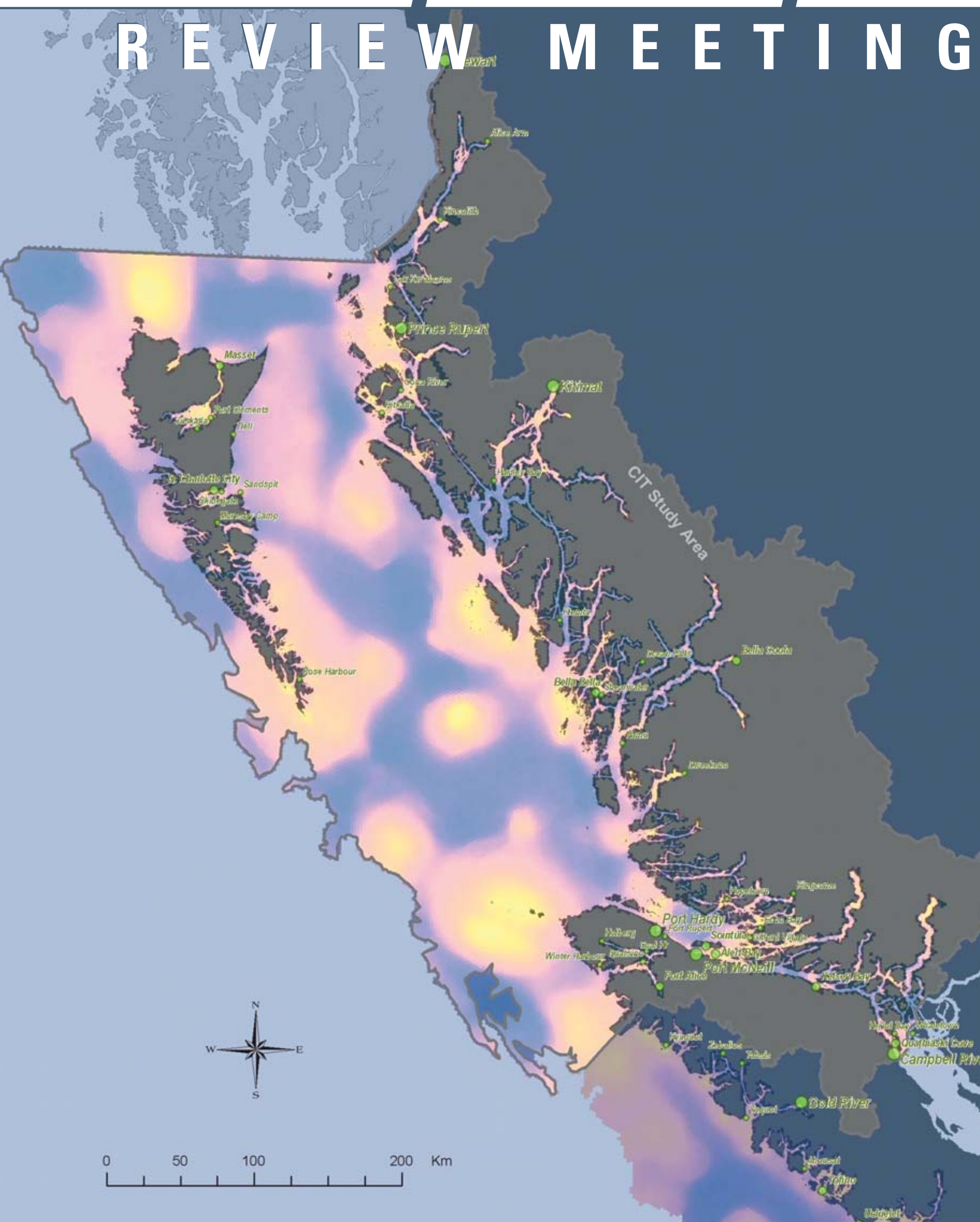
Conservation Utility Analysis
REVIEW MEETING



Materials and Background Information

Living Oceans Society

World Wildlife Fund Canada

David Suzuki Foundation

Nature Conservancy Canada

Canadian Parks and Wilderness Society — British Columbia Chapter

November 2005

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Agenda
Conservation Utility Analysis Review Meeting

Goals and Objectives

The goal of the Conservation Utility Analysis Meeting is to undertake a detailed review of the Living Oceans Society's Conservation Utility Analysis (CUA) for the North Coast, Central Coast and Queen Charlotte Basin (CIT Region).

Methods

A review of the techniques, methods, inputs and assumptions of the CUA with a select group of 8–10 modeling and GIS experts to develop guidance for a work plan for Version 2 of the CUA.

Objectives

verification of assumptions used in the analysis or refinement of the assumptions

identification of key technical issues and solutions / methods to address them

identification of input data-related issues

guidance for the development of Version 2 of the CUA

Participants

- Mark Zacharias, INTEGRATED LAND MANAGEMENT BUREAU, PROVINCE OF BRITISH COLUMBIA
- Murray Manson, FISHERIES AND OCEANS CANADA
- Tony Pitcher, UBC FISHERIES CENTER
- Amanda Vincent, PROJECT SEAHORSE
- Scott Wallace, CONSULTANT
- Jacky Booth, CONSULTANT
- Dave Nicholson, NATURE CONSERVANCY CANADA
- Krista Munro, LIVING OCEANS SOCIETY
- Jeff Ardron, LIVING OCEANS SOCIETY
- Rick Ellis, FACILITATOR

Agenda

9:00 Introductions, review of agenda, logistics for the workshop — chair / facilitator

9:15 Welcome from PacMARA — Michele Patterson

9:30 Welcome by Living Oceans Society– context, goals and objectives — Jennifer Lash

9:45 Presentation of the CUA, part 1: overview and methods — Jeff Ardron

10:30 Refreshments

10:45 Presentation of methods of the CUA, part 2: a review of the conservation targets and data use — Jeff Ardron

11:15 Discussion leading to listing of key aspects of the CUA that the review will focus upon

12:15 Discussion of key review topics from list

12:30 Lunch (provided – short lunch)

1:15 Discussion of key review topics (continued)

3:00 Refreshments

3:20 Discussion of key review topics (continued)

4:00 Next steps

4:30 Adjourn

Background Information for Workshop Participants

This document contains four sections with the following information

Section 1: Conservation Utility Analysis: Context and Background

Section 2: Conservation Utility Analysis Central Coast Pilot Study: Results of the Expert Review (2002)

Section 3: Coast Information Team Ecosystem Spatial Analysis: Results of the Expert Review (2004)

Section 4: Conservation Utility Analysis Review Paper

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Conservation Utility Analysis: Context and Background

Conservation Utility Analysis: Context And Background

Introduction

A strategy to protect marine biological diversity in British Columbia is necessary if we are going to ensure a healthy ocean and healthy coastal communities. A comprehensive strategy should consider both the physical marine environment and the people who depend on it.

There are currently many analysis, research and planning initiatives led by various First Nations, environmental non-governmental organizations (ENGOs), and government agencies that can become part of a province-wide strategy to conserve marine biological diversity. There are also many gaps that must be filled in order to complete a comprehensive strategy. Furthermore, some of the existing analysis initiatives require an external review to identify weaknesses and concerns and ensure that any further work or future versions are as accurate and robust as possible.

This one-day workshop has been designed to review the Conservation Utility Analysis (CUA) developed by Living Oceans Society and currently supported by World Wildlife Fund, Canadian Parks and Wilderness Society, Nature Conservancy Canada, and David Suzuki Foundation as one viable and important tool in the effort to identify areas of conservation interest/value, identify candidate marine protected areas (MPAs), and ultimately contribute to the conservation of marine biological diversity.

Living Oceans Society and our partner groups are not advocating that this analysis replace or supersede other analyses or initiatives that use scientific information to identify MPAs, or more broadly, areas of conservation interest. However we do believe that the CUA, combined with other approaches, will play an important role in the efforts to establish a network of MPAs and carry out integrated marine planning.

Living Oceans Society and our partner groups believe that using biological, ecological, and oceanographic data to identify MPAs and other areas of high conservation value should be only one tool in the effort to establish a comprehensive ocean management plan that includes a network of MPAs. We also need tools to identify, address and integrate social and economic values and interests. We fully support the work of other agencies and organizations to develop additional tools and approaches, and we are actively leading our own projects that incorporate the socio-economic needs of commercial and recreational fishermen and the cultural and traditional needs of the First Nations. Descriptions of these initiatives are located in Appendix 3.

Conservation Utility Analysis Review Meeting

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A review of the techniques, methods, inputs and assumptions of the CUA with a select group of 8–10 modeling and GIS experts to develop guidance for a work plan for Version 2 of the CUA.

Objectives

1 verification of assumptions used in the analysis or refinement of the assumptions

2 identification of key technical issues and solutions / methods to address them

3 identification of input data-related issues

4 guidance for the development of Version 2 of the CUA

Study Area

The CUA was designed to be applied at both a regional and coast-wide scale. To date Living Oceans Society has applied this analysis approach twice: initially in the Central Coast as a pilot project (2000–2002) and later as part of the Coast Information Team (CIT, 2002–2003) encompassing the coast of BC, extending as far as the edge of the continental shelf, with the exception of the Strait of Georgia.

This workshop will mostly focus on the second analysis, which was applied to the Central Coast, North Coast, and Queen Charlotte Islands under the CIT. This focus was chosen for two reasons:

- The CIT CUA represented a refinement of the pilot study Central Coast CUA, based on reviews received of that analysis.
- The CIT region has almost the same boundaries as the Pacific North Coast Integrated Management Area (PNCIMA), which is Fisheries and Oceans Canada's priority area for integrated marine/ocean planning in BC.

Conservation Utility Analysis

Goal & Objectives of the Conservation Utility Analysis, version 2

The goal of the Conservation Utility Analysis (CUA) is to identify options for marine protected areas (MPAs) and other conservation measures for the coast of BC based on marine reserve design theory, employing available biological, ecological, and oceanographic data.

Its objectives are to:

- Use the best available information, including the latest in marine reserve design theory, and biological, ecological, and oceanographic data
- Produce, when appropriate, classification systems that realistically represent the known physical and biological structures and processes
- Utilize methods that are transparent in their application and produce results that are repeatable
- Faithfully reflect the accuracy and scale of the data
- Incorporate design attributes that can accommodate additional information a a later date
- Consider existing parks, areas of interest, and year-round fishery closures

- Acknowledge the various human uses of the sea while still meeting conservation objectives†
- Allow for a variety of solutions

†*Work developed to meet this objective includes the Fisheries Use Analysis and the First Nations Traditional Knowledge Analysis. The long-term goal is to integrate these analyses with the CUA to identify a network of MPAs that minimize economic dislocation and incorporate cultural and traditional needs.*

History of the Development of the CUA

September 1999

Living Oceans Society hosted a workshop to discuss prevailing theories of MPA design. Scientists met in Sointula to discuss the principles of design for marine protected areas. Below are the decision points that were drawn from the workshop and used to develop the Goals and Objectives for the Conservation Utility Analysis.

The goal of marine protected areas

There is a long-standing debate on whether MPAs are designed for the conservation of biological diversity or the development of sustainable fisheries. Sustainable fisheries rely on the continual production of fish. This, in turn, relies on maintaining ecosystem function. However, defining ecosystem functioning is tough and largely beyond our present abilities. Therefore, until our knowledge of the sea increases, the best we can do in most cases is protect biological diversity.

Principles of design for a network of MPAs

The goal of a network of marine protected areas is the conservation of biological diversity and the development of sustainable fisheries. A network of MPAs should be better than the sum of its parts and should:

- Include core no-take zones
- Represent all habitat types
- Include replication of all habitat types
- Include distinctive features
- Protect rare and endangered species
- Locate no-take zones close enough to anticipate larval transfer and "connectivity"
- Locate no-take zones far enough apart overall to avoid localized disasters such as oil spills

Marine planning

MPAs, while necessary, cannot alone conserve biological diversity and develop sustainable fisheries. MPAs should be established within the context of Integrated Management to ensure that the management of marine resources outside of MPAs complements the goals of the MPAs. However, Integrated Management is a huge undertaking, and the development of the process must not delay the identification and establishment of marine protected areas.

MPA Design Workshop Participants†

Dr. Callum Roberts,
University of York, York, England

Dr. Peter Auster,
National Undersea Research Center,
University of Connecticut

Dr. Elliott Norse,
Marine Conservation Biology Institute

Dr. Colin Levings,
Fisheries and Oceans Canada

Dr. Tom Tomasick,
Parks Canada

Dr. Rod Fujita,
Environmental Defense

†Participants from the provincial government and World Wildlife Fund were invited but were unable to attend

Focal species

The use of one or two megafauna as the main focus for designing a network of MPAs could fail to identify many habitat types. A better choice would be a suite of focal species that are linked to a variety of habitats through their life cycle.

Sources and sinks

Identifying sinks and sources requires a massive amount of information that is not presently available, so this is not a criteria in the current MPA design. However, we can assume that any no-take area will be a source for some species.

Size, area, and distribution

There is no definitive answer on how many MPAs we need, nor how large they should be. We need to start establishing them in order to learn more about the impact of size, area, and distribution. However, a general rule of thumb is to design no-take areas to be as large as possible and still be supported by communities and user groups.

Enforcement

An MPA without the support of user groups will not be enforced (especially in remote areas), and therefore it is paramount to build approval amongst First Nations, fishermen, and other user groups for each site.

Spring 2000

Living Oceans Society hosted a meeting of conservation organizations to build agreement on a common definition of a marine protected area.

Definition of a marine protected area

A marine protected area consists of one or more core no-take areas and should be surrounded by a buffer zone. This means the following levels of protection would apply:

- Core no-take areas that prohibit all fishing, exploration and extraction of oil, gas, and minerals, open net-cage aquaculture, bottom trawling, dumping, and dredging
- Buffer zones that, at a minimum, prohibit exploration and extraction of oil, gas, and minerals, open net-cage aquaculture, bottom trawling, dumping, and dredging
- Case-by-case prohibition of additional stressors (such as sewage outfalls, log booming and dumping, recreational artificial reefs, and whale watching) as needed

In this report, the word "reserve" was used interchangeably with core no-take MPA.

Spring 2000 – October 2001

Based on the principles of design and the definition stated above, Living Oceans Society developed a methodology for identifying candidate marine protected areas. This involved 18 months of reviewing data, other methodologies, and the real-world conditions of the BC coast. Ultimately, Living Oceans Society designed the CUA methodology using MARXAN software to analyze many layers of data.

Living Oceans Society applied this methodology on the Central Coast region of BC, and the results were published in the report *Modeling a Network of Marine Protected Areas for the Central Coast of BC*. This report can be downloaded from http://www.livingoceans.org/mpa/index.shtml. The Central Coast region was chosen for three reasons:

- Living Oceans Society is based in the Central Coast and therefore we have a good understanding of the region.
- The provincial government was conducting the Central Coast Land and Coastal Resource Management Plan for this region, so our analysis could inform that planning process.
- The federal government had identified the Central Coast as the priority area for Integrated Marine Planning.

June 2002

Living Oceans Society identified a team of MPA design experts to review the Central Coast Pilot Study. Participating scientists were sent copies of Modeling a Network of Marine Protected Areas for the Central Coast of BC along with a series of topics for them to consider. The comments and recommendations from these scientists can be viewed in Section 2 of this document.

Central Coast Pilot Study Expert Review Team

- Dr. Callum Roberts, York University, England
- Dr. Sataie Aramie, Channel Island National Marine Sanctuary, California
- Dr. Reed Noss, University of Florida
- Dr. John Roff, Acadia University
- Dr. Barbara Dugelby, Independent Consultant, Texas
- Dr. Ian Perry, Fisheries and Oceans Canada, Nanaimo

July 2002 – March 2004

Living Oceans Society was contracted to conduct the marine portion of the Coast Information Team (CIT) Ecosystem Spatial Analysis (ESA).

The Coast Information Team brought together the best available scientific, traditional, and local knowledge to develop independent analyses to inform terrestrial ecosystem-based management (EBM) in the north and central coastal region of British Columbia, including Haida Gwaii/Queen Charlotte Islands. This included an Ecosystem Spatial Analysis using SITES and, later, MARXAN software. Because the land and sea are interconnected, many CIT participants, especially the First Nations, identified the need to extend the ESA to include the nearshore and marine environment.

Living Oceans Society was selected to complete the marine portion of the CIT ESA because we were the only organization in BC that had developed a methodology for a marine ESA. Furthermore, our approach used MARXAN, which is a further refinement of the SITES software that was being used in the terrestrial analysis, and would therefore integrate well. (The terrestrial analysis eventually stopped using SITES, in favour of MARXAN.) Many of the comments raised during the technical review of the Central Coast Pilot Project were addressed in this second larger analysis, which covered a much larger region – the entire coast of BC, with the exception of the Strait of Georgia.

The information from the CIT was reviewed by technical experts. Due to the terrestrial focus of this process, no marine experts were brought in to review the marine portion. Nonetheless, there were some comments made on the marine portion of this study. The results of this review can be found in Section 3 of this report.

The results of all CIT studies were provided to the three sub-regional Land and Resource Management Planning (LRMP) tables and the several First Nations Land Use Planning (LUP) tables to assist them in developing practical recommendations to resolve land use and natural resource management issues. Ultimately, however, the LRMPs and LUPs did not address marine issues, and therefore the analysis completed by Living Oceans Society was not used in decision making.

It was during its work with the CIT that the Living Oceans Society analysis or marine ESA was renamed the Conservation Utility Analysis.

June – September 2005

The lack of progress in establishing MPAs, coupled with Fisheries and Oceans Canada's decision to develop an integrated marine planning initiative in the Pacific North Coast Integrated Management Area (PNCIMA), led to a series of meetings of BC's environmental non government organizations (ENGOs). At these meetings existing and future tools for identifying a network of MPAs were discussed, including the Conservation Utility Analysis. The participating groups, including World Wildlife Fund, Canadian Parks and Wilderness Society, Nature Conservancy Canada, and the David Suzuki Foundation, agreed that the Conservation Utility Analysis is one tool that provides a variety of solutions for identifying a network of MPAs.

At this meeting it was agreed that another, more broadly based, technical review that included leading GIS experts and scientists from British Columbia would help strengthen further revisions of this analysis.

Conservation Utility Analysis Central Coast Pilot Study: Results of the Expert Review (2002)

Selected Reviewer Comments From Central Coast Pilot Study

Reviewers

- Satie Airame
  Channel Islands National Marine Sanctuary
  Santa Barbara, California
- Barbara Dugelby
  Independent Consultant
- Reed F. Noss
  Davis-Shine Professor of Conservation Biology
  University of Central Florida
  Orlando, Florida
- R. Ian Perry
  Fisheries & Oceans Canada
  Pacific Biological Station
  Nanaimo, BC
- Callum M. Roberts
  Professor of Marine Conservation Biology
  University of York, UK
  Pew Fellow in Marine Conservation
- John C. Roff
  Canada Research Chair, Environment and Conservation
  Acadia University
  Wolfville, NS

Responses

Jeff Ardron, MSc

Jeff is the primary author of this methodology and report. He worked for Living Oceans Society (LOS) for six years and is retained by LOS as a consultant. He is currently employed as the Scientific Advisor on Marine Protected Areas for the German Federal Agency for Nature Conservation. He is also Secretariat of the MPA Intersessional Correspondence Group for the OSPAR marine region (NE Atlantic) and is Vice-President of the Pacific Marine Analysis and Research Association (PacMARA).

Notes

Note that some of the following comments have been edited for length and/or clarity.

JAA

The Living Oceans Society / Coast Information Team marine Conservation Utility Analysis (2003) followed the Central Coast analysis (2000). Many of the Central Coast reviewers' comments were incorporated. For reasons of brevity, this newer analysis has been shortened to "CUA" in my responses below.

Overall Review of Report

Perry

It is a good report, with careful analyses and results that are reasonable, based on the available data. It should be very helpful in stimulating discussion of conservation hotspots, and starting a debate on the purpose and arrangement (size, proximity, etc.), and even the definition, of protected areas in the Central Coast.

I have concerns with the issue of connectivity among sites and with some aspects of data sources and assumptions and limitations. The model also needs further examination to determine its sensitivity and weaknesses to the available data. On the whole, however, I find no reason to reject the model or the report.

JAA

Yes, the reviewer is correct in noting that connectivity has not been directly addressed. At present, there are three problems hampering the proper consideration of connectivity: 1) the lack of dispersal data (both larval and mature) for most BC species; 2) an inadequate understanding of dispersal mechanisms; and 3) a lack of models to consider dispersal from a collection of sites. Having said that, there are best practice approaches that can help. Foremost, the MPAs should be spatially well-distributed, taking into account proximity to each other, allowing for a "stepping stone" effect. Secondly, similar habitats should be replicated, allowing for associated species to mix genetically, rather than becoming isolated. In the Conservation Utility Analysis (CUA), both spatial proximity and habitat replication were considered.

The reviewer also mentions sensitivity to weaknesses in the data. In the CUA, this was partially explored, through the simple removal and addition of datasets. Generally, reserve selection models are sensitive to data in data-poor areas, but less sensitive in data-rich areas, where there are several considerations in MPA selection. Also, features that are given a high penalty value tend to direct the algorithm. A good example of a data-poor region and a high-penalty feature is the hexactinellid sponge reefs in Queen Charlotte Sound. In this case, the reefs clearly are "seeds" around which reserves grow to collect other features.

Dugelby

It appears you have developed a well-grounded approach for MPA design, considering the young age of the field and the relative lack of model MPA projects.

One of the general weaknesses of the report is the lack of published references supporting critical statements or assumptions. Throughout the document, I found myself asking the question "how do other scientists and practitioners in the field feel about this statement or assumption; is there consensus or evidence supporting it?"

JAA

I feel that this comment has been better addressed in the CUA. However, as time passes, more such references do become available from similar work elsewhere.

In terrestrial reserve design, a three-track approach used by Noss and others includes special elements, focal species, and representation tracks. You discuss the possibilities for applying the latter two tracks, but not the special elements. I think that in the marine realm, the special elements track would prove quite effective. Indeed, many of the features you mention could be considered special elements: estuaries, salmon and herring holding areas, kelp beds, etc.

JAA

This was addressed in the CUA, under the guidance of Reed Noss, using the approach developed by The Nature Conservancy.

Roberts

This is a superb report that applies the latest in thinking and technology to designing candidate networks of marine protected areas in central British Columbia. The overall approach represents an example of current best practice in the design of protected area networks. Throughout the text the authors have been scrupulous about stating the limitations and assumptions of all the analyses. Such transparency and honesty will be of great value in presenting these proposals to stakeholders and in eliciting their participation in planning and implementation of protected areas.

Noss

I think the general comparisons made to terrestrial conservation planning (e.g., focal species, connectivity, etc.) are valid. An interesting specific comparison will be with the CIT effort for the coastal ecoregions.

Roff

The report is a good start and a valuable contribution to West Coast planning. It contains several novel and thoughtful ideas, and is dispassionate in its approach. It is generally transparent in its objectives and methodology, and the sub-sections on assumptions and limitations are particularly valuable. However, I would very much like to see whether other approaches would yield similar results (yes, I saw the comparisons you presented). Just as you have made many runs of a single model type to converge to these present results, so we should look for convergence of plans for a network of MPAs from several model types.

JAA

Since the time this review was written, Fisheries and Oceans Canada Pacific has published a PSARC report (Evans et al 2004) which recommends MARXAN as the most appropriate option for meeting the needs of Oceans Act MPA selection.

The term "connectivity" in the title is misleading: you really have not addressed this issue to any degree. Where do you consider the genetic level of biodiversity in this report?

JAA

I address the connectivity issue in response to Perry's comment above. Genetic biodiversity was not considered simply because there are no such data, except perhaps for salmon, which is still quite controversial. For salmon, a modicum of diversity was sought through the stream classification system (CUA Appendix 2) and bioregional representation.

What you really have here is one scenario for the selection of a set (not a network) of MPAs. It has been developed by a series of apparently logical steps, using one set of algorithms. However, we do not know its virtues, nor do we really know what is captured in terms of overall biodiversity.

JAA

Agreed, the term "network" could have been misleading. The CUA has made it clearer that the initial results are a first iteration in a MPA selection process. Conservation Utility (CU) can only identify the most useful sites. Once these are selected, then in subsequent iterations full representation of biodiversity can be addressed. Having said that, the reviewer is correct in identifying the need to more clearly list what is and is not being represented. This will be addressed.

Remember: All MPAs should not be created equal! They can be established to accomplish different primary functions, and then perform various secondary roles. You have not explored this.

JAA

This comment relates to the proper management of MPAs. We did not attempt to cover this in the CUA, believing that addressing management considerations would be a subsequent step, after the identification of sites.

B. Introduction

B.1 Report Overview

Roff

I am not a fan of hybrid classifications. My preference would be to use biological and physical data separately.

JAA

Neither analysis actually used hybrid classifications. Rather, biological data were treated separately.

Saying the model appears to be "on the right track" is a loaded statement. What you apparently mean is that your outcomes for recommended MPA sites shows similarities to other studies.

JAA

The similarity of the analysis results to other expert identifications of sites was felt to lend support to the model.

B.2 Marine Conservation

Dugelby

Threats to the marine realm need to be more fully described and analyzed (you do not even mention pollution here, but I'm sure it's a major threat to most marine areas).

JAA

A threat/risk analysis is a necessary component of MPA selection and management. However, we simply did not have the resources to do this. Whether such an analysis should be part of the MARXAN selection, or subsequent to it, is a question worth exploring.

Perry

There is a tendency early in the report (e.g. p. 4) to suggest that focal species have to be megafauna – this is absolutely incorrect, and is corrected later in the report.

JAA

This has been addressed in the CUA.

Roff

The focal species approach can be used very successfully for areas where local seasonal use is made of resources (see Roff and Evans). An additional advantage is that such areas can be specified in terms of process and size. My approach would be to fix distinctive areas (based on focal species, endangered species, fisheries, anomalies, processes, etc.) first, then conduct further analysis of representative areas to anneal them around these areas. This could be done either with MARXAN or in a simple ARCVIEW program.

JAA

The advantage of MARXAN is that it allows distinctive and representative areas to be optimized together. Separating them out would, in my opinion, reduce the efficiency of the model. That said, MARXAN tends to build up sites around high priority areas that act as "seeds." Thus, in effect, the reviewer's outcome is achieved in any case. MARXAN also will keep an inventory of what was captured for each feature, so it can be checked to make sure the desired distinctive areas were indeed included.

B.3 Project Goals and Objectives

Dugelby

These are not biological conservation goals; they are process goals. Perhaps you should have two sets of goals and objectives: process goals and conservation or biological goals. The biological goals clarify what you hope will be achieved over the long term by the larger MPA effort (i.e., including and beyond the scope of this report). I realize that this report is meant to provide input and/or guidance to a multi-stakeholder process and you are hesitant to appear as trying to predetermine the outcomes of that process, but it is still important to be transparent about your biological/conservation goals for the overall campaign.

JAA

These process "goals" were not included in the text of the CUA.

Noss says that goals and objectives should be stated in quantitative terms when possible so that progress toward achieving them can be measured. I agree, although I think that the quantitative issue is much more important at the level of the objective. Each objective should be linked to one or more of the goals.

JAA

These process "goals" were not included in the text of the CUA.

Noss

The stated goals are really more planning and implementation objectives than fundamental conservation goals. The stated objectives sound more like action items or implementation tasks. I suggest relating these goals and objectives explicitly back to the Ecosystem Objectives of Fisheries and Oceans Canada from the previous page. How will your goals and objectives fulfill these fundamental biological and ecological goals? That's the key consideration.

JAA

These process "goals" were not included in the text of the CUA. Fisheries and Oceans Canada goals were not included in the CUA because the work was not for Fisheries and Oceans Canada, but rather for the province. In the Coast Information Team report, such goals were included. However, in my opinion, they were rather lofty, and I did not include them in the excerpted and expanded CUA report under consideration. More realistic goals could be added, as will likely be discussed at the November workshop.

C Background

C.4 Human Impacts

C.4.1 Over-Exploitation

Perry

The implication that sardine stock declines are due to overfishing should be balanced by comments on the strong environmental control on this species –they thrive when waters are warmer and do poorly when waters are cool. Therefore, with the recent return to cooler water temperatures, we expect sardines to do poorly even without fishing.

JAA
This paragraph has been removed the CUA report.

Have cruise ship strikes of marine mammals been documented, or is it supposition extrapolated from other places?

JAA
This paragraph has been removed the CUA report.

C.4.3 Water Quality

Perry

Logging can cause siltation problems into local coastal areas, and different runoff characteristics. This point speaks to a need to integrate marine with land use planning, as the report recognises in the Discussion.

JAA
This paragraph has been removed the CUA report.

Sea lice are not euphausiids, although both are crustaceans.

JAA
This paragraph has been removed the CUA report.

C.4.4 Introduced Species

Perry

Note that some species introduced to the region decades ago are now the subject of major fisheries (e.g. Manila clams).

JAA
This paragraph has been removed the CUA report.

C.5 Marine Protected Areas

C.5.2 MPA Design Principles

Roberts

Some other MPA principles have been suggested in studies, such as avoiding areas where human threats are too great, avoiding foci of natural catastrophes (such as low oxygen events), including sites that provide high levels of ecosystem services to people (such as shoreline protection by marshes or dunes), and including areas of high production. However, the omission of these as stand-alone criteria in no way undermines any of the conclusions drawn.

JAA

As also mentioned earlier, a threat/risk analysis is necessary. The question open for discussion is whether it should occur during initial identification of sites, or afterwards during selection. The CUA's primary purpose was to identify sites to be used as a first round in discussion, not to select a final network.

Perry

Some of the criteria for size, area, and distribution will be species-dependent. For example, an MPA primarily for abalone could be much smaller than an MPA for herring or eulachon. It comes back to the question of understanding the objective for each MPA. One way around this scale issue is to consider the critical habitats in the life cycles of species to be protected, and to try to protect these smaller areas, rather than very large areas which may have little public support. To some extent you come to this idea later in the report.

JAA

Agreed.

At the top of p. 15, you state that the goal of an MPA network is the conservation of biological diversity. I agree with the general intent, but feel it is too vague in practice. How do you define "biological diversity"? Number of species? As you point out in your later analysis, diversity says nothing about abundance. So what is the principal objective? Are there key species that you see as being in danger that need protection (e.g. rockfish)? It seems here you really want some broad general goal such as "ecosystem health" – but that too is not well defined (or measured!).

JAA

The reviewer has raised a good point. The measurement of most political and management objectives remains difficult to impossible. In the CUA, it was assumed that capturing representative and distinctive areas would serve as a proxy for biodiversity. This is a common assumption made in studies worldwide, but so far as I know, it has not been thoroughly tested.

Roff

The goal of MPAs is not really an either/or debate. Marine conservation can achieve several goals simultaneously. At least some ecosystem level functions can be identified, defined spatially and temporally, and linked (at least seasonally) to migrant focal species. This is a large part of the concepts in Roff and Evans. Certainly without consideration of ecosystem-level processes you will not get connectivity.

JAA

Agreed. As discussed above, due to a lack of data, connectivity was not explicitly considered. Rather, proximity and replication were used as proxies.

Airame

Why begin the section on the goals of MPAs with the assumption that there is a conflict between conservation and sustainable fisheries? Perhaps you could focus on the concept that long-term sustainability of fisheries requires conservation.

JAA:
This paragraph has been removed the CUA report.

Consider other principles of design, such as biogeographic variation.

JAA
This was considered in the CUA.

C.5.3 Definition of a Marine Protected Area

Roff

The definition you cite is an older concept. Why core and buffer areas? What do they separately achieve?

JAA
This paragraph has been removed the CUA report.

C.6 Site Selection

C.6.1 Overview

Noss

I think that complementarity, rather than irreplaceability, was the main guiding principle in later heuristics, along with efficiency.

JAA
This paragraph has been removed the CUA report. In any case, they are quite closely related, and I would not argue with the reviewer.

C.6.2 MARXAN Software

Roff

I have not been impressed with the outcomes of MARXAN, but this may be due to our lack of experience with the program itself. I think it can be a powerful tool, but I suspect that it needs a great deal of expertise to use it well (which Ardron certainly has).

JAA
I agree that a degree of expertise is required, and that use of the tool is only as good as that of the data and analyst. Since the time that the reviewer made this comment, I would say that both he and others have become generally more comfortable with MARXAN, which was at the time a very new tool.

D Assumptions and Limitations

Dugelby

I was quite impressed with the assumptions and limitations section. Never before have I seen such a careful, thorough, and honest articulation of a research project's limitations and assumptions.

D.2 Best Available Data

Dugelby

By all appearances, you have obtained an amazing amount of data given the paucity of research and publications for the region. You have also done an excellent job acknowledging the various limitations of this data (by dataset in many cases!), while outlining goals for obtaining higher quality and additional data in the future.

Roberts

Such models are only as good as the data and assumptions that underpin them, and it is therefore necessary to be sure that the inputs are robust enough to warrant the conclusions. It is clear that the authors have been extremely careful to gather the best available data for the exercise. Addition of new data will help refine the model, and may lead to the detection of new areas of conservation importance.

The major omission in this analysis is the lack of data on patterns of human use of the region, and the authors recognize this problem. Such data will be of great value in taking the process of reserve designation through the stakeholder and agency input phases on the path to implementation.

JAA

Living Oceans Society, as led by the author, has since that time conducted interviews with fishers, and has developed methods to include this local knowledge into the analysis. This was not done in the CUA; however, this possibility will be discussed at the November workshop.

Perry

You have done a good job at gathering what data you could. The disadvantage is your reliance on pelagic fish species, e.g. salmon and herring. Have you looked at the broader fish catches (including groundfish and invertebrates) by statistical sub-area? Although not spatially detailed, they are perhaps somewhat like substrate data, and you might find them useful at least for verification. Another approach would be to build the trust and involvement of the fishing industry, to obtain log-book information directly. Presumably you are building these bridges now anyway by exploring local fishing knowledge, and you will need to build them when it comes to discussions on implementing an MPA network.

JAA

Obtaining fisheries data remains an ongoing issue. Since the time of the CUA, Living Oceans has received trawl data and some rockfish data. These could be included in a new version of the CUA, if the current reviewers see this as appropriate.

Roff

I am not sure that this is the best available data. In discussions with Mark Zacharias, I have been led to believe that much other data on biological community types and physical processes (or their surrogates) is available.

JAA
The reviewer is likely referring to the provincial shorezones, which were not available for the Central Coast analysis. The shorezones were, however, used in the CUA.

Airame

I recommend that you continue formal discussions with stakeholders to obtain a database of ethnographic knowledge. In the Channel Islands, we conducted interviews with various stakeholders to determine the level of their experience, their main occupation, the location of their activities, their perception of the status of resources they use, and their observations of any changes that may have occurred in those resources over time. We asked people to draw the locations of activities on maps, which were subsequently digitized. We cross-checked the information about particular resources by interviewing several individuals with similar backgrounds. This is probably the cheapest and most effective way of obtaining missing data, although they may be quite coarse.

JAA
Agreed. This process has been ongoing since 2002.

D.3 Habitat Representivity

D.3.2 Limitations

Perry

For highly mobile and migratory species, the representative habitat approach can be used, but "habitat" should be defined differently from terrestrial uses – i.e. based on oceanographic conditions rather than geographic conditions such as related to bottom type and features.

JAA
Agreed. Such data were not available for the CUA. It is possible some might be available for a revised version, though this would have to be investigated with Fisheries and Oceans Canada.

D.4 Focal Species

Roff

Migration is not the issue with applying the concept of umbrella species to marine systems. The important point is the areas that such species use on a seasonal basis.

JAA
Agreed. I'm not sure what the reviewer is referring to exactly, but the CUA approach tried to follow this.

Perry

I would not consider clams as focal species in the sense that you seem to use, but as indicator taxa for the presence of sandy beaches. It is not a good group to represent changes of impacts to sandy shores, because it includes several different species often with their own habitat characteristics.

JAA
This feature (clams) was removed the CUA analysis.

D.4.1 Assumptions

Perry

I presume you have selected the species mostly because of available data; they may not necessarily be characteristic of particular habitats. The idea of focal species is to find a few that represent the habitat requirements and responses of a larger number of species. Therefore assuming species used in the analysis to be focal species seems redundant at best, and more likely wrong. I think you would do better to ask specifically what each species for which you have data represents, and if other species might have similar habitat requirements. For example, marbled murrelets seem to represent themselves, as perhaps do salmon.

JAA

A good point. However, the fact remains that one cannot include species for which there are no data. In the absence of such data, some less than ideal focal species may have to be employed. There is, unfortunately, a divide between theoretical ecology and pragmatic analysis. The Precautionary Principle dictates that we try to make do as best we can with what we know currently, while remaining open to new data as they emerge.

D.6 Distinctiveness

Noss

The representation objective, as often applied in the past, does not require setting aside large areas. Unless it is specified that examples of a given feature have to be of some minimal size in order to be counted as representation, very small units might be chosen. Moreover, in modern approaches to representation, the goal is generally to represent the full spectrum of environmental variation (i.e., complete environmental gradients at relatively fine resolution). Therefore, "distinct" areas should be captured under this approach – they don't have to be representative of an entire region.

JAA

This reviewer appears to disagree with the reviewer below. To err on the side of caution, both a distinctiveness and representative approach were used.

D.6.1 Assumptions

Roff

Such distinctive areas show anomalies of various sorts. This is a complex area that has not yet been tackled.

D.8 Connectivity

Perry

I think that connectivity among the sites needs to be looked at explicitly, either within or outside of this model, as a full analysis of the appropriateness of these hotspots as MPAs. The issue of connectivity is discussed briefly in the report, concluding that there is insufficient data to assess. In fact, there have been a number of studies modelling the circulation in this region, in particular by Drs. Mike Foreman and Patrick Cummins of DFO (I.O.S., Sidney). Some of these have been published. There was also a 1980s tidal circulation model built by Dr. Pat Crean (formerly of U.B.C., now retired) for at least part of the area, although I doubt it includes the inner passages. The issue of connectivity seems important because there is no point in making a sink into a reserve area without also protecting its source. I do not agree with the comment that a sink for one species will be a source for another – this might be true in open waters, but in high-current areas with limited directions such as the Central Coast, through-flow and loss of animals (larvae) could be an important issue. Dr. Cliff Robinson of Parks Canada and Mike Foreman have recently looked at connectivity in this region.

JAA

The reviewer is helpful in giving these references. However, despite several attempts by the Coast Information Team (CIT), a cooperative agreement between Fisheries and Oceans Canada and the CIT was not achieved, and remained ad hoc at best. The CIT simply ran out of time to pursue the matter any further. I would urge Fisheries and Oceans Canada to cooperate more with external analyses such as these, but the issue is really out of our hands.

I agree that more categories are needed than just >3 kts.

D.9 Fragmentation

Roff

The report does not adequately address the issue of size of MPAs. This is a tractable problem, but there is no unique solution (see my draft SEPA report on this subject). There are many criteria that can potentially be used to define size.

JAA

In the CUA, the issue of size is for the moment put aside by exploring a range of sizes, and looking at the emergent trends.

D.10 Benthic Complexity

Perry

How much different would the model results be if you used a more standard measure such as roughness? The assumption that varying habitat leads to more niches leads to taxonomic richness and more organisms is central to the interpretation of much of the analysis. However, other factors than just benthic complexity will also be involved. For example, consider mountain tops (which the report briefly mentions later), which have great benthic complexity but low diversity when compared with lowland valleys. The additional key factors are physical conditions such as temperature and moisture. The same is likely true for complex marine conditions. I suggest that the importance of benthic complexity is sufficiently central to the analysis that it should be tested – the question is how. There may be a way to examine this in a general sense by looking at catch statistics by statistical sub-areas, and comparing sub-areas with high versus low benthic complexity. What data were used to calculate the complexity analysis? Are the soundings data dense enough, or have you used interpolated fields (which will have low complexity)?

JAA

Since the time of this comment, complexity methods and appropriateness with regard to rockfish have been investigated and published, although more work could certainly still be done. See the following two peer-reviewed publications:

Ardron, J.A., (2002). A Recipe for Determining Benthic Complexity: An Indicator of Species Richness. In Joe Breman (Ed.), Marine Geography: GIS for the Oceans and Seas (pp. 169-175). Redlands, CA: ESRI Press.

Ardron, J.A. & Wallace, S. (2005). Modelling Inshore Rockfish Habitat in British Columbia: A Pilot Study. In Dawn Wright and Astrid Scholtz (Eds.), Place Matters: Geospatial Tools for Marine Science, Conservation, and Management in the Pacific Northwest. Eugene, OR: University of Oregon Press.

Roff

This is an interesting and well argued section. I take many of the "assumptions" under advisement. However, as for slope analysis, complexity is scale dependent. This is really a fractal (cross-scale) problem. The analysis here is probably as good as we can do with the available data. If we must work at a single local scale, then complexity may be a more informative measure than rugosity or slope.

D.11 Scale

Roff

I am not comfortable with the whole set of issues relating to boundaries in MARXAN.

JAA

The use of boundaries has been made more sophisticated in the CUA and will be explained in the November workshop.

D.11.2 Limitations

Roff

I still consider it vital to separate water column and benthic realms.

JAA

Agreed. It is only a lack of access to such data that prevents their inclusion.

E Methods

Perry

There is a tendency to suggest that because the results of these thousands of runs converge, the results must be "real." However, while there is a stochastic component to each run, they are each based on the same data and often the same parameter values, so they are not truly independent analyses. While the details may vary, the general features are likely already there. The classical way to build and test models against data is to build the model using only part of the data, then test them using the reserved part. In this case that doesn't seem to be a practical approach (although if there were some way to do this, it would present a very compelling set of results!).

JAA

As mentioned above, some basic sensitivity analyses of the sort suggested by the reviewer were performed in the CUA. However, more could be done. As discussed above, the sensitivity of the model varies according to the data richness or data scarcity of an area, with data-scarce areas being much more sensitive to the addition or removal of data.

I believe it is important to verify the model results – or if these can't be verified in a truly independent way, then to at least understand fully the sensitivity of the model to the assumptions and to the data in particular. For example, Table 5 indicates relatively high target and penalty weightings applied to alcid birds and benthic complexity. To what extent are the results driven by the high weightings for these input variables? If the results are robust to these sorts of changes, then it instills greater confidence that the model is not dependent on a very few variables and how they are measured.

JAA

See comments in above para.

Another way to assess the model performance is to alter your input data sets. For example, you could run the model leaving out some particular set of data entirely, and examine how much the results vary from your base case with all the data included. This will provide understanding of exactly which data appear to be strongly influencing the model. If these data are also poorly determined, then it shows a clear need for improving these data (or down-weighting them heavily so they are not as influential). For example, the sponge reefs and sea otter haulouts seem to have strong influences in the outer coastal waters. While the sponge reefs are probably quite well known, critical sea otter habitat probably is not.

JAA

See comments in above para.

Dugelby

I believe you have most, if not all of the key pieces of necessary methodology represented in your approach (given the challenges of MPA design), but key information is lacking about some of the steps (e.g., details about how qualitative conservation and penalty target levels translate into quantitative levels and as well about the Trials3 analyses). The selection of what features will represent your conservation targets is one of the most critical decisions in the reserve design process. You need to better justify your selection of features (species, etc.) and discuss what other features should be included if more information becomes available.

JAA

Brief justifications are given in Appendix 1 of the CUA. These can be expanded upon in the November workshop.

Roff

The data included are somewhat arbitrary, especially in terms of individual species. There is a strong bias towards commercial fisheries that is not well justified from a conservation perspective (although it could be). The data used is also limited in its representation of biodiversity or ecodiversity. It is not clear exactly how the geophysical data on representative areas have been used or weighted in these analyses.

JAA

See above para.

Airame

An interesting question is how the model behaves when one or several of these data sets is removed. If this has not been attempted, I recommend running the model using just physical data (benthic complexity, depth, substrate, and current speed). Subsequently, each of the biological data sets could be added to the physical data to determine their influence on the model output. Are there data sets missing that could affect the distribution of potential reserve sites? Perhaps some information about the locations of other types of invertebrates, fishes, birds, and marine mammals could affect the model outcome.

JAA

Sensitivity has been discussed above.

E.2 Data Classifications

Roff

This is a rather limited data set, especially for the biological species – it is largely of commercial significance. How do you justify this from a conservation perspective?

JAA

These are the only species for which we had data.

E.2.1 Geographic and Oceanographic Spatial Hierarchy

Roff

This is very thoughtful and may be the preferred approach and use for data.

Airame

The classification of geographic and oceanographic data appears to be appropriate. The classification of tidal current appears to be somewhat limited. The relative importance of various areas for salmon and herring appear to be quite rigorous, but again, possibly exaggerated by conversion factors. The classification of important areas for birds appears to be quite sparse, at best. Data on rare and endangered features may strongly influence the model output, and these data should be used only when goals for MPAs indicate that their use is critical in the design process.

Airame

I agree that hierarchical classifications can perpetuate and magnify errors in the data. Most of the data used by the authors are not inherently hierarchical.

E.2.2 Regions & Subregions

Roff

My continued preference is to consider estuarine types separately from fully marine waters. You have combined them together, which is not my preferred approach, but given the nature of the area is reasonable in BC.

JAA

Circulation in inlets is a result of the combined effects of freshwater input and tides.

Perry

How was the boundary between passages and outside (inshore) waters determined? A number of your hotspots seem associated with boundaries between regions: both between outside (inshore) waters and passages, and between passages and inlets. One can think of several good biophysical reasons why these may be important regions, but it also indicates that care is needed in defining these boundaries so as not to introduce artefacts to the model.

JAA

The boundaries were created partially from the BC ecoregions and ecounits, and partially from visual interpretation of depth and geographical features.

E.3 Physical Features and Enduring Processes

E.3.1 Benthic Complexity

Roff

Complexity is scale dependent. This is really a fractal (cross-scale) problem. The analysis here is probably as good as we can do with the available data.

E.3.2 Depth/Substrate

Perry

I am unclear from where these data originate. In our study of the Queen Charlotte Strait region we found the density of substrate data inadequate for our analyses. Yet you have substrate (and depth combinations) in all hexagons. As you are aware, substrate type can vary between hard and sandy bottom over very short spatial scales. How much of the bottom had to be of a certain type for you to classify it as hard, sand or mud? Although substrate data are often down-weighted, the assumption that they are adequately known through the entire region (p. 66) can potentially have significant influence on the results. While these data may have been obtained from elsewhere, you should still carefully consider if they are appropriate for your needs.

JAA

After several requests for better substrate data, we received a slightly improved dataset from the province. However, I would agree that the substrate data remain an area for future improvement.

E.3.3 High Current

Roff

Currents are a useful variable, but stratification is of major significance in this area. Also, in this analysis you really have not attempted to capture (or even mention) the major water masses in terms of temperature and salinity data.

JAA

Temperature/salinity data were provided very late in the CUA analysis by Fisheries and Oceans Canada, but in a format that could not be used. Our requests for other formats were not answered.

E.4 Biological Features

Roff

You have put too much emphasis on commercial species. How do you rationalize this from a conservation perspective? Surely the emphasis should be explained better, namely to allow exploitation of biomass rich areas (usually of low species diversity), but to protect spawning and recruitment areas.

JAA

Available data, unfortunately, revolves around commercially important species.

E.4.7 Birds

Roff

How was the size of bird feeding areas defined?

JAA
Expert opinion.

E.6 Data Gaps

Perry

See comment on substrate in E.3.2.

E.7 Representing Data in Planning Units

Roff

Were analyses done on combined geophysical and biological data? If so, I do not see how this would be appropriate.

JAA
Geophysical and biological data were not combined pre-analysis, but were indeed part of the overall suite of features in the analysis itself.

E.8 Setting Up MARXAN

E.8.1 Conservation Targets & Penalties

Perry

See comment on substrate in E.3.2.

Airame

I am wary of setting penalties for failure of the model to meet various targets because the penalties are somewhat arbitrary in nature. The authors must determine the importance of various data sets and assign penalties accordingly. I suggest experimenting with the model to see what happens without penalties and a limit on total reserve size. At this point, setting targets is an academic exercise. In the implementation process described, stakeholders themselves will determine appropriate goals for MPAs, and thus the features to be included in the model and the target levels of representation for each feature.

JAA
Penalties were set in part as a reflection of the confidence we had in the dataset, and in part as a reflection of its ecological importance. This is briefly noted in Appendix 1 of the CUA, and remains open to further discussion.

In the Channel Islands, we set the targets at 10%, 20%, 30%, 40%, 50%, 60% and 70%. The higher levels of set-aside, although unrealistic for implementation, actually provided more information than the lower values. Because so much area was required for the reserve under a 70% scenario, the model selected many more potential reserve sites, offering a wider range of sites that include suitable habitat. In the Channel Islands, no limit on total reserve size was established, so the model found a set of solutions that included the largest amount of each feature. The actual distribution of potential reserve sites in any one solution was not particularly interesting to the stakeholders – they were most interested in the "summed solutions" map, showing the relative number of times each planning unit was included in a final solution, which they used to identify potential reserve sites. However, they drew the actual boundaries of each reserve themselves, without any assistance from the MARXAN model!

JAA

High targets were considered, but did not have the same effect as the reviewer describes. Rather, they tended to point out data-poor areas. The CUA used summed solutions from 5% – 50% overall area.

E.8.2 Separation Distance, Number & Clump Size

Airame

We determined that the minimum separation distance between reserves varies enormously, depending on the potential dispersed distance of the species during adult and larval stages, the availability of various habitats, and the potential risks from human activities. Thus, many scientists suggested that we identify numerous reserves of variable size and species throughout the region.

JAA

Agreed. The CUA has not actually gotten to this level of detail yet – the CUA is viewed as a first iteration for presentation to a planning table where such issues would be hashed out.

Roff

Is the minimum clump size essentially a default procedure for establishing reserve size? If so, I do not like this approach at all.

JAA

No, it is not a default.

E.8.3 Planning Unit Cost, Boundary Cost & Boundary Length Modifiers

Airame

Including the cost as part of MARXAN may be an interesting academic exercise, but it complicates the output as well. In the Channel Islands, stakeholders wanted to see the ecological value of each planning unit, independent of cost.

JAA

As the reviewer suggests, the cost function was not used in the CUA.

Roff

I do not see that planning unit cost has anything to do with marine planning. In my view it is a significant weakness of the model for marine purposes. It may have validity for decisions on tropical reserves (mainly coral reefs), but I do not see its value for temperate systems.

JAA

As the reviewer suggests, the cost function was not used in the CUA.

Roff

For temperate waters, boundary cost is not a primary issue. Borders can be adjusted later for policing purposes. Borders will naturally be very different between inlets and open waters.

JAA

The study area consisted of inlets, passages, and shelf waters. Each of these is constrained by different geographic boundaries, which reflect different scales. In general, MPAs in shelf waters would be expected to be larger than those in inlets. A parameter in MARXAN, the Boundary Length Modifier, was adjusted in the CUA to account for these differences in scale amongst the natural regions. In the CUA, the shelf slope was also included.

Roff

Boundary length should not be a major planning issue until selection is complete, when it can be adjusted as needed for management. I am very skeptical about what this all means, and its value in MPA planning in temperate waters.

Airame

In the Channel Islands, we adjusted the boundary length modifier to 1. In doing so, we found that no minimum separation distance was needed to create a suitable array of reserves.

JAA

In the CUA, several boundary length modifiers were explored. As found by the reviewer, a minimum separation distance was not necessary and allowed the model to process in a tractable time period.

E.8.4 Annealing & Heuristics

Noss

Irreplaceabilty is best understood as a quantitative measure of the extent to which each site contributes to conservation goals. Hence, irreplaceability (as measured by summed runs or summed irreplaceabilty) is especially useful for prioritizing the sites selected by an algorithm. See Margules and Pressey (2000, Nature 405:243-253).

Roff

The annealing function of MARXAN can be very useful, but this is not how I would use it. We are still experimenting with this, but I expect that our final approach will be to determine the preferred set of distinctive areas first, fix these, then anneal the desired set of representative areas around these using MARXAN or simply ARCVIEW. It is easy to let MARXAN "run away with you." Were it not for the fact that I have a healthy respect for Jeff Ardron's capabilities, I would suggest that this may well have happened in the selection of parameters here.

JAA

I believe the reviewer has altered this opinion since the time of writing.

F Analyses & Results

F.1 Conservation Hotspots

Dugelby

Your discussion of the analysis itself is clear and sufficient, but presentation of the results of this analysis and their implications for the network is lacking.

Roberts

The identification of these areas using this method offers a great complement to previous Delphic approaches to looking for candidate reserve sites. The method of detecting areas with high levels of change in slope appears to be a good way of identifying potentially important regions. The findings will have to be ground-truthed against data, but I suspect that the method will perform well as a proxy for biological richness.

Roff

This is generally a fine approach. However, I do not like the term "hotspots," which mean many different things to different people. See the classification in Roff and Evans.

JAA

The term "hotspots" was changed to Conservation Utility.

Airame

In the Channel Islands, we found the map of conservation hotspots to be the most valuable contribution to the process. It is simple, yet it provides a tremendous amount of information. Unlike a map showing potential reserves, which can be viewed as a threatening final solution, it provides the stakeholders with a tool to help them identify and draw boundaries of potential reserves. The key is to provide flexibility in the process of designing a reserve network.

F.2 SLOSS

F.2.1 Plotting Reserve Fragmentation

Roff

This is an interesting approach, but I do not believe that it is useful for reserve site selection. Clearly there must be an inverse relation between perimeter length and size of MPA. However, for selection purposes, it is size that matters. Size must be a function of purpose, and all MPAs should not be created equal. The critical issue is management, which does require a balance of number of sites and boundary shapes. However, this is a separate issue that arises later. The whole SLOSS debate is a non-issue that can be resolved by planning for distinctive and representative areas together.

JAA

This section was removed from the CUA.

F.2.2 MARXAN Penalties vs. Fragmentation

Roberts

I was impressed by the method used to achieve a reasonable level of tradeoff between meeting reserve targets and preventing too much fragmentation. While it is easier to meet targets with lots of small reserves, such networks would be impossible to manage. The set of hotspots identified provides a strong basis for a practical network of reserves because it includes units of a reasonable size and number.

Airame

I like the method you have used to identify the point of diminishing return. However, this academic exercise is unlikely to influence the final number and size of MPAs in your study area. During the process of developing potential reserve designs, stakeholders are likely to identify important areas for conservation of natural and cultural resources. They may be influenced by the conservation hotspots that you have identified. However, they are unlikely to include either several small or one large reserve because it is considered an optimal solution in the model. Stakeholders will attempt to protect the areas they value for conservation and aesthetic reasons. In contrast, they will attempt to keep certain areas open, particularly those that have economic value. Economic values are more likely to affect the actual outcome than conservation values, no matter what the model indicates.

JAA

This section was removed from the CUA.

F.3 Conflict

Dugelby

I encourage to you work with experts to further refine and develop this conflicts model, as the results may be very helpful to stakeholders once they begin bargaining and considering the impacts of alternative scenarios.

JAA

This is ongoing.

Roberts

The conflict analysis was particularly revealing, showing the impossibility of achieving targets for an adequate, representative, replicated network of protected areas when the total area to be protected is set too low. Protecting 12% of the land is clearly too low to safeguard important habitats, species and outstanding places. The analysis shows that it is also too low in the sea.

F.3.1 Irreconcilable Differences

Roff

I do not think that these differences are irreconcilable: several approaches are complementary. At this point I would resort to simple pragmatism. Fisheries science is once again leaning to setting aside protected areas, in combination with limiting catch. The proportions recommended vary from 20% to 50%, although 50% is unlikely. Assuming that MPAs can overlap with closed fishing areas, we can likely plan for >10% as reserves. In addition, we can get areas where fishermen do not go for a variety of reasons, including rough ground where they lose gear. Has mapping of trawling paths been done for the West Coast? Combining this information with your models should be a real winner!

JAA

Since the CUA, Living Oceans Society has received the midpoints of trawls from 1996–2002.

Perry

This section illustrates well the potential gaming and learning/discussion opportunities of the model. It also drove home to me the need for general agreement and understanding on what the process is trying to achieve.

Airame

This section was somewhat unrealistic. We constantly encounter the perception of large conflicts between conservation and fisheries goals where no or little conflict in fact exists. By providing a stark contrast between targets and potential impacts, the developer of the scenario actually creates conflicts.

JAA

Agreed. I was attempting to show that all sectors need to cooperate, because otherwise no solutions will exist. This section was removed from the CUA.

F.4 Existing BC Marine Parks

Roff

These scenarios are generally based on use by the largest non-migratory species – i.e. commercial fisheries. We need to explore these synergies and not think of them as mutually exclusive or irreconcilable.

Locking in existing parks is exactly the approach called for. However, I would lock in closed fishing areas and distinctive areas as well, building on what you have and conducting a GAP analysis of representative areas.

JAA

A 2000 analysis by Living Oceans Society, and a subsequent repeat analysis by Fisheries and Oceans Canada in 2005, both indicated that there are extremely few areas in BC where fishing closures actually overlap.

Airame

Currently, is there any real relationship between conservation hotspots and existing protected areas? For example, will the existing protected areas be re-examined in light of the information in the report? In the Channel Islands, the new reserve network was designed without considering existing protected areas. Once it goes into effect, old protected areas will be removed. Alternately, will Parks Canada retain existing protected areas and supplement the network with additional sites, based partially on the conservation hotspots identified by the model? In that case, existing reserves should be built into the model and conservation targets should be adjusted to account for any existing protection.

JAA

A good point. It is unlikely that parks would be removed, but this decision is clearly outside of the jurisdiction of Living Oceans Society or the CIT. We were instructed to look at conservation values only, without locking in parks.

G Discussion

G.1 The Model

Dugelby

One general concern about your methodology is whether you have adequately addressed the guideline (proposed by Noss and others) to establish quantitative goals and objectives. Very much related to this is establishment of quantitative conservation targets and penalties in the MARXAN program.

JAA

Quantitative goals were not finally settled upon. As discussed earlier, such targets appear difficult to justify. Thus, a range of targets was explored and trends were examined.

Roff

See comment on size in F.2.2.

Roff

Not only is your data of varying quality, it is rather limited. There is a much longer list of items that you could have considered.

JAA

The list of features was expanded from 61 to 93 in the CUA.

Airame

The model appears to be quite robust to small adjustments. In the Channel Islands, we also found that MARXAN was robust to small adjustments in data classification and additional data. We ran the model with various sets of data to identify the effects of each data set on the outcome. The most influential were rare habitats or species, which formed the basis for each of the core areas. The model is sensitive to over-classification of data.

p. 84 Accuracy of Results

Roff

Accuracy is not a good term!

JAA

This wording was removed from the CUA.

It is encouraging that all the Parks Canada Candidate Areas overlapped with the report's conservation hotspots. Does this convergence of several scenarios lead to confidence in what we are doing, or the suspicion that all scenarios are wrong?

JAA

I tend to view it as a positive sign, although because science always has a degree of uncertainty, this cannot be stated as a fact.

G.2 Implementation

Perry

The discussion of MARXAN implies that it is specifically designed to develop a network of possible protected sites, which means that any one site on its own may be sub-optimal. This is a key point for the conclusions, which is not brought out clearly enough. Therefore, it should not be seen as effective if an agency picks some locations but not others (although this is not to say that all must be implemented). This makes implementation more difficult, but may mean that any individual MPA could be smaller than that area might be if it was an MPA on its own.

JAA

Agreed. The wording "network" has been removed.

G.2.1 Recommendations

Perry

MPA objectives are a topic that perhaps needs more thought. You clearly state your definition of a core marine protected area (p. 87), but it is very general. You might get further if you were clearer as to which species, or perhaps which types of characteristics (e.g. low mobility benthic invertebrates such as abalone), you are trying to protect with each MPA. I understand the intent to conserve biodiversity, but to me it is too general. You might get further, at least initially, if you were to have some specific focal species in mind to represent each area and could argue the merits of each area for that species.

JAA

Agreed. It was envisioned that this would be a subsequent step – a part of developing management objectives – once general sites were selected. Otherwise, a lot of time and effort could be wasted creating management plans for areas that a planning table would not accept anyway.

K Appendix 2: Classifications & Hierarchies

Roff

This is a very thoughtful section with a very good analysis of errors. For some time, I have considered that the term "hierarchy" is perhaps not the best, although we can argue that ecology is geophysically hierarchical, in the same way that biology is taxonomically hierarchical.

Coast Information Team Ecosystem Spatial Analysis: Results of the Expert Review (2004)

Selected Reviewer Comments From CIT Ecosystem Spatial Analysis

Reviewers

- J.P. Kimmins
  Professor of Forest Ecology, Department of Forest Sciences
  UBC, Vancouver
- Fiona Schmiegelow
  Associate Professor, Department of Renewable Resources
  University of Alberta, Edmonton

Responses

Jeff Ardron, MSc

Jeff is the primary author of this methodology and report. He worked for Living Oceans Society (LOS) for six years and is retained by LOS as a consultant. He is currently employed as the Scientific Advisor on Marine Protected Areas for the German Federal Agency for Nature Conservation. He is also Secretariat of the MPA Intersessional Correspondence Group for the OSPAR marine region (NE Atlantic) and is Vice-President of the Pacific Marine Analysis and Research Association (PacMARA).

Notes

Note that some of the following comments have been edited for length and/or clarity.

> ***JAA***
> Note that the "nearshore analysis" was completed The Nature Conservancy. Therefore I have not responded to those comments.

Overall Review of Report

Kimmins

> The important linkages between the terrestrial/freshwater systems and the marine system receive little attention in this lengthy report

JAA

This is true. Initially there were lofty plans to link the two, but it never happened because: (a) both the terrestrial and marine sides were working to the same deadlines, meaning that there was no time to actually link them; and (b), we long ago ran out of time and money… It's a shortcoming.

I found that, within the limitations of my knowledge, the freshwater and marine sections of the report appear to be more rigorous and credible than the terrestrial section, which covered topics I am more familiar with. In part this may be because these two sections appear to have used more appropriate spatial scales in their analyses, and to be more ecosystem-based.

While the marine section of the report appears to my relatively unqualified eyes to be well done, I am surprised that the internationally respected UBC Fisheries Center was not involved in the analysis, or at least in the review.

JAA

The Fisheries Centre and UBC were approached by the province, but my understanding is that the short timeframe was viewed as unrealistic.

2.4 Marine Targets

Kimmins

I was pleased to see that this section deals with a shoreline habitat scale (25m) that is much more ecologically meaningful than that used in the terrestrial section (500ha).

3.3 Goals for the Marine Nearshore Environment

Schmiegelow

This represents a radically different philosophy and approach than was employed for terrestrial and freshwater components of the ESA. There needs to be a discussion somewhere as to why this occurred, and what are the implications for integration of the resultant analyses, and interpretation of results.

CIT Response

The nature of data available for the nearshore environment differed radically from that used by the terrestrial and freshwater teams and resulted in different approaches to handling that data. The need to explore integration of marine and terrestrial methodologies and results is discussed in next steps and conclusion sections.

3.3.1 Representation (Coarse Filter) Goals

There is considerable variation in goals among the major environments considered by the ESA (terrestrial/freshwater: 30-70% in 10% increments; marine nearshore: 10-30%, depending on target; marine offshore: 5-50%. It would be prudent to run all analyses across the same range of goals, and to devote a portion of Section 6.4 (Integrated Spatial Analysis) to interpreting the results appropriately.

CIT Response

The nature of data available for the nearshore environment differed radically from that used by the terrestrial and freshwater teams and resulted in different approaches to handling that data. The need to explore integration of marine and terrestrial methodologies and results is discussed in next steps and conclusion sections.

JAA

Time constraints made this impossible. However, improved marine terrestrial integration should be considered in the future.

5.0 Spatial Analysis

Kimmins

If there is no single "correct" MARXAN run (I agree with this), how do you design the system? How do you know that the average of many runs is the "best design"? Does such an average reflect the mathematics of the algorithm or the biology/ecology of the conservation values of interest? This will depend in part on the degree to which the focal species sub-models have incorporated causal relationships rather than simple correlations.

JAA

Causal or functional relationships amongst species and datasets were not incorporated. I would be open to doing so, but to date have not seen this successfully done.

CIT Response

Text has been clarified; please see section 5.2.2.1.

5.2.4 Nearshore Marine Spatial Analysis

5.2.4.4 Spatial Analysis

Schmiegelow

This is an excellent description of the goal-setting, analytical process, reporting and interpretation of the MARXAN scenarios.

6.3 Offshore Marine Spatial Analysis Results

6.3.2 Utility

Schmiegelow

This is a very informative description of results and interpretation, and the related map (Map 34) clearly illustrates concentrations of conservation sites by applying a continuum from seldom chose to chosen frequently.

Conservation Utility Analysis Review Paper

Marine Conservation Utility Analysis for Haida Gwaii, North Coast, and Central Coast British Columbia

[Excerpted and revised text from full report.]

Jeff Ardron, Living Oceans Society

Version 1.3; November, 2005

This report is a revised excerpt from the BC Coast information Team An Ecosystem Spatial Analysis For Haida Gwaii, North Coast, and Central Coast British Columbia

Ecosystem Spatial Analysis

Citation of this report:

Ardron, J. 2003. BC Coast Information Team Marine Ecosystem Spatial Analysis, v. 1.2. Excerpted and revised from: Rumsey, C., Ardron, J., Ciruna, K., Curtis, T., Doyle, F., Ferdana, Z., Hamilton, T., Heinemyer, K., Iachetti, P., Jeo, R., Kaiser, G., Narver, D., Noss, R., Sizemore, D., Tautz, A., Tingey, R., Vance-Borland, K. An ecosystem analysis for Haida Gwaii, Central Coast, and North Coast British Columbia. DRAFT, Sept. 22, 2003. (184 pages.) www.livingoceans.org/library.htm 44 pages.

1 Table of Contents

2 Executive Summary

The results presented in this paper are the outcomes of modelling hypothetical marine protected areas (MPAs) based on 93 data layers – physical and biological – for the Central Coast, North Coast, and Queen Charlotte Islands.

Rather than just examining one set of model parameters, we have chosen instead to look at a range of different MPA sizes and a range of MPA fragmentation. From these, we then examined the results for emergent trends. Thus, rather than debating what is the "right" percentage to set aside, or whether larger MPAs are better than several smaller ones, we have hopefully avoided these arguments for the time being by focussing on those areas that emerge under a variety of conditions. Those areas that were selected repeatedly we interpret as having a high "utility;" that is, usefulness, to MPA network design. While not necessarily meeting all goals, these areas of high overlap give clear direction as to where initial conservation efforts should be focussed (Figure 1). During the CIT process, this analysis was called the Ecosystem Spatial Analysis (ESA). Since then, it has become commonly referred to as the Conservation Utility Analysis (CUA). This report has been update to reflect this change.

The examination of 24 combinations of modelling parameters indicates that regardless of whether MPAs are many and small, or few and large, certain areas recur over and over again.[1] For example, within the Central Coast, the following larger areas of high conservation utility emerge:

- Hexactinellid Sponge Reefs
- Goose Islands, Bardswell Islands, and vicinity
- Rivers Inlet
- Scott Islands
- Entrance to Queen Charlotte Strait
- Broughton Archipelago
- Head of Knight Inlet
- Cordero Channel

While these areas alone would not constitute a fully representative Central Coast conservation portfolio, it is very likely that were they not included, such a portfolio would be difficult or impossible to achieve. Thus, regardless of what exact percentages were chosen by whatever planning processes, and the exact shape of the boundaries, we would expect the bright yellow areas to be key components of most conservation planning.

Larger areas of high conservation utility within the North Coast include:

- Hexactinellid Sponge Reefs
- West Aristazabal Island (& NW Price I.)
- Kitimat Arm
- Anger Island & vicinity
- SW & N Porcher Island, and Kitkatla Inlet

[1] We ran the model 2,400 times, examining 24 combinations of parameters. For each of the 2,400 solutions, the computer went through 15,000,000 iterations, examining possible combinations.

- S. Chatham Sound
- Mouth of Nass R.

Larger areas of high conservation utility within the Haida Gwaii waters include:

- W. Dixon Entrance
- Naden Hr.
- Masset Inlet
- Skidegate Inlet (Kagan Bay)
- South Moresby Island

Larger areas of high conservation utility off N west coast Vancouver Island include:

- Scott Islands
- Mid-Quatsino Sound
- Brooks Peninsula (Cape Cook) westward to the base of the continental slope

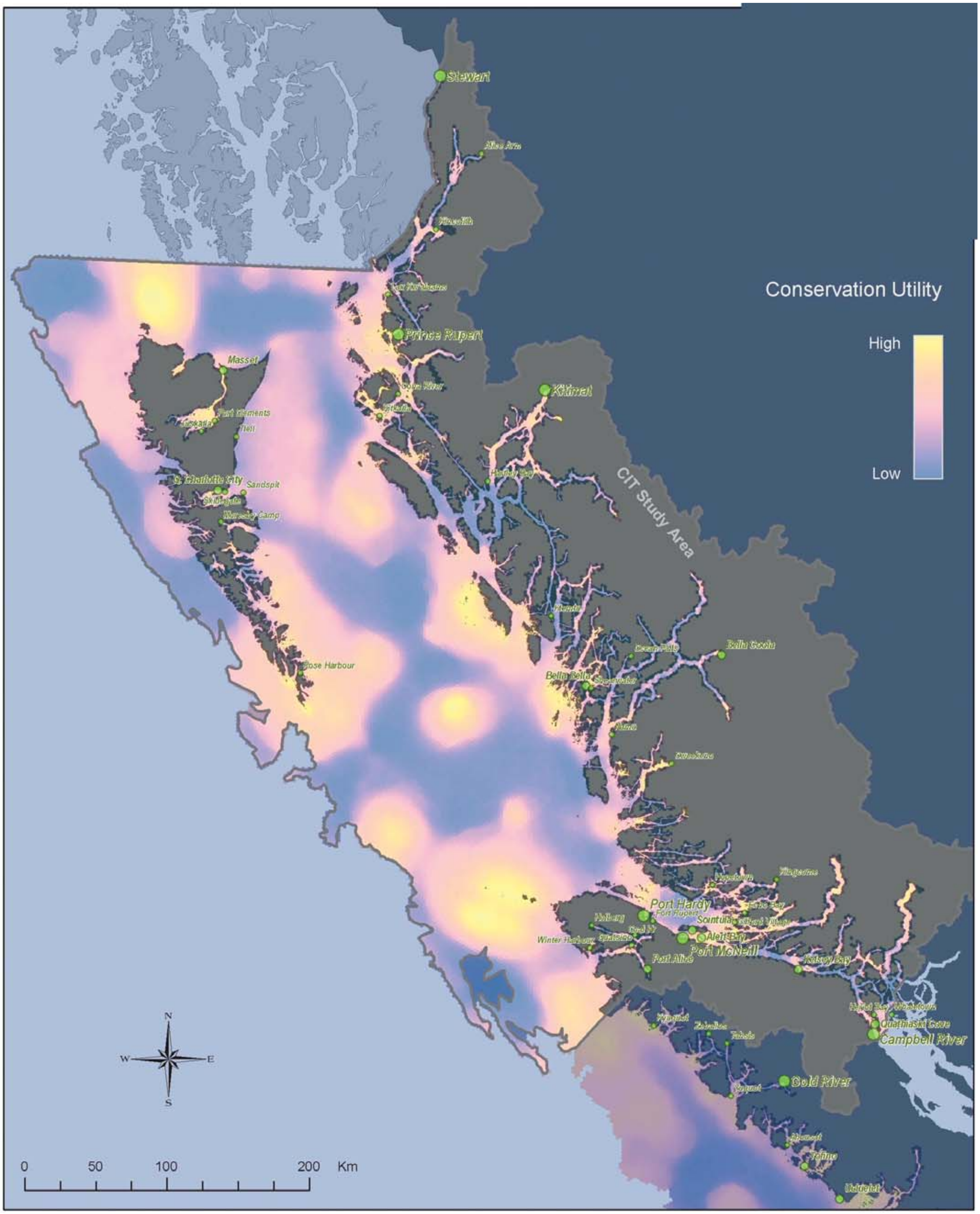

Figure 1: Summation of 2,400 Modelling Solutions

3 Introduction

This report presents the Conservation Utility Analysis completed for the Coast Information Team (CIT) in November 2003 as part of the ecosystem spatial analysis. This report does not include the nearshore analysis done by The Nature Conservancy & Nature Conservancy Canada, nor does it include any of the CIT terrestrial analyses. For these, we refer the reader to the main report, which is posted on our web site: www.livingoceans.org/library.htm. For more information about the Coast Information Team visit www.citbc.org

The CIT study area includes Haida Gwaii, Central Coast, and North Coast regions of British Columbia. This region has a land area of 11 million hectares; its sea area is another 11 million hectares. Important ecological elements in the region include unregulated rivers supporting large populations of spawning salmon and grizzly bears, estuaries, kelp beds, seabird colonies, archipelago/fjord terrain, deep fjord and cryptodepression lakes, and intertidal flats with abundant invertebrates and resident and migratory waterbirds. Haida Gwaii is an especially significant part of the region, containing an insular biota with distinctive, disjunct, and endemic taxa. The diversity of species within the CIT region is far greater than previously thought, but still incompletely known.

The purpose of the Conservation Utility Analysis (CUA)is to identify priority areas for biodiversity conservation and, ultimately, to serve four well-accepted goals of conservation:

1. represent ecosystems across their natural range of variation;
2. maintain viable populations of native species;
3. sustain ecological and evolutionary processes within an acceptable range of variability; and
4. build a conservation network that is resilient to environmental change.

In pursuit of these goals, the CUA integrates three basic approaches to conservation planning:

- Representation of a broad spectrum of environmental variation (e.g., vegetation, terrestrial abiotic, and freshwater and marine habitat classes).
- Protection of special elements: concentrations of ecological communities; rare or at-risk ecological communities; rare physical habitats; concentrations of species; locations of at-risk species; locations of highly valued species or their critical habitats; locations of major genetic variants.
- Conservation of critical habitats of focal species, whose needs help planners address issues of habitat area, configuration, and quality. These are species that (a) need large areas or several well connected areas, or (b) are sensitive to human disturbance, and (c) for which sound habitat-suitability models are available or can be constructed.

Marine protected areas (MPAs) are increasingly accepted as a tool in conserving marine biological diversity and enhancing exploited fisheries (Lubchenco et al 2003). MPA design theory includes criteria such as representation of habitat types, replication, rarity, focal species, and connectivity (Roberts et al 2003). However, the application of design theory remains largely untested, especially in the Northeast

Pacific. While marine classification systems designed to delineate habitat types already exist, they do not prioritize candidate areas for protection (Zacharias et al 1998).

How one chooses an efficient collection of marine MPAs amongst innumerable combinations of many differing features has become the focus of several algorithms, with *simulated annealing* emerging as one very promising approach (Possingham et al 2000, Sala et al 2002, Ardron et al 2002, Airame et al 2003). It is this approach, using the software MARXAN, that has been applied in the Conservation Utility Analysis.

4 Conservation Features

4.1 Overview

The Conservation Utility Analysis (CUA) consists of 93 features, both biological and physical, considering representivity, distinctiveness, focal species, and rare or threatened species. Data were compiled from Fisheries and Oceans Canada (DFO), BC Ministry of Sustainable Resource Management (MSRM), Canadian Wildlife Service (CWS), Natural Resources Canada (NRCan), private researchers, and local knowledge.

Table 1, below, summarizes the breakdown of these layers by type:

Table 1

Feature Category	Feature Sub-Category	No. of Layers
Regional Representation	Data Regions	6
Ecosystem Representation	Ecosections	8
Ecosystem Representation	Ecosystem Regions	3 regions + 3 sub-regions
Ecosystem Representation	Enduring Features & Processes	7 exposure + 21 substrate/depth
Focal Species	Flora	13
Focal Species	Seabirds	15
Focal Species	Anadromous Spp. Richness x Stream Magnitudes	1
Focal Species	Mammals	1
Focal Species	Fish	1
Special Elements	Rarity	6
Special Elements	Distinctive Features	4 complexity + 4 current
48 Coarse Filter	45 Fine Filter	93

In the following sections, each of these feature categories is discussed. For a more detailed table of the features, please refer to Appendix 1: Marine Layers

4.2 Representation (Coarse Filter)

Capturing a representative selection of various habitats (as well as species, and processes as they occur in a region) has become a commonly stated objective towards achieving and monitoring biodiversity goals in terrestrial conservation (Noss 1991) and has been applied to marine conservation with an emphasis on physical and enduring features (Day & Roff 2000, Zacharias & Roff 2000). In the CUA, we considered a wide range of enduring features and processes, coupled with regional representation to account for variations in survey efforts and methodologies.

4.2.1 Regional Representation

The study area comprises 10.6 million hectares of sea, spanning several regional planning initiatives and data collection efforts. Some regions such as Haida Gwaii have been reasonably well studied (though more work is still required), while others, such as the north Central Coast, have hardly been surveyed at all. As such, there is a real danger that areas with more data could *appear* to harbour greater biological richness and diversity, when in actual fact, this may not be the case. In order to account for regional biases in data collection and planning, the study area was divided into five Data Regions: North Coast, Haida Gwaii, N. Central Coast, S. Central Coast, and N. West Coast Vancouver Island. Each one of these Data Regions was included as a target feature in the marine analysis to ensure broad scale geographic representivity, and to ameliorate possible regional biases in data collection effort.

4.2.2 Ecosystem Representation

Ecosections

The CUA sought to gain a representative sample of each provincial ecosection within the study area. These include eight marine ecosections: Dixon, Hecate, Queen Charlotte Sound, Vancouver Island Shelf, Queen Charlotte Strait, Johnstone Strait, North Coast Fjords, and Continental Slope. Each one of these ecosections was included as a target feature in the marine analysis to ensure broad scale ecosystem and geographic representivity.

Ecological Regions

In addition to the BC ecosections, the CUA considered broad marine ecosystems based on the following four classifications: Inlets, Passages, Continental Shelf, and Continental Slope. The transition from Inlets to Passages to Shelf to Slope broadly reflects the transition from sheltered to exposed areas; as well as mixing regimes: from the fresh water stratified estuarine system of the inlets, to tidally mixed passages, to continental shelf circulation of the outer coastlines where freshwater stratification is minimal. Likewise, salinity increases from inlets westward to the deep sea. These are widely recognized categories and are described briefly below.

Inlets

> "Fjords [inlets] are often seen (as with archipelagos) as definitive of the BC coastline. Indeed, the entire BC coast has been placed within the category 'West Coast Fjords Province,' Dietrich's (1963) biogeographic classification scheme. Few areas of the world (Norway, Chile and New Zealand) have such an abundance of fjords. Many of BC's fjords are large, exceeding 100 km in length. These generally comprise many habitats, including several which are of special importance to a variety of well-valued species." — Dale 1997

To delineate inlets, we examined areas of low exposure (LUCO 1997) and estuarine circulation (Booth et al 1998, Parks Canada 1999). Fine-tuning the boarder between an Inlet and Passage involved visually choosing the hexagons where the inlet fed into a larger water body –usually quite obvious.

Because the Inlet class encompassed a wide variety of features, ranging from large inlets such as Knight Inlet, to small semi-enclosed water bodies, it was further subdivided into three size classes. To arrive at this classification, area of each inlet was log-transformed. Then, the data were broken into four classes based on Jenks natural breaks algorithm. Because the largest two classes had much fewer numbers than the others they were merged together. The resulting three classes are based on actual inlets and therefore there are gaps in the ranges where there were no inlets of that size:

- Very Small Inlets: 5 – 260 ha.
- Small Inlets: 292 – 3167 ha
- Medium to Large Inlets: 3483 – 122,089 ha.

Inlets include such major features as Dean and Burke Channels (north Central Coast); Belize and Seymour Inlets (south Central Coast); Gardner Channel and Kitimat Arm (north Coast), as well as smaller inlets such as Sewell Inlet (QCI) and Klaskino Inlet (WCVI).

Passages

> "This feature is characterized by elongate channels where the maximum fetch direction is often parallel to shore. Fetches are usually restricted to less than 50 km and often less than 10 km so shorelines along straits and channels are often current-dominated rather than wave dominated. The open-ended nature of the channels tends to make water properties more marine than that found in fjords." — Booth et al 1998.

Passages are characterized by generally moderate wave exposures, with moderate to strong tidal currents mixing with the less saline waters exiting the inlets. They include such places as Grenville Channel (N. Coast), Fitz Hugh Sound (N. Central Coast), and Johnstone Strait (S. Central Coast).

Continental Shelf

These waters comprised all outside waters out to the 200 metre isobath, which is the conventional delineation of BC's continental shelf (Thomson 1981). These are areas with broad fetch and high wave exposure. While the shorelines and euphotic benthos are exposed to strong wave energy, there is generally weak tidal action except at headlands. Offshore circulation is characterized by continental shelf currents with a surface component of wind driven currents.

This layer is mostly a one to one mapping of the BC Marine Ecological Classification's High Wave Exposure class (>500km fetch). It also includes most of Parks Canada's Open Ocean Transitional regime and most of Parks Canada's Open Coast class. Biologically, it embraces much of BC's flatfish communities, particularly in Hecate Strait. The shelf includes much of Queen Charlotte Sound, and the shelf extending from the Scott Islands southeastward to Brooks Peninsula.

Continental Slope

This includes all outside waters between the 200m and 2000m -the westernmost edge of the Study Area. The waters are all highly exposed on the surface, but plunge to depths where the effects of storms are not felt, though some gullies may be swept by deep tidal currents (Thomson 1981). Steeply crenulated canyons, gullies, and troughs characterize the region. These offer habitat and refuge to a wide variety of rockfish (*Sebastes sp*) and are markedly different in species assemblages than neighbouring shelf regions (Fargo & Tyler 1991, Perry et al 1994). The continental slope includes areas of localized seasonal upwellings, such as the Scott Islands, which can provide nutrients and prey for a variety of surface and near-surface species including seabirds and plankton communities (Crawford & Thomson 1991). This region includes deep incursions into queen Charlotte Sound, notably Moresby Gully.

4.2.3 Enduring Features and Processes

Substrate and Depth

Substrate and depth are two of the most important variables affecting the distribution of biota in the ocean. The substrate type has major consequences for the morphology, behaviour and biomechanics of biota (Levinton 1995). Species must also adapt to the light levels, temperature and pressure that change with depth. As such, many species' habitat preferences appear to be a combination of the two. For instance, a 100 metre deep mud bottom is considerably different than a 10 metre mud bottom with a seagrass bed.

We have examined depth and substrate according to region (inlets; passages; shelf and slope together) applying appropriate class breaks for each region. For example, for Hecate Strait (shelf and slope), we looked at depth intervals as defined in the literature thought to best delineate flatfish assemblages: 0-50m, 50-135m, 135-240m, 240m-2000m (Fargo & Tyler 1991, Fargo & Tyler 1992, Perry et al 1994). For passages and inlets, however, which are generally characterized by steep-sided deep U-shaped channels, we looked at only photic (0-50m) and non-photic (>50m) depths, as that intermediate depths are unusual and fragmented. In this case, defining depth according to the penetration of sunlight (photic), as suggested by other practitioners (Day & Roff 2000; Alidina in review) is the only meaningful class break.

We used the three substrate classes from the BC Marine Ecological Classification (LUCO 1997, version 1). They are similar to the three WWF classes (Day & Roff 2000) though differ from the five WWF classes used in an earlier east coast analysis (Day & Lavoie 1998). While we would prefer more than just three classes, it is presently beyond our means to do this independent analysis of the Central Coast (raw data are unavailable), and so we have had to rely on the existent Marine Ecological Classification. Nonetheless, these three classes do still delineate many of the benthic species in the Central Coast region (Levings et al 2002). The classes are as follows:

- Hard (Bedrock, boulders, cobble, and some sand/gravel)
- Sand (Sand, sand/gravel, and some muddy areas)
- Mud (Mud and sandy mud)

Within the study area, substrate generally follows a progression from rocky shallower waters, to sandy slopes of moderately deeper waters, to muddy deepest bottoms. One notable exception is Johnstone Strait, a deep passage with significant bottom currents, which therefore does not gather much fine sediment and thus is not muddy (LUCO 1997, Thomson 1981). Sections of Moresby Gully are also swept by significant bottom currents, which are believed to account in part for the extremely rare Hexactinellid sponge communities there (Conway et al 2001).

Within the analysis some classes were aggregated to avoid the possibility of overly sub-dividing the regions into classes too small or fragmented for consideration at the CIT planning scale, and to compensate for weaker data layers. In all, there are 21 classifications of depth and/or substrate by region, for example, *Passages Hard Substrate Photic Depth* (for a full listing, see Appendix 1: Marine Layers). For areas where data were not available, these were noted as *Unknown Depth* and/or *Unknown Substrate*. By representing these areas as separate feature targets with associated goals, we are ensuring that these areas are not ignored simply because they are data-poor.

Shoreline Exposure

We included the seven shoreline exposure categories of the BC shorezone classification (very protected to very exposed) as well as an "unknown exposure" category to account for areas where the shorezone surveys had not been completed. Wave energy, a function of exposure, has been found to be a key indicator of shoreline communities (Connolly & Roughgarden 1997).

4.3 Focal Species & Special Elements (Fine Filter)

4.3.1 Focal Species

Focal species have received a lot of attention in terrestrial conservation (e.g., Noss 1991, Lambeck 1997), but have received less attention in marine conservation (e.g., Day & Roff 2000, Zacharias & Roff 2001, Roberts et al 2003). Different categories of focal species exist, such as indicators, keystone, umbrella, and flagship species (for a complete discussion, see Zacharias and Roff 2001). A common concept in terrestrial conservation is that of the umbrella species, whose conservation is believed to also spatially protect other species' habitat. Unfortunately, umbrella species are not as widely applicable in the marine environment, though they can prove valuable at more local scales (Zacharias and Roff 2001). One problem with the applicability of this concept to marine systems is that many candidate umbrella species, fitting the typical (terrestrial) apex predator profile, such as killer whales (*Orcinus orca*), exhibit massive migrations and utilise areas too large to be useful as marine umbrella species at most planning scales.

On the other hand, marine focal species can still be identified that are useful in conservation. Zacharias and Roff (2001) note that composition indicators, or species who's presence indicates other species or are used to characterize a particular habitat or community are particularly useful. They feel that seabirds, sea grasses, macroalgae, and benthic invertebrates are good candidates for focal species. We feel that seabirds may be also be seen at least partially as umbrella species, since protecting their foraging habitats will afford some protection to their prey species. Likewise, kelp beds (*Nereocystis luetkeana* and *Macrocystis intergrifolia*) were treated as local-scale umbrellas for the many species associated with them, as were eelgrass beds (*Zostera* sp). Herring (*Clupea pallasii*) spawn were treated as a keystone species, since so many other species are attracted to, and rely upon, these areas to feed on the eggs (Hay and McCarter 2000).

Flora

For the CUA, we considered the following focal vegetation species: Eelgrass, kelp, marsh grasses (*Salicornia* sp.), surf grasses (*Phyllospadix* sp), and a general shoreline vegetation class, aggregated from the BC Shorezone classification that includes *Fucus*, *Ulva*, halosaccion layers, "reds," "soft browns," and "chocolate browns." (For a more detailed shoreline vegetation analysis, we deferred to the nearshore ESA team – see full CIT report.)

Seabirds

All major BC breeding seabird populations and colonies were considered: Ancient Murrelet, Black Oystercatcher, Cassin's Auklet, Cormorant spp., Glaucous-winged Gull, Pigeon Guillemot, Puffin spp., Rhinoceros Auklet, and Storm Petrel sp. (data provided by Canadian Wildlife Service). In addition, very small islets, far from shore were also considered as surrogates for unsurveyed colonies (Gary Kaiser pers. comm.).

Seabirds are known to prefer certain marine waters. These we treated as "habitat capability" layers. We considered pelagic seabirds (shearwaters, fulmars, albatross, some gulls, and terns); waterfowl (ducks, swans, geese, grebes, and loons); and shorebirds (oystercatchers, sandpipers, plovers, and turnstones). Data were provided by Decision Support Services, Sustainable Resource Management, based on known distributions and expert opinion.

Moulting seaducks (Scoter sp. and Harlequin Ducks) inhabit certain nearshore BC waters during summer months. Because they are unable to fly, they are particularly susceptible to stressors such as oil spills (Savard 1988). These areas were also considered separately for each species grouping (data from CWS Coastal Waterbird Inventory; and from Savard 1988, digitized by J. Booth).

Anadromous Streams

BC's anadromous streams were captured using a species richness x stream magnitude ranking. Eight of BC's nine anadromous spp were considered (eulachon, the ninth, was treated separately). These include all *Oncorhynchus* spp and Dolly Varden (*Salvelinus malma*). About 1 out of 10 BC stream systems were considered likely to support significant numbers of anadromous species. Of those, about half were assigned a low score (1-4 out of a possible 24), meaning that they are small streams supporting only a few species. Only the Fraser River (outside the study area) received a top score (24), with the Nass and Skeena rivers tied in second place (20). For a full description of this layer, please refer to Appendix 2: Stream Richness x Magnitude.

Seller Sea Lion

Seller Sea Lion (*Eumetopias jubatus*) haul-outs and rookeries were ranked on a scale of 1-4 based on population density.

Herring spawn

At all stages of their lives, herring are an important link in marine food webs. Consequently, there are important ecosystem effects to the protection of spawning sites and the maintenance of healthy herring stocks. Annual herring spawn events also contribute greatly to the overall productivity of the local area (Hay and McCarter 2001). Invertebrates, fish and seabirds, and particularly ducks and gulls, are all predators of herring eggs (Hart 1973; Hay and McCarter 2001). Herring eggs and larvae are also important prey of Gray whales (Darling et al. 1998). Once herring have hatched, they become vulnerable to predators in the zooplankton such as jellyfish, chaetognaths, ctenophores and pilchards and other filter-feeding fish (Hart 1973; Purcell 1990; Purcell and Grover 1990). Adult herring are also main prey item that have been described as a major fodder animal of the sea (Hart 1973). They are fed upon by fish, sharks, whales, seals, sea lions, and marine birds (Hart 1973; SoE 1998). Herring are a considerable proportion of the diet of many commercially important fish species: lingcod (71%), chinook salmon (62%), coho salmon (58%), halibut (53%), Pacific cod (42%), Pacific hake (32%), sablefish (18%), and dogfish (12%) (SoE 1998).

Herring spawn (Clupea pallasii) shorelines were ranked on a density measure based on DFO's Spawn Habitat Index (Hay & McCarter, 2001), using the latest available times series data (DFO 2002). Data were cube root transformed and standardized to shoreline length per hexagonal planning unit.

4.3.2 Rare and Threatened Species

Rare, threatened and endangered species are generally given a lot of conservation attention. However, the inaccessible nature of the sea makes it much harder to survey and therefore know most of what is rare. Declining populations may go unnoticed through to their extirpation (Thorne-Miller 1999). In the CUA, we consider five Special Elements, on account of their rare or threatened status: Hexactinellid sponge reefs, Eulachon estuaries, Sea otter (not WCVI), estuaries containing red or blue listed species, and Marbled Murrelet marine habitat.

Hexactinellid Sponge Reefs

Hexactinellid sponge reefs are unique to the BC coast and are important in terms of their ecology and their similarity to extinct Mesozoic sponge reefs. There is already evidence that they have been damaged by bottom trawling (Krautter et al 2001, Conway et al 2001, Conway 1999). In the spring of 2002, while setting a mooring to monitor one of the last undisturbed mounds, researchers discovered that it had been trawled since the previous visit (K. Conway pers. comm. July 2002). We strongly support the recommendations of Conway (1999), Krautter et al (2001), and Jamieson & Chew (2002), all who suggest that these sponge reefs be permanently protected from trawling. Since the summer of 2002 they have been given some protection in the form of a fishing closure, however closures can be lifted at any time at the discretion of fisheries managers. There are only four such reefs known to exist in the world, all of which are in the study area.

Eulachon Estuaries

Eulachon (*Thaleichthys pacificus*) are an ecologically and culturally important fish species (Hart 1973). Eulachon spawning areas in the Central Coast are limited (McCarter and Hay 1999). Although larval eulachon spend very little time (hours) in their natal streams, the associated estuary or inlet is important juvenile habitat. Eulachon streams and estuaries should therefore be considered for protection.

Eulachon are heavily preyed upon during spawning migrations by spiny dogfish, sturgeon, Pacific halibut, whales, sea lions, and birds. In the ocean, it is also preyed on by salmon and other large predatory fishes (Fishbase 2001, Pacific States Marine Fisheries Commission 1996).

Data were downloaded from DFO Habitat and Enhancement Branch's public web site (DFO 2003), and were compared to FISS data, and published literature (McCarter and Hay 1999). Points were snapped to the BC Watershed Atlas when appropriate.

Sea Otter

Sea otters (*Enhydra lutris*) were once abundant throughout the Northeast Pacific but were hunted to near extinction from the mid-1700's to early 1900's. Apocryphally, the last known sea otter in British Columbia was accidentally shot in 1929. Between 1969 and 1972 eighty-nine sea otters were reintroduced to Checleset Bay off northwest Vancouver Island and the population has been increasing at a rate of 17 percent per year (Estes 1990; Watson unpublished). Sea otters are important predators of invertebrates such as sea urchins and have been shown to play an important ecological roll as a keystone predator (Estes 1990).

Unlike other marine mammals, sea otters do not have a blubber layer. They rely on their fur to keep warm and are therefore particularly vulnerable to oil spills, even minor ones. Several thousand (approx. 5000) sea otters died in the 1989 Exxon oil spill in Valdez, Alaska (Marine Mammal Center 2000).

While the WCVI population appears to be increasing, the only known established colony in the study area is in the Goose Islands.

Red-Blue Estuaries

Estuaries in the North Coast and QCI harbouring provincially red (rare) or blue (threatened) listed species, mainly birds, were identified by Remington (1993), and digitized by Living Oceans Society for the CIT.

Marbled Murrelet Marine Habitat Capability

Marbled murrelets, in the auk family, are on the provincial "Blue" list of vulnerable species. They may be moved to the "Red" list of endangered species in the near future since the marbled murrelet population has suffered an estimated 40% drop in the past decade alone (Cannings and Cannings 1996). Both natural and human-related factors may be contributing to the species' decline; potential causes include the loss of suitable nesting habitat, accidental death in gill-nets, oil pollution, increases in predator populations, and declines in food supplies due to recent El Nino events (SEI 1999).

Marbled murrelets lay a single egg on wide, mossy branch of old growth conifer trees (Cannings and Cannings 1996). Therefore, during breeding season, murrelets can be found foraging just offshore of old growth forests. Concentrations of foraging murrelets are sometimes found associated with tidal rips, high current areas, or river plumes. Researchers have identified a marbled murrelet juvenile nursery area in a semi-protected Nereocystis bed in Alaska (Kuletz and Piatt 1999). Although no similar areas have been identified in the Central Coast of BC, kelp beds and high current areas have also been considered in the CUA.

Marbled Murrelets are known to prefer certain marine waters. These we treated as a "habitat capability" layer. Data were provided by Decision Support Services, Sustainable Resource Management, based on known distributions and expert opinion.

Habitat-Forming Corals

We considered areas known to harbour large habitat-forming corals, which may well be threatened or endangered, but due to a lack of surveys their status largely remains unknown. Coral outcrops and "forests" are important habitat for adult fishes, crustaceans, sea stars, sea anemones and sponges because they provide protection from these currents and from predators. Some commercially important fish species are found in association with these reefs, such as Atka mackerel, *Pleurogrammus monopterygius*, and shortspine thornyhead, *Sebastolobus alascanus*, in Alaska. Rockfish are associated with *Primnoa* corals in the Gulf of Alaska (Etnoyer & Morgan 2003).

4.3.3 Distinctive Features

One shortcoming of a representative areas approach is that it requires examining and possibly setting aside very large areas. Pragmatically, there may not be the political will or management capability to fully realize this approach. Furthermore, smaller but ecologically valuable areas may be passed over. Roff & Evans (2002 unpublished) argue that such smaller "distinct" areas are by definition different from their representative surroundings and may harbour higher (or lower) species diversity, richness, and abundance. These, they suggest, must also be considered in reserve design. Distinctive areas may also be thought of as representative of a certain type of habitat, but at a finer scale than the nominal scale of the study (John Roff, pers. Comm.). In the CUA, we included two separate indicators of distinctive habitats: Benthic topographical complexity, and high current.

Benthic Complexity

Areas of high taxonomic richness are often associated with areas of varying habitat. The more kinds of niches available in which organisms can live will usually lead to a wider variety of organisms taking up residence. Furthermore, the complexity of habitat can interrupt predator-prey relationships that in a simpler habitat might lead to the clear dominance or near extirpation of certain species (e.g., Eklov 1997). Thus, in complex habitats species may co-exist in greater diversity where elsewhere they might not. Likewise, a greater variety of life stages may also be supported. Thus, complex habitats may exhibit greater ecosystem resilience (e.g., Peterson et al 1998, Risser 1995). Furthermore, if complex habitats do encourage biodiversity, as is being suggested, then it follows that they likely also offer greater resistance to invasive species (Kennedy et al 2002).

Benthic topographical complexity is indicated by how often the slope of the sea bottom changes in a given area; that is, the density of the slope of slope of the depth. Note that this is not the same as relief, which looks at the maximum change in depth. Benthic complexity considers how convoluted the bottom is, not how steep or how rough, though these both play a role. Complexity is similar but not the same as "rugosity" as is sometimes used in underwater transect surveys, whereby a chain is laid down over the terrain and its length is divided by the straight-line distance. Rugosity can be strongly influenced by a single large change in depth, however, whereas complexity is less so, since all changes are treated more equally (Ardron 2002).

We used this analysis because we felt it captured biologically and physically meaningful features that the other measures missed. For example, archipelagos and rocky reefs are invariably picked out as areas of higher benthic complexity. Both are associated with several marine values. While "obvious" to the casual observer, they had hitherto no simple quantitative definition that could be used to identify them using a GIS. Benthic complexity will often also identify physical features such as sills, ledges, and other distinctive habitats that are associated as biological "hotspots" providing upwellings, mixing, and refugia (Ardron 2002).

In the CUA, benthic complexity was examined separately within each of the four Ecological Regions (inlets, passages, shelf, slope).

High Current

This layer was extracted from the BC Marine Ecological Classification, version 2 (LUCO 1997, Axys 2001), as well as incorporating additional local knowledge. High Current is defined as waters that regularly contain surface currents (tidal flow) greater than 3 knots (5.5 km/hr or 1.5 m/s). These are areas of known mixing and distinctive species assemblages. In addition, high current areas often represent physical "bottlenecks" to water movement and as such are important to larval transfer and nutrient exchange.

The strong currents of the southern half of the Central Coast, particularly in Johnstone Strait and Discovery Passage, are probably the most influential oceanographic variable of that region. They mix the water column so that nutrients, oxygen, temperature and salinity levels are almost uniform throughout (Thomson 1981). The constant re-suspension of nutrients in particular is most likely responsible for the rich biota of the south Central Coast passages. Mann and Lazier (1996) explain that tidally-induced mixing in relatively shallow coastal waters prevents stratification of the water column, but the potentially adverse effects on phytoplankton are more than compensated for by the increased nutrient flux to the water column from the sediments. Annual primary productivity in tidally mixed areas tends to be above average for coastal waters (Mann and Lazier 1996). Highly productive and biologically diverse areas, such as the world-renowned dive site, Browning Passage (Queen Charlotte Strait), result from these nutrient-rich, mixed waters.

Because high current areas are always well mixed subsets of whatever larger mixing regime may exist, we have classified them as distinctive areas. They were considered separately for each of the four Ecological Regions (inlets, passages, shelf, slope).

5 Conservation Goals (Targets)

Halpern (2003) reviewed 89 studies of no-take marine MPAs and found that regardless of size, MPAs lead to increases in density, biomass, individual size, and diversity in all functional groups. However, larger MPAs did produce larger increases. Halpern goes on to caution "…that to supply fisheries adequately and to sustain viable populations of diverse groups of organisms, it is likely that at least some large MPAs will be needed." (ibid pp129-130)

A variety of MPA sizes ranging from 10% to 50% have been suggested as being efficacious as a conservation and/or fisheries management tool (MRWG 2001, NRC 2000, Roberts & Hawkins 2000, Ballantine 1997, Carr & Reed 1993), with an emphasis on larger MPAs coming from the more recent literature. Furthermore, it has been found that larger MPAs often have beneficial effects disproportionate to their size (Halpern 2003). In the CUA, we explored a variety of conservation goals (also know as "targets" in the literature) that produced overall areas ranging from 5% – 50% of the study area. Specifically, we looked at Marxan solutions that comprised 5, 10, 20, 30, 40, and 50 percent of the study area. However, this does not imply that equal amounts of each of our 93 feature elements were represented. Rather, as explained below, each feature was assigned a goal based on a range of six relative rankings.

Before choosing actual percentages per feature as a goal, we examined each dataset and assigned to it a relative term, where "moderate" was taken as the common baseline or average value. The five terms used were: *low, moderate-low, moderate, moderate-high, high*, and *very-high*. In general, we assigned lower rankings such as low or moderate-low to features that were common (i.e. plentiful), and higher rankings features that were more unusual or rare. Umbrella and keystone species were generally assigned a *moderate-high* ranking. By using these six simple qualitative rankings, we were able to class the features relative to each other. Once that was completed, we could then implement a range of actual numerical targets and observe the effects. Such a strategy (though not in the context of MARXAN) has been suggested by Levings and Jamieson (1999) as "dimensionless scores," to be used to meet various criteria such as distinctiveness, and naturalness. The addition of the computer software allows for quick feedback to compare scenarios. Table 2 displays the actual percentages attached to each qualitative ranking. Columns display each conservation scenario, while the rows display the rankings.

Appendix 1: Marine Layers lists all 93 features in the CUA, and their assigned relative goals.

Table 2

Relative Ranking	**Conservation Goals** (percentages)					
Low	2	4	8	12	16	20
Mod-Low	4	8	16	24	32	40
Moderate	6	12	24	36	48	60
Mod-High	8	16	32	48	64	80
High	10	20	40	60	80	100
V. High	12	24	48	72	96	120†
Overall Size	5	10	20	30	40	50

†Goals greater than 100% cannot be met, but do serve to give these features a higher emphasis.

6 Portfolio Assembly

6.1 Site Selection

Conservation biologists have been developing practice and theory that began from little or no methodology in early park design to our current, albeit imperfect practices. A systematic approach to MPA design is strongly urged (Margules & Pressey 2000, Possingham et al 2000). Experience from other jurisdictions have shown that an ad hoc approach to marine protection can lead to decisions which do not necessarily ensure efficient or effective MPA design, and may later be regretted (Stewart et al 2003, Gonzales et al 2003).

While it should be clear that more is to be gained by looking at biology than scenery, and networks of protected areas rather than MPAs in isolation, designing such MPAs is also much more difficult. The selection of any planning unit over another involves evaluating it with regard to its role within a context of many thousand such units. One planning unit with several valuable features on its own may or may not be the best choice overall, depending on distribution and replication of those features in the study area. Furthermore, as demands on the environment increase, the need to choose a network of MPAs that will capture the "most" for the least "cost" becomes imperative. Good guesses are not good enough to user groups, particularly those whose livelihood depend on harvesting the resources.

Creating large tally sheets, or inventories (Booth et al 1998) can go far in helping identify what is distinctive, natural, or representative of a particular region. These tallies can also aid in determining the relative importance or influence that various features ought to have and they can be used in GAP analyses. Still, the question as to *where* the new MPAs ought to be placed remains unanswered. Choosing an area with the highest tally, for example, and then the next highest, and so forth, does not guarantee a representative sample of features.

Some computer selection algorithms have been put forward. Most attempt to mimic the human selection process, and as such are called "heuristics." For example, choosing the areas with the most abundance and/or diversity of species has been labelled the "richness," or "greedy" heuristic (Ball & Possingham 2000). While this can produce a good initial reserve, it does not look at rarity or representivity and consequently it is not well suited for network design.

Unfortunately, these algorithms do not necessarily produce the best answer, and can be up to 20% from the ideal (Possingham et al. 2000). One reason for this is that they are linear, approaching the problem in a predictable and repeatable fashion, choosing the highest value first (as per whatever system of valuation), the next highest second, and so forth until the reserve is built. As such they can get trapped in situations where the reserve built on these attractive units cannot effectively make up the remaining goals with what is left; whereas, a few less "optimal" choices earlier on may free up the choices later.

6.1.1 Marxan Software

MARXAN, a software developed by Dr Hugh Possingham, University of Queensland, and Dr Ian Ball, now at Australian Antarctic Division in Tasmania, attempts to address the problems identified above. In order to design an optimal reserve network, MARXAN examines each individual planning unit for the values it contains. It then selects a collection of these units to meet the conservation targets that have been assigned. The algorithm will then add and remove planning units in an attempt to improve the efficiency of the MPAs. What makes this algorithm different from other iterative approaches is that there is a random element programmed into it such that early on in the process the algorithm is quite irrational in what it chooses to keep or discard, often breaking the rules of what makes a good selection. This random factor allows the algorithm to choose less than optimal planning units earlier that may allow for better choices later. As the program progresses, the computer behaves more predictably -but not entirely. The process continues, with the criteria for a good selection getting progressively stricter, until finally the reserve network is built.

Given a sufficiently diverse set of features, it follows that because of the random element, no two runs are likely to produce exactly the same results. Some may be much less desirable than others. Still, if enough runs are undertaken, a subset of superior solutions can be created. Furthermore, the results from all runs may be added together to discern general trends in the selection process. Planning units that are consistently chosen can be said to have higher utility than those that are not. Often these can represent important features, but not necessarily so. They may be useful in their ability to round off a MPA network's design; i.e., fill in the gaps, even if they are not particularly attractive on their own.

MARXAN comes from a lineage of successful selection algorithms, beginning with SIMAN, then SPEXAN (as used in the SITES package by The Nature Conservancy). SPEXAN has been used to look at the Florida Keys Reserve (Leslie et al 2003). MARXAN was developed from SPEXAN in part to aid in work on the Great Barrier Reef Marine Park Authority's re-evaluation of their park designations. MARXAN brings with it several features that make it easier to experiment with different conservation targets and costs of various features. This can be valuable in sorting out what values lead to certain reserve shapes. It still requires, however, that the user be technically fluent. There are several parameters that can be adjusted (see 6.3below).

6.2 Planning Units

The CUA planning units are a regular grid of 500 hectare hexagons. There are about thirty-two thousand of these hexagons in the analysis which covered the entire marine study area, and down the west coast of Vancouver Island.

To get an accurate picture of how abundant a feature is within a planning unit (hexagon) we considered two factors:

1. How much of it is there
2. How much of it could there be there (i.e., its possible maximum). In our analysis this often equals the amount of seawater contained in the hexagon, but for shoreline features would be a total measure of shoreline per hexagon.

Considering just the summation of a feature's presence (point #1) would unfairly penalize hexagons that had full 100% presence of the feature, but not 100% water. This situation might prove to be important when, for example, the nearshore component plays a critical role, such as in estuaries. In this situation, a planning unit is very unlikely to contain but a fraction of its area as water, and yet may play a far more important functional role than an offshore planning unit with the same amount of the feature, but surrounded by water.

In our model we make allowances for how much water is available per planning unit, accounting for feature density, as well as occurrence.

Presence/Absence Areal Data

For presence/absence data, the formula we generally used is:

$HexScore_{f(presence)} = \sqrt{((\sum f)^2 / (2 N_f))}$ 1

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:

$HexScore_{f(presence)} = \sqrt{(\sum f * f_{mean})/2}$ 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.

For presence/absence features, the scores can range from 0 to 16 per hexagon.

Our sensitivity analyses indicate that this compression of values was found to be robust to random grid shifts and variations in base shorelines used by different datasets.

For weighted ("Relative Importance" –RI–) features, the above formula is multiplied by the mean of the feature cell weightings:

$HexScore_{f(RI)} = HexScore_{f(presence)} * RI_{mean}$ 3

Where, $RI_{mean} = \sum f_{(RI)} / N_{f(presence)}$;

And $\sum f_{(RI)}$ is the sum of all the RI feature cells

And $N_{f(presence)}$ is the total number of presence feature cells.

Line and Point Features

The above formulae were used for most of our two-dimensional areal features (GIS "polygons"). For line features, we used the same formulae, except that Nf represents the total number of possible shoreline cells, instead of water.

Point features were all given buffers to convert them into appropriate areas, and then were treated as above.

6.3 Marxan Parameters

Marxan consists of 8 main parameters to direct the optimization algorithm:

1. ***Conservation Targets (Goals)***: How much of a feature is aimed for in the MPA network.
2. ***Penalty Values***: How much cost is accrued for not attaining the conservation target.
3. ***Boundary Length Modifier***: The relative cost of a reserve's perimeter
4. ***Minimum Separation Distance***: The minimum distance that distinct groupings of a feature should be from one another.
5. ***Separation Number***: The number of distinct groupings of a feature required (i.e. replication).
6. ***Minimum Clump Size***: The minimum number of planning units (hexagons) needed to count as a valid grouping of the feature.
7. ***Planning Unit*** Cost: A relative value applied to planning units such that some may be more difficult or "expensive" to set aside than others.

8 ***Boundary Cost***: The relative cost of the planning units' shared boarders.

Of these, the first three are the most important. The first parameter, conservation goals, has been discussed above (section 5), and is equivalent to stating how much of a feature is enough to meet one's conservation objectives. In the CUA, we explored a wide variety of goals so as to provide planning tables with a range of possibilities, from low to high conservation objectives.

The other Marxan parameters are discussed below.

6.3.1 Penalty Values

Assigning a penalty to a feature is in effect saying how much it matters if this feature's goal (target) is *not* met. That is, for features that do not meet their goals, penalties are assigned (on a sliding scale based on how closely the goal was achieved); and in turn it is these penalties that will "direct" the algorithm in its search for features. Thus, features with higher penalties are generally met first (if they can be met) than similarly distributed features with lower penalties. Generally, we used the penalty value as a relative factor to reflect the relative importance of a feature, and sometimes to also reflect the relative confidence in that dataset or its spatial completeness, as compared to others. We assigned lower penalties to those datasets in which we had lower confidence. We did not want these datasets driving the analysis. We assigned higher penalties to rare, threatened, & endangered species, as well as to features that play important ecological roles (such herring spawn).

As with goals (targets), penalties were first given a relative ranking. From those weightings were assigned as follows:

Relative Penalty	Marxan Weighting
Low	0.25
Mod-Low	0.50
Moderate	1.00
Mod-High	2.00
High	4.00
V. High	8.00

Appendix 1: Marine Layers lists all 93 features in the CUA, and their assigned relative penalties.

6.3.2 Boundary Length Modifier (Clumping)

Boundary Length Modifier (BLM): The relative cost of a reserve's perimeter. Higher costs will force larger (but fewer) MPAs, whereas a low cost will allow for several small ones. We have explored a wide range of this parameter (BLM= 0.004, 0.008, 0.016,… 8.000) but have focused on four to cover the range from fragmented to moderately clumped (BLM= 0.0625, 0.250, 1.000, 4.000) This is an arbitrary parameter that must be arrived at through experimentation. While we found that solutions using a BLM near 1.0 offered good efficiency with realistic manageability, we also discovered that the more fragmented solutions (which more truly represented the densities of conservation values) were valuable when summed together to show trends or "hotspots."

As solutions progressed from scattered to clumped, they behaved predictably, shedding smaller MPAs and aggregating onto the larger ones. This would indicate that the data populate the planning units in a consistent fashion and that the planning units themselves are consistent.

6.3.3 Other Parameters

The other Marxan Parameters were handled as follows:

- ***Minimum Separation Distance***: Not used. This parameter greatly increases processing requirements. For such a large number of planning units (32,000) and features (93), its use was impractical.
- ***Separation Number***: Not used. (As above.)
- ***Minimum Clump Size***: Not used. We felt the 500 hectare hexagons were already sufficiently large. In practice, the hexagons naturally clump together.
- ***Planning Unit Cost***: All planning units treated the same. Cost set to 1. As that the objective of this exercise was to explore just conservation values, we did not consider whether some planning units might in practice be more difficult to protect than others.
- ***Boundary Cost***: This parameter was used to fine-tune the relative clumping of hexagons in the four Ecological Regions (inlets, passages, shelf, slope). To determine this value we looked at the edge to area ratio of each of these regions and then created an appropriate scalar. The non-dimensional measure we used was: ÷(P2/A where P = total perimeter of region, and A = total area of the region. By altering the boundary costs per region, we allowed for more fragmented solutions in areas constrained by geography, such as inlets, but encouraged more clumped solutions in open waters, such as over the continental slope. The resulting boundary costs were as follows:

Region	Boundary Cost
Continental Slope	1.54
Continental Shelf	1.00
Passages	0.34
Inlets	0.21

7 Results

Rather than just examining one set of model parameters, we have chosen instead to look at a range of different MPA sizes and a range of reserve fragmentation. From these, we then examined the results for emergent trends. Thus, rather than debating what is the "right" percentage to set aside, or whether larger MPAs are better than several smaller ones, we have hopefully avoided these arguments for the time being by focussing on those areas that emerge under a variety of conditions. Those areas that were selected repeatedly we interpret as having a high "utility;" that is, usefulness, to MPA network design. While not necessarily meeting all goals, these areas of high overlap give clear direction as to where initial conservation efforts should be focussed.

7.1 24 Scenarios; 2,400 Solutions

We examined 6 MPA network sizes: 5%, 10%, 20%, 30%, 40%, and 50%. In addition, we examined four MARXAN clumping parameters: very scattered, scattered, moderate, and moderately clumped (BLM = 0.0625, 0.250, 1.00, 4.00). For each of these 24 combinations of variables (6 reserve sizes x 4 clumpings), we ran MARXAN 100 times. Thus, we examined a total of 2,400 MARXAN solutions. For each of those 2,400 solutions, the algorithm performed 15 million iterations.

7.2 Utility

By looking at how many times a particular planning unit is included in a solution, we can get an indication of its *utility* in overall MPA network design. That is, those hexagons that are repeatedly chosen likely represent areas that are more useful for effective and efficient MPA network design. While it has been suggested that these hexagons may be "irreplaceable," we have avoided using this terminology for two reasons:

1. This may cause some confusion with the irreplaceability heuristic which is part of the MARXAN software package, and is based on a completely different set of assumptions (Pressey et al 1994, cited in Ball & Possingham 2000).
2. We are not actually saying that these areas are irreplaceable. While this may be true for some sites that harbour rare species (such as the Hexactinellid sponge reefs), it is not necessarily so for all sites. Rather, these areas of high utility represent places that appear to be the most useful in the development of optimal reserve network solutions that best approach our targets, using a minimum of area. Less optimal solutions could possibly be found using larger areas of lower utility.

We have indicated the sum total of these 2,400 solutions as shades of blue (seldom chosen) to yellow (chosen frequently) in figure 1. The examination of various clumping values indicates that regardless of whether MPAs are many and small, or few and large, certain areas recur over the course of many runs. For example, within the Central Coast, the following *larger* areas of high conservation utility emerge:

- Hexactinellid Sponge Reefs
- Goose Islands, Bardswell Islands, and vicinity
- Rivers Inlet

- Scott Islands
- Entrance to Queen Charlotte Strait
- Broughton Archipelago
- Head of Knight Inlet
- Cordero Channel

While these areas alone would not constitute a fully representative Central Coast conservation portfolio, it is very likely that were they not included, such a portfolio would be difficult or impossible to achieve. Thus, regardless of what exact percentages were chosen by whatever planning processes, and the exact shape of the boundaries, we would expect the bright yellow areas to be key components of most conservation planning.

Larger areas of high conservation utility within the North Coast include:

- Hexactinellid Sponge Reefs
- West Aristazabal Island (& NW Price I.)
- Kitimat Arm
- Anger Island & vicinity
- SW & N Porcher Island, and Kitkatla Inlet
- S. Chatham Sound
- Mouth of Nass R.

Larger areas of high conservation utility within the Haida Gwaii waters include:

- W. Dixon Entrance
- Naden Hr.
- Masset Inlet
- Skidegate Inlet (Kagan Bay)
- South Moresby Island

Larger areas of high conservation utility off N west coast Vancouver Island include:

- Scott Islands
- Mid-Quatsino Sound
- Brooks Peninsula (Cape Cook) westward to the base of the continental slope

7.3 Flexible Solutions

Areas of high conservation utility alone would not constitute a fully representative conservation portfolio. The individual network solutions produced by Marxan can be diverse. Such diversity allows for greater flexibility when considering external factors, such as user interests, parks, local politics, and access & enforcement.

Once an initial selection of conservation areas has been chosen, probably based on the areas of high utility, but also taking into account the needs of the communities and stakeholders, the Marxan algorithm can be re-run, locking these areas into the network. Areas required to complete the portfolio (i.e. meeting the agreed-upon conservation goals) can then be explored. These could once again be taken to stakeholders for comment, and then locked in or out of the analysis as the case may be. It is anticipated that three such iterations would be sufficient to create a core network of conservation areas. Finer scale planning could contribute to rounding out the portfolio on a local basis.

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Appendix 1: Marine Layers

Marine Feature Name	Goal	Goal Rationale	Penalty	Penalty Rationale	Weighted?	Range	Mean: Hexes >0	No. of Hexes >0	Total Values
Ecosystem Representation									
Shelf Region	Moderate	Broad Representivity	High	Overarching Region	No	0-16	15.2	13997	212370
Passages Region	Moderate	Broad Representivity	High	Overarching Region	No	0-16	11.7	2740	32032
Inlets Region	None	See Inlet Sub-regions	None	See Inlet Sub-regions	No				0
Medium to Large Inlets	Moderate	Broad Representivity	High	Overarching Region	No	0-16	9.2	3432	31667
Small Inlets	Moderate	Broad Representivity	High	Overarching Region	No	0-15	6.8	391	2660
Very Small Inlets	Moderate	Broad Representivity	High	Overarching Region	No	0-11	4.4	152	671
Slope Region	Moderate	Broad Representivity	High	Overarching Region	No	0-16	15.6	11174	174053
Dixon Ecosection	Moderate	Provincial Classes	Low	Broad Representation	No	0-16	14.9	2471	36935
Hecate Ecosection	Moderate	Provincial Classes	Low	Broad Representation	No	0-16	14.5	2928	42483
QC Sound Ecosection	Moderate	Provincial Classes	Low	Broad Representation	No	0-16	15.3	7546	115762
Van I Shelf Ecosection	Moderate	Provincial Classes	Low	Broad Representation	No	0-16	14.2	4014	57024
QC Strait Ecosection	Moderate	Provincial Classes	Low	Broad Representation	No	0-16	12.6	649	8145
Johnstone Ecosection	Moderate	Provincial Classes	Low	Broad Representation	No	0-16	10	884	8832
N Coast Fjords Ecosection	Moderate	Provincial Classes	Low	Broad Representation	No	0-16	10.3	3808	39272
Cont Slope Ecosection	Moderate	Provincial Classes	Low	Broad Representation	No	0-16	15.2	6504	99048
Regional Representation									
North Coast Data Area	Moderate	Compensate Uneven Sampling	Mod-High	Geographic Representation	No	0-16	13.4	5079	67908
Haida Gwaii Data Area	Moderate	Compensate Uneven Sampling	Mod-High	Geographic Representation	No	0-16	14.9	9652	143946
NWCVI Data Area	Moderate	Compensate Uneven Sampling	Mod-High	Geographic Representation	No	0-16	15.4	6596	101350
N Central Coast Data Area	Moderate	Compensate Uneven Sampling	Mod-High	Geographic Representation	No	0-16	11	2084	22955
S Central Coast Data Area	Moderate	Compensate Uneven Sampling	Mod-High	Geographic Representation	No	0-16	11.2	2097	23389

Marine Feature Name	Goal	Goal Rationale	Penalty	Penalty Rationale	Weighted?	Range	Mean: Hexes >0	No. of Hexes >0	Total Values
WCVI Data Area	Moderate	Compensate Uneven Sampling	Mod-High	Geographic Representation	No	0-16	14.9	6333	94261
Enduring Features & Processes					No				
Shelf Sand Photic	Moderate	Common	Mod-Low	Weak Substrate Data	No	0-16	12	2226	26753
Shelf Mud Photic	Mod-High	Unusual	Mod-Low	Weak Substrate Data	No	0-16	3.9	171	672
Shelf and Slope Hard Photic	Moderate	Common	Mod-Low	Weak Substrate Data	No	0-16	8.8	2973	26306
Shelf and Slope Hard not Photic	Low	Very Common	Mod-Low	Weak Substrate Data	No	0-16	11.3	6739	75883
Shelf and Slope Sand not Photic	Low	Very Common	Mod-Low	Weak Substrate Data	No	0-16	13.2	8219	108757
Shelf and Slope Mud not Photic	Moderate	Common	Mod-Low	Weak Substrate Data	No	0-16	12.2	1660	20193
Shelf and Slope Mid-depth a	Mod-Low	Representivity	Moderate	Reliable Bathymetry	No	0-16	11.6	7827	90756
Shelf and Slope Mid-depth b	Mod-Low	Representivity	Moderate	Reliable Bathymetry	No	0-16	11.6	7145	82596
Shelf and Slope Deep	Mod-Low	Representivity	Moderate	Reliable Bathymetry	No	0-16	14.6	10311	150626
Pass Hard Photic	Moderate	Physical Representivity	Mod-Low	Weak Substrate Data	No	0-16	5	643	3222
Pass Sand Photic	Moderate	Physical Representivity	Mod-Low	Weak Substrate Data	No	0-16	4.2	562	2357
Pass Mud Photic	Moderate	Physical Representivity	Mod-Low	Weak Substrate Data	No	0-16	3.2	925	2984
Pass Hard not Photic	Moderate	Physical Representivity	Mod-Low	Weak Substrate Data	No	0-16	4.9	731	3577
Pass Sand not Photic	Mod-Low	Quite Common	Mod-Low	Weak Substrate Data	No	0-16	8.2	830	6809
Pass Mud not Photic	Mod-Low	Quite Common	Mod-Low	Weak Substrate Data	No	0-16	8.7	1275	11080
Inlets Photic	Moderate	Physical Representivity	Mod-Low	Weak Substrate Data	No	0-16	2.9	2626	7671
Inlets Hard not Photic	Moderate	Physical Representivity	Mod-Low	Weak Substrate Data	No	0-15	4	346	1373
Inlets Sand not Photic	Moderate	Physical Representivity	Mod-Low	Weak Substrate Data	No	0-16	5.3	313	1669
Inlets Mud not Photic	Low	Very Common	Mod-Low	Weak Substrate Data	No	0-16	6.9	2709	18769
					No				
Unknown Substrate	Moderate	Account for Knowledge Gaps	Mod-Low	Knowledge Gaps	No	0-16	15	6924	103799

Marine Feature Name	Goal	Goal Rationale	Penalty	Penalty Rationale	Weighted?	Range	Mean: Hexes >0	No. of Hexes >0	Total Values
Unknown Depth	Moderate	Account for Knowledge Gaps	Moderate	Knowledge Gaps	No	0-16	3.3	4816	16010
Very Protected Shorezones	Mod-High	Distinctive Habitats	Mod-High	Sensitive to disturbance	No	0-12	3.4	101	339
Protected Shorezones	low	Very Common	Moderate	General Feature	No	0-15	4.7	4417	20831
Semi-Protected Shorezones	low	Very Common	Moderate	General Feature	No	0-14	4.2	3613	15191
Semi-Exposed Shorezones	Mod-Low	Common	Moderate	General Feature	No	0-12	4.1	1747	7095
Exposed Shorezones	Moderate	Representative Habitat	Moderate	General Feature	No	0-9	3.6	637	2283
Very Exposed Shorezones	Mod-High	Distinctive Habitats	Moderate	General Feature	No	0-10	4.9	86	422
Unknown Exposure	Moderate	Account for Knowledge Gaps	Moderate	Knowledge Gaps	No	0-15	4.8	982	4714
Distinctive Features									
Complexity Shelf	Mod-High	Distinctive Areas	Mod-High	Important to many Spp	Yes 1-7	0-107	29.4	6517	191799
Complexity Passages	Mod-High	Distinctive Areas	Mod-High	Important to many Spp	Yes 1-6	0-82	16.2	2036	32926
Complexity inlets	Mod-High	Distinctive Areas	Mod-High	Important to many Spp	Yes 1-7	0-63	12	2052	24552
Complexity Slope	Mod-High	Distinctive Areas	Mod-High	Important to many Spp	Yes 1-7	0-113	30.7	4530	139188
High Current Areas Shelf	Mod-High	Distinctive Areas	Mod-High	Connectivity	No	0-16	9.7	253	2453
High Current Areas Passages	Mod-High	Distinctive Areas	Mod-High	Connectivity	No	0-16	7.8	234	1832
High Current Areas Inlets	Mod-High	Distinctive Areas	Mod-High	Connectivity	No	0-14	7	145	1018
High Current Areas slope	Mod-High	Distinctive Areas	Mod-Low	Questionable Data		0-16	9.5	160	1518
Special Elements: Rarity									
Hex Sponges	Very High	Rare	Very High	Extremely Rare	Yes 2-3	0-48	24.4	203	4944
Eulachon Estuaries	High	Threatened	High	Threatened	Yes 1-5	0-125	26.4	34	896
Seaotter (not WCVI)	High	Locally Rare	High	Rare	No	0-14	6.9	21	144
Large Corals	High	Likely Threatened and/or Rare	Moderate	Weak data	Yes 1-4	0-64	20.7	3614	74934

Marine Feature Name	Goal	Goal Rationale	Penalty	Penalty Rationale	Weighted?	Range	Mean: Hexes >0	No. of Hexes >0	Total Values
Red-Blue Bird Estuaries	Very High	Red-Blue Spp Critical Habitat	Moderate	Incomplete South	Yes	0-100	44.9	73	3275
Marbled Murrelet Capability	Moderate	Habitat	Mod-High	Red Listed Sp	Yes 2-3	0-48	29.7	2540	75382
Focal Species									
Eelgrass Polygons	Mod-High	Umbrella; critical habitat	Mod-High	Biodiversity, Nursery	Yes 1-4	0-38	4.5	304	1358
N Coast Eelgrass Biobanding	Moderate	Few Other Data	Moderate	Unknown Reliability	Yes 1-2	0-21	4.4	483	2132
QCI Eelgrass Biobanding	Mod-Low	Other Data Available	Mod-Low	Unknown Reliability	Yes 1-2	0-20	5.6	326	1815
NWCVI Eelgrass Biobanding	Mod-Low	Other Data Available	Mod-Low	Unknown Reliability	Yes 1-2	0-20	4.1	152	620
NCC Eelgrass Biobanding	Moderate	Few Other Data	Moderate	Unknown Reliability	Yes 1-2	0-15	3.7	645	2417
SCC Eelgrass Biobanding	Moderate	Few Other Data	Moderate	Unknown Reliability	Yes 1-2	0-14	2.8	297	822
WCVI Eelgrass Biobanding	Mod-Low	Other Data Available	Mod-Low	Unknown Reliability	Yes 1-2	0-22	4.2	229	969
Kelp	Mod-High	Umbrella; critical habitat	Mod-High	Biodiversity, Juveniles	Yes 1-4	0-18	2.4	1174	2822
Kelp Biobanding	Mod-Low	Many Occurrences Recorded	Mod-Low	Other Data Available	Yes 1-2	0-25	6.1	3161	19336
Marsh Grasses Biobanding	Moderate	No Other Data	Moderate	Unknown Reliability	Yes 1-2	0-24	4.1	3077	12723
Surfgrass	Moderate	No Other Data	Moderate	Unknown Reliability	Yes 1-2	0-24	4.8	1448	7001
Other Vegetation Biobanding	Moderate	Amalgamation	Moderate	Increased Reliability	Yes 1-5	0-45	7.1	6099	43310
Unknown Biobanding	Moderate	Account for Knowledge Gaps	Moderate	Knowledge Gaps		0-15	5	868	4370
Bird Colony AnMu	Moderate	Bio Representivity	Moderate	Breeding Seabird Sp	Yes 1-5	0-79	24.9	1758	43851
Bird Colony BlOy	Moderate	Bio Representivity	Moderate	Breeding Seabird Sp	Yes 1-5	0-23	3.5	410	1416
Bird Colony CaAu	High	Largest Global Breeding Area	High	Threatened	Yes 1-5	0-80	21.4	5162	110634
Bird Colony Co	Moderate	Bio Representivity	Moderate	Breeding Seabird Sp	Yes 1-5	0-47	13.3	659	8742
Bird Colony GWGu	Mod-Low	Very Common	Mod-Low	Adaptable Sp	Yes 1-5	0-65	15.7	4245	66436

Marine Feature Name	*Goal*	*Goal Rationale*	*Penalty*	*Penalty Rationale*	*Weighted?*	*Range*	*Mean: Hexes >0*	*No. of Hexes >0*	*Total Values*
Bird Colony PiGu	Moderate	Bio Representivity	Moderate	Breeding Seabird Sp	Yes 1-5	0-69	13.9	1588	22080
Bird Colony Pu	Moderate	Bio Representivity	Moderate	Breeding Seabird Sp	Yes 1-5	0-79	23.6	397	9379
Bird Colony RhAu	Mod-High	Largest in E Pacific	Mod-High	Breeding Seabird Sp	Yes 1-5	0-79	23.3	2747	63888
Bird Colony SP	Moderate	Bio Representivity	Moderate	Breeding Seabird Sp	Yes 1-5	0-79	20.1	6410	129070
Small Islets	Mod-Low	Very Common	Moderate	Unsurveyed Colonies	Density	0-25	7.7	4624	35692
Pelagic Seabird Capability	Moderate	Habitat	Mod-Low	Coarse Data	Yes 1-3	0-49	28.9	6543	188991
Waterfowl Capability	Moderate	Habitat	Mod-Low	Coarse Data	Yes 1-3	0-48	17.8	7609	135185
Shorebird Capability	Moderate	Habitat	Low	Inconsistent Data	Yes 1-3	0-48	18.2	8566	155612
Moulting HaDu	Moderate	Bio Representivity	Moderate	Vulnerable Sp (moulting)	Yes 1-3	0-46	8.1	445	3587
Moulting Scoters	Moderate	Bio Representivity	Moderate	Vulnerable Sp (moulting)	Yes 1-4	0-47	8.5	837	7109
Anad. Richness x Str. Magnitude	Moderate	Spp Richness & Abundance	Moderate	Several datasets	Yes 1-24	0-198	25.8	742	19124
Steller Sea Lions	Moderate	Habitat	Moderate	Haul outs and Rookeries	Yes 1-4	0-63	21.9	760	16658
Herring Spawn	Mod-High	Keystone	Mod-High	Only data available	Density	0-49	8.2	1942	15906

Appendix 2: Stream Richness x Magnitude

This appendix is included to give the reader an idea of the steps involved in creating the data layers that fed into the model. In this particular example, anadromous streams are considered. Explanations of the other layers are available on request.

Overview

This measure of anadromous species richness x stream magnitude is such that it disregards very small streams, and gives higher scores only to exceptionally rich and large streams.

About 1 out of 7 (14%) of BC's stream systems were judged to be *possibly* anadromous, and 71% of those were assigned a score of greater than zero. That is, about 1 out of 10 BC stream systems were considered *likely* to support significant numbers of anadromous species. Of those, about half were assigned a low score (1-4 out of a possible 24), meaning that they are small streams supporting only a few species. Only the Fraser River received a top score (24), with the Nass and Skeena rivers tied in second place (20).

Data Sources

BC fish presence data were compiled from 3 different FISS point sources: *evp* files –sample sites on streams; *evs* files–"stream mouths" which turned out to include other reach data as well; and FISS wizard enquiries producing spatial point files in csv format. Each data source was merged separately for all of BC. It was found that while there was considerable agreement amongst the three BC datasets, they were *not* identical, and sometimes were inconsistent with each other. Thus, it was decided to use all three, although duplicate points would be generated and would need to be weeded out later. A few other databases from private researchers were also used. However, these were small. FISS line files (evz) were found to add no new species presence information not already covered by the points and were not used.

Eight of BC's nine anadromous spp were considered (eulachon, the ninth, was treated separately). These include all *Oncorhynchus* spp (FISS codes: SK, CO, CM, CH, PK; CT_ACT_CCT; ST_SST_WST) and Dolly Varden, DV_ADV (*Salvelinus malma*).

Stream Network Assignments

A network analysis was performed on the BC watershed atlas to create cohesive stream networks connecting all stream reaches to the coast. Thus, every stream reach was identified with a stream network number that corresponded to a point that intersected the coastline. This required considerable data cleaning.

Most fish presence data were then assigned to a stream network. Watershed codes were used when given. When not given, points were spatially joined to the stream networks they intersected (+/- 2 metres). However, many FISS points did not fall on streams. For these, the following operations were performed:

- Use first 14 digits of WSA code if available;
- Check for overlap with other points that had a WSA code;

- Seek a code match using first 12 digits of WSA code if available;
- Seek a code match using first 9 digits of WSA code if available;
- Check over the above work based on nearest distance to stream systems, within 100 metres. This caused 10 points to be reassigned, and allowed for 119 additional points to be assigned to a stream system.

Overall, 135 of 31,835 FISS points (0.4%) were not assigned a stream system. That is, they had no WSA code, and did not fall within 100m of a WSA stream. Some of these appear to be incomplete duplicates of other points, while others appear to be complete orphans, perhaps because the WSA is not entirely comprehensive in its coverage of streams and tributaries, or perhaps due to a mistake in coding the UTM locations of these points.

Richness

Due to inconsistencies found in the datasets, we decided that our measure of richness would require more than 1 record to appear in a stream network (per species) before it would be counted. It is believed that this would weed out many spurious points with a minimum effect on good data. Since we merged three FISS datasets together, it is likely that more than one point should appear on a stream network, were it valid. Indeed, most stream networks had several points. The difference between >0 records (conventional approach with perfect data) and >1 records (our criterion based on inconsistent data) is given in the table below:

	Networks >0	Networks >1
Chinook	229	129
Chum	1040	577
Coho	1227	787
Pink	826	401
Sockeye	308	184
Cut throat	746	522
Steelhead	371	240
Dolly Varden	496	346

1590 systems of 8175 had >0 anadromous sp records; whereas 1120 had >1 records. Species Richness Relative Importance was assigned a number 1-4 based on steps of every two species, as shown

Spp Richness (8175 systems)	Networks >0	Networks >1	RI
1	325	338	1
2	318	267	1
3	363	210	2
4	213	114	2
5	136	67	3
6	95	51	3
7	87	39	4
8	53	34	4

Magnitude

Stream magnitude (attribute of the WSA) was log-transformed (natural logarithm). The resulting range was 0-11. This score was scaled to 1-6. This eliminated all streams of magnitude 2 or less, a subset of second order streams. Only three BC rivers exceeded a score of 4: The Fraser (6), Skeena (5), and Nass (5). Thus, excluding these three exceptional rivers, the measure was designed to have the same weighting, RI=1-4, as richness.

Magnitude x Richness

Richness RI measures and magnitude RI measures were then multiplied together to produce a composite measure of richness and magnitude, with 796 river systems in BC receiving a score of 1 or greater. The only river to get a top score (24) was the Fraser, with the Skeena and Nass both tied in second place at RI=20. About 30% all possibly anadromous streams (>1 spp) were eliminated because they were either too small, or in fewer cases because they had no more than one observation record per species. Of the remaining half, about half of those scored a low score of 1 - 4.

Note: the table below considers all stream systems with >0 anadromous sp, records even though we actually looked at >1 record (see above). This was to allow for comparisons later between the two approaches. Consequently, looking at the table, one can see that about half of these have a score of 0. As noted above, 30% of streams with >1 record scored 0.

RI: Richness x Magnitude	No. of Stream Systems
24	1: Fraser
20	2: Skeena, Nass
16	11
12	26
9	22
8	26
6	67
4	96
3	40
2	244
1	261
0	794
Total >0	796

Coast Information Team Marine Analysis

To incorporate this data layer into the CIT marine analysis, stream mouths (points) were expanded one grid cell (100m) in all directions to account for those that fell near the boundary of two hexagons. This created 300m squares (9 grid cells) for each point. They were neither clipped to the shoreline nor rationalized to the hexagons, as that the buffer was used only as a way to distribute the stream's scores across boundaries, and does not correspond to an actual physical feature. This "blurring" of the stream mouths was to account for spatial differences between watershed atlas data and other data used in the CIT, as well to spread the score more evenly across hexagons that by chance happened to bisect or nearly bisect a stream mouth.

Appendix 3: Conservation Groups

Living Oceans Society MPA Program

Living Oceans Society is a marine conservation organization founded in 1998. The vision of Living Oceans Society is to bring together diverse sectors including First Nations, governments, commercial and recreational fishermen, tourism operators, and the general public to build strategies that ensure long-term health of the ocean and coastal communities on the Pacific Coast of Canada.

The goal of Living Oceans Society's Marine Protected Area Program is to design a network of MPAs based on good science and incorporating the needs of the people who work and live on the coast. Furthermore, we believe that final designation of MPAs should happen within the context of a public process that enables all affected people to discuss and learn about the economic and conservation implications of a network of MPAs or any individual MPA.

To reach this goal we have embarked, to date, on the following three initiatives designed to develop partnerships with First Nations, commercial fishermen, and recreational fishermen to gather and analyze data and distribute it to coastal communities:

The Fisheries Use Analysis

Living Oceans Society works with commercial and recreational fishermen to identify areas important to them for their livelihood. This information is used, with their permission, to identify a network of marine protected areas that minimize economic dislocation and is available for them to communicate their economic needs to decision makers, NGOs, and others. A Pilot Project has been completed in the South Central Coast. Living Oceans Society is now partnering with World Wildlife Fund on the North Coast and Ecotrust Canada and Ecotrust US on the West Coast of Vancouver Island to expand this to a coast-wide project.

Traditional Use Analysis

This project is designed to incorporate the needs of the First Nations into MPA site selection and marine conservation. We are currently conducting a pilot project with the Musgamagw Tsawataineuk Tribal Council Society to identify important fishing areas and cultural areas that need to be considered when designing marine protected areas. This project has been underway for one year.

Conservation Utility Analysis

Living Oceans Society developed this analysis to develop possible options for marine protected areas based on marine reserve design theory and biological, ecological, and oceanographic data.

All of these initiatives – along with others – contribute to the establishment of a network of MPAs and conservation or marine biological diversity. However the Conservation Utility Review Meeting will focus on reviewing only the Conservation Utility Analysis to ensure that it is accurate and credible. More information about our other analyses can be obtained from Living Oceans Society. An expert review of these other analyses will take place in the future.

Other conservation groups in British Columbia, including World Wildlife Fund (WWF) and Canadian Parks and Wilderness Society (CPAWS), are also working on various initiatives to build public awareness and government commitment to establishing a network of MPAs.

Nature Conservancy Of Canada, Bc Region – Coastal Program

Using a science-based, non-advocacy business strategy, the Nature Conservancy of Canada (NCC) has pursued its mission of protecting areas of biological diversity throughout Canada for the last 40 years. NCC's non-confrontational approach allows us to develop strategic partnerships with other conservation groups, private corporations, governments, local communities and individuals. NCC focuses on the conservation of large, relatively intact, functioning landscapes, and emphasizes a community-based approach to its initiatives.

NCC-BC's goal to protect functioning ecosystems is supported by a robust science program. The purpose of our science program is two-fold: we seek to compile comprehensive information on British Columbia's ecosystems to evaluate risks and opportunities, set priorities and make informed programmatic decisions. We do so by engaging diverse stakeholders in the process, in order to create a platform for consensus-based decision-making and partnerships.

NCC-BC has been actively involved in conservation efforts relating to BC's coast. In 2003/4, NCC-BC led the Ecosystem Spatial Analysis of BC's Coastal Information Team (CIT). The ESA was provided to the 2 LRMP and 1 LUP tables as independent scientific analysis to help inform land-use planning decisions. This body of work led to an agreement between First Nations, government, environmental groups and the forest industry, which delineated new protected areas along BC's coast, and established a process for managing the remaining lands through ecosystem-based management (EBM). NCC-BC recently completed a classification of freshwater ecosystems in BC (the first in Canada) that will be used by the provincial government to aid in the management of freshwater biodiversity and resources. NCC-BC was invited by the Marine and Anadromous Fishes Specialist Group of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to develop Designatable Units for all Pacific salmon species under Canada's new Species at Risk Act. The results of this work will inform government policy and management decisions.

Currently, NCC-BC is focused on a number of coastal and marine related initiatives:

Ecoregional Assessments

Over the past six years, we have completed assessments of biodiversity status, and identified critical areas for biodiversity conservation within large "ecoregions" within BC, in partnership with government, First Nations, academics, and other ENGOs. These science-based ecoregional assessments are openly shared with stakeholders and communities in an effort to develop a shared conservation vision for an ecoregion and effective partnerships for biodiversity conservation. With the completion of the North Cascades ecoregional assessment, projected for spring 2006, NCC-BC will have achieved a first iteration biodiversity assessment for British Columbia's entire nearshore.

NCC-BC's Pacific Salmon Program

While numerous players on BC's coast are now seeking solutions for conservation of land-based ecosystems, based largely on the CIT work, freshwater and marine ecosystems have not been adequately addressed in current land use planning activities. NCC-BC believes that, to develop an effective conservation program in coastal areas, a full understanding and assessment of aquatic ecosystems, both freshwater and marine, and their keystone species – Pacific salmon – is required.

With our background of conducting ecoregional assessments and freshwater ecological classification, NCC-BC is poised to develop a multi-stakeholder driven program to create a state-of-the-salmon georeferenced database, which will then inform the delineation of designatable units for all Pacific salmon species in BC, followed by a threats assessment and unit prioritization. This science work will directly bear on four of the six strategies of the Canadian government's Wild Salmon Policy and will inform an on-the-ground, partnership-based program aimed at maintaining the viability of all Pacific salmon populations within identified priority watersheds and nearshore marine areas.

Land Securement

Work conducted through the completed ecoregional assessments has shown where NCC's land securement work should be focused, and we are engaged in a number of projects on the coast which will support maintaining the viability of biodiversity values identified, including Pacific salmon, while enabling sustainable use and development of natural resources within an EBM context.

World Wildlife Fund Canada's Pacific Marine Program

The World Wildlife Fund (WWF) global network was founded in 1961 and has grown into one of the largest and most respected independent conservation organizations in the world. WWF has almost five million supporters distributed throughout five continents, and operates in 96 countries around the world.

The focus of WWF's work is to tackle the problems of habitat loss and species destruction, with the ultimate goal of achieving the conservation of nature and ecological processes. WWF seeks to accomplish this mission by:

1. conserving biological diversity
2. ensuring the sustainable use of natural resources; and
3. promoting the reduction of pollution and wasteful consumption.

WWF employs a range of tools to accomplish its mission, including scientific fieldwork, education, and public awareness initiatives.

WWF-Canada's British Columbia activities are components of an integrated regional program aimed at achieving ecological sustainability and healthy communities in BC. The regional program has 3 main components: marine, biodiversity and forests. The marine is the most comprehensive component of the program and is WWF's priority in BC at this time.

Our pacific marine program goals are:

a to secure the establishment of an MPA network of representative ecosystems and distinctive features to protect the globally significant diversity of marine places and marine of Canada's Pacific Coast; and

b to advance the implementation of a collaborative, community-supported and science-based, integrated management plan for the Northeast Pacific marine region (led by DFO).

To achieve these goals we are working to advance an ecosystem-based approach to conservation planning that embraces and represents the aspirations and values of indigenous peoples and local communities and is based on global best practice, marine biodiversity conservation priorities and innovative, effective alliances between the public and private sectors.

Our program is delivered through a two-fold approach: bottom-up development of local capacity, new and effective alliances and delivery of community supported plans from a remote field office in Prince Rupert; and top-down development and delivery of legal, policy and planning frameworks, institutional arrangements and technical products that reflect global best practice, from key strategic locations in Vancouver and Victoria. Our BC program is also supported by a National Board of Directors and key staff in offices in Toronto and Ottawa.

Some key elements of our evolving marine program include:

1. policy development and securing key framework agreements (e.g. MPA and Integrated Management sub-agreements to the BC/Canada Oceans MOU);
2. technical product development to advance progress and decision-making, including identifying priority species and mapping and documentation of marine areas of conservation interest/value;
3. development of a collaborative, community supported, science-based vision and identification of conservation priorities for both the northeast Pacific marine region, and the Haida Gwaii/Gwaii Haanas sub-region, that can help guide sustainable development in the region and prepare WWF and local people for engagement in upcoming integrated oceans management and MPA planning;
4. engagement in place-based processes for existing MPA candidates to expedite decisions (e.g. Bowie Seamount; Gwaii Haanas NMCA; upgrades to priority provincial marine parks and ecological reserves);
5. founding and leading the Pacific Marine Analysis and Research Association (PacMARA), an independent, non-profit society, mandated to produce timely delivery of collaborative science and analysis to support ecosystem-based coastal marine planning and decision-making (including support for other technical projects in the WWF marine portfolio); and
6. building the popular case for marine conservation through development and delivery of public communications products, public outreach and new stakeholder alliances

The CPAWS Marine Campaign Program

The Canadian Parks and Wilderness Society (CPAWS) is Canada's grassroots voice for wilderness. Our focus is on science-driven campaigns to establish new protected areas and to ensure that "nature comes first" in the management of existing parks.

The CPAWS marine campaign goal is to preserve healthy, productive and diverse oceans off the coast of British Columbia that will provide ecological, social and economic services to all Canadians for generations to come. This vision includes a comprehensive network of representative marine protected areas (MPAs) for Canada's entire Pacific coast, protecting diversity of species, habitats and ecosystems.

The CPAWS MPA strategy is focused on:

MPA Policy and Legislation

Ensuring that effective MPA policy and legislation is developed that incorporates the BC ENGO definition of MPAs (i.e. having one or more core no-take areas and surrounding buffer zones);

MPA Network Approach

Ensuring that a coordinated science-based and socially sensitive MPA network strategy is developed and implemented;

MPA Designation

Securing formal designation of our campaign sites, primarily the Southern Strait of Georgia, Big Eddy International Marine Ecosystem, Hecate Strait Sponge Reefs, Scott Islands, Indian Arm and Gwaii Hanaas;

Integrated Management

Advancing and contributing to marine integrated management planning that includes an ecosystem-based approach; and

Education and Outreach

Rraising public awareness about the importance of the marine environment, threats to ecological integrity and the role of MPAs in marine conservation.

Since 1993, CPAWS has played an important role in the protection of British Columbia's marine environment. We have contributed to the development of MPA policy and legislation, public awareness and education, and the identification and documentation of large marine areas as potential MPAs. CPAWS works together with government agencies, communities, First Nations, other conservation groups, fishing organizations and others to advance the MPA agenda in BC to ensure the long-term health of the marine environment.

David Suzuki Foundation

Marine Conservation Program Overview:

The David Suzuki Foundation marine conservation program aims to reduce the negative effects of fishing and other industrial practices on Canada's pacific coast marine environment by advocating for and realizing ecosystem-based management policies and regulations for Canadian fisheries and marine oriented industries.

Our Overarching Program Goal:

To reduce, and whenever possible eliminate, the negative environmental effects of fishing, industrial operations and other human activities that degrade the health and integrity of Canada's ocean, coastal and freshwater ecosystems.

Program Objectives

- Increase the abundance of depleted populations of marine species;
- Reduce the threats to marine and freshwater species and their habitats by decreasing the occurrence of unsustainable fishing and industrial practices affecting marine species and their habitats;
- Increase the requirement for and occurrence of collaborative decision-making and authority related to the use of marine and coastal freshwater resources;
- Increase the number and area of designations that serve to protect specific and unique marine and freshwater environments; and,
- Reduce the market demand for unsustainably derived seafood products.

Proposed Outcomes

Government responsibility for many of these issues falls under the mandate of Canada's Department of Fisheries and Oceans (DFO). Changes in DFO's structure and focus over the past decade have led to failures in fulfilling their conservation mandate. We aim to build a constituency in the public and with decision makers in industry and government that will support substantive improvements in marine fisheries and marine habitat conservation. To realize our program's objectives we are engaging the following projects:

Project 1

Promote Ecosystem Based Management (EBM) through Marine Use Planning

We are currently engaged in several strategies to ensure that the use of marine resources is directed by ecosystem-based management principles and standards. We are working collaboratively with other ENGOs (Living Oceans Society, World Wildlife Fund, Sierra Club, Raincoast Conservation Society) and the BC Coastal First Nations Turning Point Initiative to ensure that Federal and Provincial governments establish a formal marine use planning process on the BC coast. Our current geographic focus is the North and Central coast regions of BC, known as the Pacific Northwest Integrated Management Area (PNCIMA).

Project Goal

- To realize increased conservation of our marine resources through the application of an ecosystem-based management plan on the BC coast.

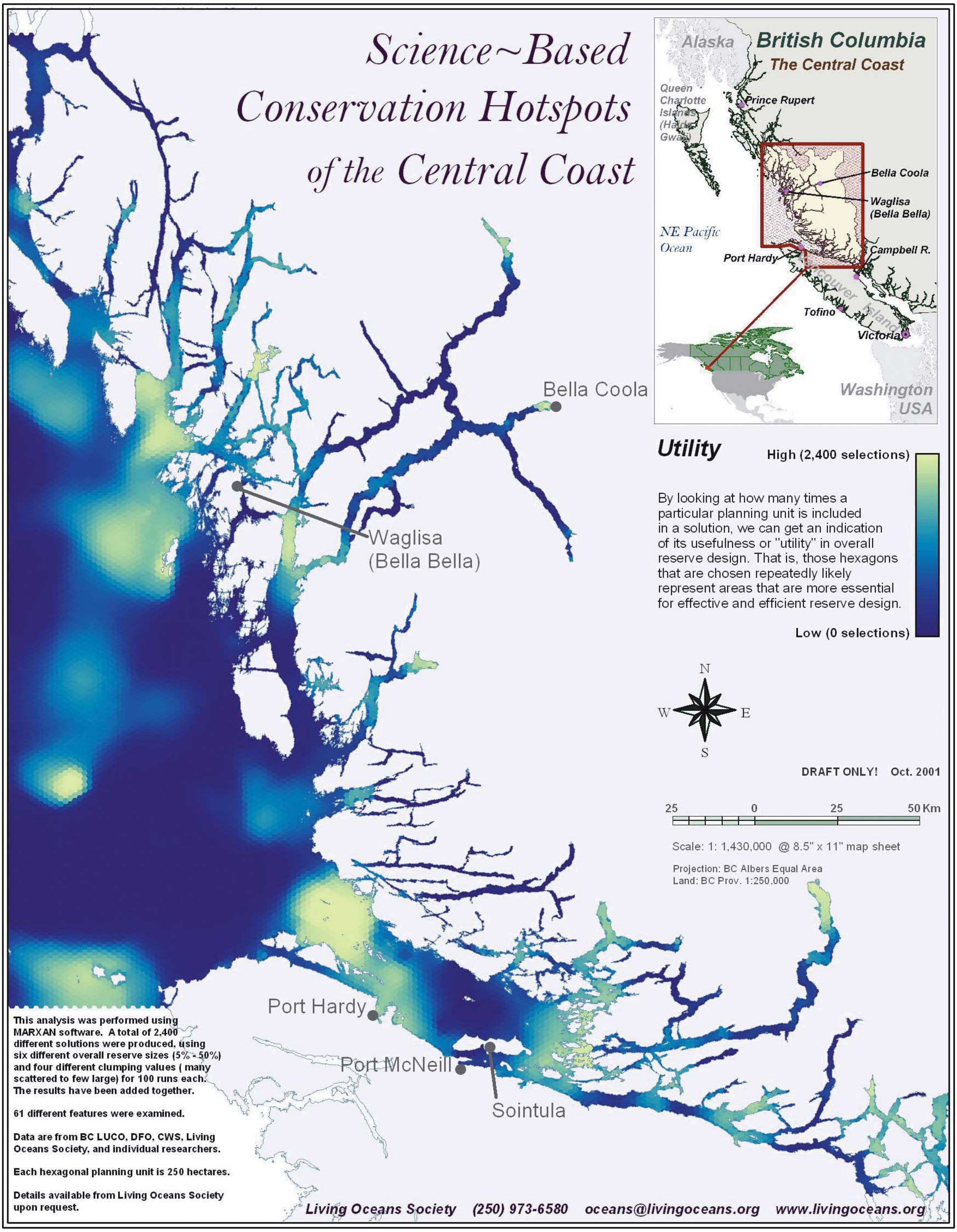
Project Objectives

- Ensure that ecosystem-based management (EBM) principles drive the framework, objectives and decision-making at regional marine planning forums.
- Enhance the level of conservation analysis required to support the marine use planning processes.

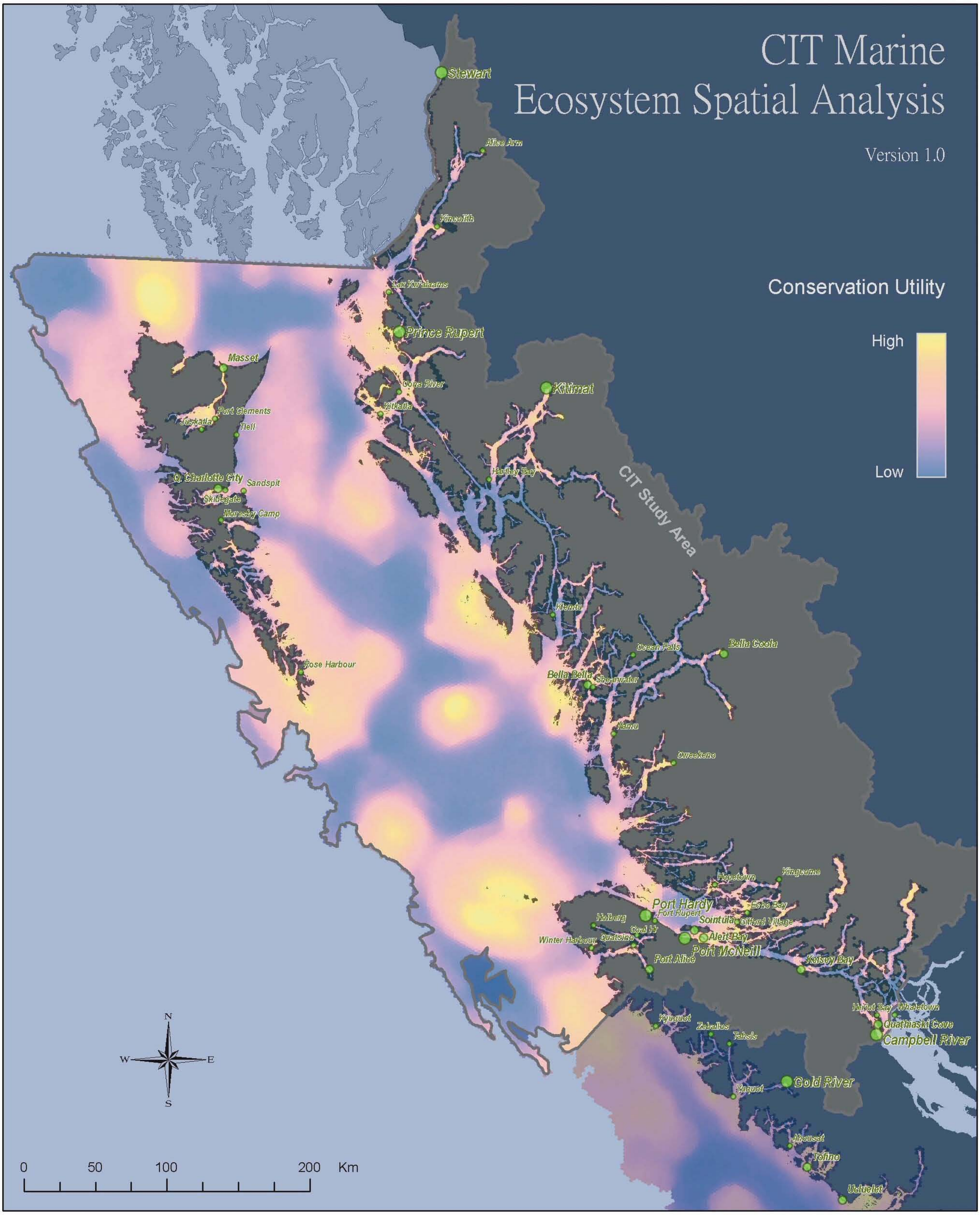
2005-2006 Activities

- Promotion of marine use planning – direct engagement with the Coastal First Nations and the Federal and Provincial governments to develop and implement marine use planning on the BC North and Central Coast regions, including Haida Gwaii (Queen Charlotte Island);
- Strategic communications/outreach – develop and implement a communications strategy aimed at increasing public awareness of the need for marine conservation. This includes both opportunistic and planned media initiatives related to specific marine conservation issues;
- Collaboration on scientific analysis and research – Encourage and participate in science forums that plan and undertake independent research and analysis for marine use planning;
- Production of investigative reports – highlight the conservation needs of specific marine fish, mammal and invertebrate stocks on the BC coast and profile industrial activities that are destructive for marine environments and species;
- Strategic alliances with other ENGOs – We will actively partner on initiatives that support our overarching marine conservation goals and objectives. We are currently engaged in several highly effective partnerships dealing with salmon aquaculture, offshore oil and gas development and marine use planning. We host discussions to help coordinate roles and advocacy work amongst the various stakeholders.

Appendix 4: Maps



Science~Based
Conservation Hotspots
of the Central Coast
British Columbia
The Central Coast
Alaska
Queen Charlotte Islands
Prince Rupert
Bella Coola
Waglisa (Bella Bella)
NE Pacific Ocean
Port Hardy
Campbell R.
Tofino
Victoria
Washington
USA
Bella Coola
Waglisa
(Bella Bella)
Utility
High (2,400 selections)
By looking at how many times a particular planning unit is included in a solution, we can get an indication of its usefulness or "utility" in overall reserve design. That is, those hexagons that are chosen repeatedly likely represent areas that are more essential for effective and efficient reserve design.
Low (0 selections)
N
W
E
S
DRAFT ONLY! Oct. 2001
25 0 25 50 Km
Scale: 1: 1,430,000 @ 8.5" x 11" map sheet
Projection: BC Albers Equal Area
Land: BC Prov. 1:250,000
Port Hardy
Port McNeill
Sointula
This analysis was performed using MARXAN software. A total of 2,400 different solutions were produced, using six different overall reserve sizes (5% - 50%) and four different clumping values (many scattered to few large) for 100 runs each. The results have been added together.
61 different features were examined.
Data are from BC LUCO, DFO, CWS, Living Oceans Society, and individual researchers.
Each hexagonal planning unit is 250 hectares.
Details available from Living Oceans Society upon request.
Living Oceans Society (250) 973-6580 oceans@livingoceans.org www.livingoceans.org



This Map depicts the trends resulting from 2,400 different conservation solutions added together. Six overall reserve sizes ranging from approximately 5% to 50% were examined. Four "clumping" variables (very scattered, scattered, moderate, and clumped) were examined for each of the six reserve sizes, producing 24 variations. Each variation was run 100 times, producing 2,400 solutions. Each solution was created using Marxan (simulated annealing) software for 15,000,000 iterations.

There are approximately 32,000 planning units in the analysis. Each planning unit is a 500 hectare hexagon. Hexagons that were chosen repeatedly in analysis solutions are said to have high "conservation utility;" that is, they are very useful (perhaps essential) in a variety of conservation scenarios. Although these brightly coloured areas represent important areas, they do not necessarily capture all ecological values within the study area. For this, one must look at individual solutions.

CIT Marine Ecosystem Spatial Analysis

Sept. 13 2003

This analysis is the result of 93 feature layers. Data collected by the Coast Information Team, and Living Oceans Society. Data provided by Fisheries and Oceans Canada; Decision Support Services, MSRM; Canadian Wildlife Service; Natural Resoruces Canada; Parks Canada; private researchers, and local knowledge.

Mapping & Analysis by Jeff Ardron, Living Oceans Society.

CIT/LOS Conservation Utility Analysis