost methodologies in Marxan as it could pertain to climate change. Is it possible to incorporate catastrophic events into reserve design?

Based on the above stated goal and discussion points, the Climate Change Breakout Group proposed the following concepts and methods as a means of incorporating climate change considerations in the BCMCA's Marxan analyses. The concepts and methods would be applicable to other studies as well.

At a fundamental level, the BCMCA needs to interpret its overall conservation objectives in light of climate change. This will require the BCMCA to examine each of its specific objectives and identify how they can be interpreted in light of climate change. The BCMCA will also have to define what 'success' is in terms of the project with regard to climate change.

4.4 Climate Related Approaches for Selecting a Conservation Network

1. Mitigate risk of changing features (e.g., the risk of loss of valuable features such as a keystone species or important ecosystem services).
2. Provide opportunities for ecosystem adaptation (e.g., reduce or eliminate non-climate change stressors, for example through protected areas, so that ecosystems have the best chance to adapt naturally).

Marxan climate change analyses will only be as good as the inputs from other sources (e.g., modeled data etc.). The level of understanding regarding climate change and associated variabilities is the limiting factor, not Marxan. It is important to focus on the data availability and quality, and the background on climate change, not on how Marxan can be parameterized or calibrated.

4.5 General Principles

- Continue to use good conservation planning (C.A.R.E. – Comprehensive-Adequate-Representative-Efficient).
- Do not stall conservation work waiting for climate change data inputs. Lack of climate change data is not a reason to delay conservation, nor does it limit the utility of the BCMCA product for decision makers.
- There is pressure to respond to climate change, but the uncertainties regarding what the climate change impacts will be, and how extensive they will be, must be stated and acknowledged. Assess risks in the context of this uncertainty.
- Assess and draw information from partners working on climate change. This will help inform the assessment of impacts on the region.
- Focus on critical persistent components (physical, abiotic, static).
- Identify and focus on key high value and vulnerable (ecological, socio-economic, cultural)

features. Conduct vulnerability analyses on these high value features[15].

- Update constraints (threats/risks/cost layers) to take climate change into account. This would include socio-economic impacts and constraints on conservation (e.g., areas likely to be lost or greatly changed in climate change scenarios).
- Identify climate related opportunities (e.g., carbon sinks, storm mitigation) to create 'win/win' situations (e.g., ecosystem based management meeting multiple objectives). Place more value on these new opportunities, or features that have value beyond existence for conservation that may arise from climate change awareness (e.g., ecosystem services such as protecting freshwater resources).
- Practice dynamic and adaptive, as opposed to static, conservation planning.
- Plan for redundancy and connectivity in protected area networks to offer greater resilience to climate change, whereby species can shift out of one area and into another, if required, but that the persistent habitats of each area remain protected. This will have the effect of reducing the risk of vulnerability of individual areas to climate change (see methods below).

4.6 Methods

The methods outlined below have been categorized based on the level of resource (time/money) investment. Note that the following methods are not mutually exclusive. All of the following are inputs that can be used in Marxan in various ways, but not all will be relevant for all analyses. The 'low investment' methods can be employed using the BCMCA's current resources (time/money/data). With additional resources, 'moderate' and 'large' investment methods can be used.

<u>Low Investment</u>

- Incorporate C.A.R.E. principles: Comprehensiveness (represent every habitat), Adequacy (conserve enough, spread risk, ensure connectivity), Representativeness (the reserve system is reflective of the broader study area and includes good, representative examples of feature), Efficiency (socially/economically efficient).
- Represent persistent features (those features unlikely to be affected by climate change).
- Adequate size, replication and connectivity for high value features at risk under climate change.
- Build in greater redundancy (higher targets and replication).

<u>Moderate Investment</u>

- Climate refugia (e.g., sea surface temperature, data analyses).
- Vulnerability assessment of key conservation features to climate change.
- Species range / habitat envelope modeling to capture representation within the future climate.
- Capture expected variability on all temporal scales of oceanographic variables (e.g., extreme events/decadal and seasonal variability).

[15] See for example: Wilson et al, 2005. Measuring and Incorporating Vulnerability into Conservation Planning. http://www.ecology.uq.edu.au/docs/publications/2005_Wilsonetal_MeasuringandIncorporating.pdf

- Identify conservation features that can/are likely to migrate (potential future habitat suitability).

Large Investment

- Intensive modeling of complete ecosystem consequences of climate change. (e.g., climate forcing with Ecopath/Ecosim models).
- Modeling complete future probabilistic abundance, distribution, and interactions of conservation features.

4.7 Risk and Conservation Planning

- Application of C.A.R.E. principles mitigate some level of risk.
- Need to know details on specific risks and potential impacts of climate change in the region, coupled with the expected general trends and variabilities.
- Need to determine priorities in terms of preserving conservation features before trying to minimize costs.
- Carefully consider how each risk is operationalized in Marxan – should risk be considered as a cost or influence targets?
- Insurance (risk) multiplier principle – if there are features that are vulnerable to climate change events, then increase representation for those events based on what portion of the population it is believed will be impacted (e.g., as a simple example, representation goal is 30%, but 10% are at risk, then goal or target should be adjusted to 40%).

5 Appendix

5.1 Meeting Agenda

Day 1 – May 26, 2009

9:00 – 9:30 am	Plenary talk – overview of BCMCA
9:30 – 10:15 am	Breakout groups
10:15 – 10:30 am	**Nutrition Break**
10:30 am – Noon	Breakout Groups
Noon – 1:15 pm	**Lunch (provided)**
1:15 – 2:45 pm	Breakout Groups
2:45 – 3:00 pm	**Nutrition Break**
3:00 – 4:30 pm	Report out - report on progress to date, and allow input by and for other breakout groups
6:00 pm	Optional Dinner

Day 2 – May 27, 2009

9:00 – 9:30 am	Recap on yesterday's discussion
9:30 – 10:15 am	Breakout groups
10:15 – 10:30 am	**Nutrition Break**
10:30 am – Noon	Breakout Groups
Noon – 1:15 pm	**Lunch (provided)**
1:15 – 2:45 pm	Breakout Groups
2:45 – 3:00 pm	**Nutrition Break**
3:00 – 4:30 pm	Report out and Wrap Up

5.2 BCMCA Marxan Objectives and Principles

Six objectives and principles guide the development of the BCMCA's Marxan analyses:

- 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;
- Build a conservation network that is resilient to environmental change;
- Identify options that minimise impacts and maximise benefits to marine users while still meeting conservation objectives; and
- Consider a variety of conservation scenarios and options.

5.3 Attendees Contact Information

	Affiliation	Day1	Day2
Robust Analysis - Group 1			
Dave Nicolson: moderator	BCMCA Project Manager - Plenary lead Director, PacMARA	y	y
Jason Thomson: note taker	BCMCA Project Assistant - General workshop logistics	y	y
Charles Steinback	Director of Marine Planning Ecotrust	y	y
Dan Dorfman	Consultant - Intelligent Marine Planning	y	y
Dan Kelly	GIS Analyst - The Nature Conservancy, Oregon	y	y
Grant Humphries	Graduate Student -University of Alaska	y	y
Jeff Ardron	Conservation Oceanographer, Director High Seas Program - Marine Conservation Biology Institute Vice-President, PacMARA	y	y
Human Use / Socio-Economic Group 2			
Natalie Ban: moderator	Postdoctoral Research Fellow - James Cook University BCMCA Project Team	y	y
Tanya Bryan: note taker	Marine Ecologist- Nature Conservancy of Canada – BC Region - BCMCA Project Team	y	y
Dan Segan	Research Assistant - University of Queensland, Applied Environmental Decision Analysis Centre	y	y
Edwin Blewett	Consulting Economist - Counterpoint Consulting Inc.	y	n
Patrick Mahaux	Manager, Economics & Analysis DFO, Policy Branch	y	n
Rosaline Canessa	Assistant Professor University of Victoria, Department of Geography	n	y
Sarah Klain	Graduate Student University of British Columbia	y	y
Climate Change Group 3			
Dusan Markovic: moderator	MTS Consulting	y	y
Sarah Loos: note taker	Conservation Planner Nature Conservancy of Canada – BC Region	y	y
Eddie Game	Conservation Planning Specialist, Conservation Methods and Tools - The Nature Conservancy, Indo-Pacific Resource Centre	y	y
Hussein Alidina	Conservation Planner and Policy Analyst WWF Canada – Pacific Region	y	y
Marlow Pellatt	Coastal Ecologist Parks Canada, Resource Conservation	y	y
Thomas Okey	Science Director - West Coast Vancouver Island Aquatic Management Board	y	y
Zach Ferdana	Senior Marine Planner The Nature Conservancy, Global Marine Initiative	y	y
Observers			
Bruce Turris	BC Seafood Alliance - BCMCA Project Team	y	y
Carrie Robb	Living Oceans Society - BCMCA data manager	y	y
Chris Bos	Sport Fish Advisory Board -BCMCA Project Team	y	n
Greg MacMillan	Parks Canada - BCMCA Project Team	y	y
Henry Kucera	Executive Director, PacMARA	y	y
Karin Bodtker	Living Oceans Society - BCMCA Project Team (co-chair)	y	y
Krista Royle	Parks Canada - BCMCA Project Team	y	y
Rick Page	BCMCA Human Use Coordinator	y	y

5.4 BCMCA Glossary

Areas of high conservation value – areas that are important to effectively representing and conserving marine biodiversity.

Areas of importance to human use – areas that are important to marine user groups. The BCMCA project team is inviting user groups to help identify the areas that are important to them.

Biodiversity – the variety of species and ecosystems on earth and the ecological processes of which they are a part, including ecosystem, species and genetic diversity components.

Conservation – the protection, maintenance and rehabilitation of biodiversity, allowing for the sustainable utilization of species and ecosystems, and the natural resources they provide.

Conservation planning – the exercise of identifying areas important for meeting conservation objectives (e.g., biodiversity representation within a defined region) and then designing management measures to ensure that those conservation objectives are met (the BCMCA is only helping with the first half of this exercise – identifying important areas).

Ecosystem – is a dynamic complex of plant, animal and microorganism communities and their abiotic environment, all interacting as a functional unit in an area.

Engagement – the BCMCA's process of inviting the feedback and participation of user groups on the BCMCA project.

Expert workshops – The project team organized five workshops where experts on the theme of each workshop (e.g., marine mammals, marine birds) were invited to participate. At these workshops, experts identified sources of the best available ecological data for the BCMCA atlas and spatial analyses, and made recommendations to help define the parameters for analyses.

Feature (Marxan context): Features are the spatial layers to be mapped and included in site selection analyses by the BCMCA. (e.g., broad ecological units, species habitats, aquatic features, areas of ecological or human use focus).

Human Use Data Working Group – a committee of user group representatives that provides advice to the project team about the preparation and use of human use data in the BCMCA project.

Marxan – a decision support tool used around the world to identify areas that meet conservation objectives (e.g., representing biodiversity) at a minimal cost to marine users (see http://www.bcmca.ca/Marxan.html for more details).

Planning Unit (Marxan context): The building blocks of Marxan are the parcels of land or water that are compared to one another – these parcels are called planning units, or sometimes called analysis units. The amount of each feature present in each planning unit is recorded and used in site selection analyses.

Planning Unit Cost (Marxan context): The individual 'cost' of each planning unit. The 'cost' can reflect any relative economic, social or ecological measure and is sometimes referred to as a suitability measure. (e.g., How 'suitable' is each planning unit for meeting the objectives of any specific Marxan scenario).

Project team member – project team members are responsible for implementation of the BCMCA project according to a Terms of Reference drafted by members at the outset of the project (available at www.bcmca.ca). Strategic and major project decisions are taken after input from all project team members. The project team strives for consensus in all decisions.

Project team observer – An observer has been invited to the Project Team to represent a constituent group. Observers are invited to speak, question, and participate fully in Project Team meetings. However, observers can choose whether or not to be part of a decision. If they choose to be part of a decision they agree to follow the decision making procedures. Where observers choose not to attend meetings or participate in decisions, the Project Team will make the decisions necessary to move the project forward in their absence. Observers self-designate themselves as such.

Richness map – a map that results from laying multiple maps on top of one another to highlight where the areas identified on each individual map overlap with each other (use a visual example)

Sector – the term that refers to the broad groups of human users in BC's marine environment that have been identified by the BCMCA. The sectors are (1) commercial fishing, (2) recreational fishing, (3) energy, (4) marine recreation and tourism, (5) shipping and marine transport, and (6) marine and foreshore tenures. Each sector may consist of multiple distinct user groups.

Spatial analyses – the process of deriving new information through the assembly and interpretation of existing spatial data. Two separate spatial analyses will be conducted for the BCMCA:

1. Identifying areas of high conservation value (using ecological data only); and
2. Identifying areas of high conservation value that minimize overlap with areas important to human use (using ecological and human use data).

Targets (Marxan context): Quantitative values that define how much of each particular feature is required to meet the goals or objectives of any specific Marxan scenario.

User group – a more specific term than sector, used to refer to a set of human users that essentially all participate in the same marine activity (e.g., halibut fishing or industrial shipping or sea kayaking). There may be numerous user groups within a sector and there may be multiple representative bodies for any given user group.

5.5 Marxan Glossary

Algorithm: A mathematical process that systematically solves a problem using well-defined rules or processes. Marxan can use several optimization algorithms (exact algorithm, heuristic algorithm, simulated annealing and iterative improvement) to identify reserve design solutions for a minimum cost, subject to the constraint that stated objectives are achieved.

Boundary cost: Also referred to as *boundary length*. A boundary cost is specified between two planning units. When one of the two planning units is included in the reserve system, the boundary cost is a relative measure of the importance of also including the other planning unit, and vice versa. Although the relationship between two planning units is typically the length of the shared boundary, boundary costs can also be specified between non-adjacent planning units reflecting ecological or economic factors.

Boundary Length Modifier (BLM): A variable controlling how much emphasis to place on minimising the overall reserve system boundary length relative to the reserve system cost. Higher BLM values will produce a more compact reserve system.

Clumping: The minimum amount of a conservation feature required within adjacent planning units before that 'clump' is considered to effectively contribute towards achieving the representation target for that feature. A number of unique clumps of a conservation feature can also be assigned (See *separation distance*).

Conservation feature: An element of biodiversity selected as a focus for conservation planning or action. This can include ecological classifications, habitat types, species, physical features, processes or any element that can be measured in a *planning unit*.

Conservation feature penalty factor: See *Species penalty factor*

Cost: The cost of including a planning unit in a reserve system. This cost should reflect the socio-political constraints to setting aside that planning unit for conservation actions. This could be: total area, cost of acquisition or any other relative social, economic or ecological measure. Each *planning unit* is assigned one cost, although several measures can be combined to create a cost metric.

Compactness: A measure of the clustering or grouping of planning units in a reserve solution. It is calculated as a ratio of the total boundary length of a reserve system to the total area of the reserve system. Stewart and Possingham (2005) describe this concept in more detail.

Efficiency: Property of a reserve system solution which meets all conservation targets (e.g., ecosystems, habitats, species) at an acceptable cost and compactness.

Irreplaceability: see Selection Frequency.

Iteration: The number of times marxan makes a decision to include or exclude a particular planning unit. A typical Marxan run will have millions of iterations. "*At each iteration, a planning unit is chosen at random and may or may not be already in the reserve system. The change to the objective function's value of the reserve system, which would occur if this planning unit were added or removed from the system, is evaluated. This change is combined with a parameter called the temperature and then compared to a uniform random number. The planning unit might then be added or removed from the system depending on this comparison."* (Marxan Manual, ver 1.8.10, pp 105)

Iterative improvement: A simple heuristic wherein the algorithm will consider a random change to see if it will improve the value of the objective function if that change were made. If the change improves the system, then it is made. In Marxan, iterative improvement can be used to discard redundant planning units from the solutions.

Objective function: An equation associated with an optimization problem which determines how good a solution is at solving the problem. In Marxan, the value of the equation is a function of planning unit costs, boundary costs, and penalties. Each solution to reserve design is assigned an objective function value; a solution with a low value is more optimal than a solution with a high value.

Planning units: Planning units are the building blocks of a reserve system. A study area is divided into planning units that are smaller geographic parcels of regular or irregular shapes. Examples include squares, hexagons, cadastral parcels and hydrological units.

Reserve system design: The approach used to design a network of areas that collectively address the objective of the conservation problem.

Run: The term used to describe the analysis of a particular scenario. A run will continue for a set number of ***iterations***. Several runs are conducted for each scenario. Because there are an almost infinite number of solutions for a Marxan analysis the number of runs should be adequate to provide a representative sample of the solutions available. This is sometimes also referred to as ***restarts***.

Selection frequency: Also commonly known as *irreplaceability*. How often a given planning unit is selected in the final reserve system across a series of Marxan solutions. This value is reported in the "Summed Solutions" output file.

Sensitivity analysis: The process of modifying input parameters, constraints and data to quantitatively assess the influence of different variables on the final solution; that is, the degree to which the outputs are "sensitive" to variations in these various parameters.

Separation distance: Defines the minimum distance that distinct clumps of a feature should be from one another in order to be considered as separate representations. This could be considered a type of risk spreading.

Simulated annealing: An optimization method (algorithm) based on iterative improvement but with stochastic (random) acceptance of bad moves early on in the process to help avoid getting stuck prematurely at local minimum objective function value.

Species Penalty Factor (SPF): A user-defined multiplier for the penalty applied to the objective function when a conservation feature target is not met in the current reserve scenario.

Systematic conservation planning: Formal method for identifying potential areas for conservation management that will most efficiently achieve a specific set of objectives, commonly some minimum representation of biodiversity. The process, involves a clear and structured approach to priority setting, and is now the standard for both terrestrial and marine conservation. The effectiveness of systematic conservation planning stems from its ability to make the best use of limited fiscal resources towards achieving conservation goals and do so in a manner that is defensible, accountable, and transparently recognises the requirements of different resource users.

Target / Representation target: Targets are the quantitative values (amounts) of each conservation feature to be achieved in the final reserve solution.