Recommendations on Applying Canada-BC Marine Protected Area Network Principles in Canada's Northern Shelf Bioregion:

Principles 1, 2, 3, 5, 6, 16, with discussion on 4, 7, 8, 12.

Produced by PacMARA for the British Columbia Marine Protected Areas Implementation Team

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Table of Contents

Acronyms

BC	British Columbia
BCMCA	British Columbia Marine Conservation Analysis
CA	California
CBD	Convention on Biological Diversity
CIT	Coast Information Team (BC)
COSEWIC	Committee On the Status of Endangered Wildlife In Canada
DFO	Fisheries and Oceans Canada (formerly Department of Fisheries and Oceans)
EBM	Ecosystem-based management
EBSA	ecologically and biologically significant area (DFO and the CBD)
EEZ	Exclusive Economic Zone (generally, areas 12 to 200 nautical miles offshore)
GBRMP	Great Barrier Reef Marine Park (Australia)
GBRMPA	Great Barrier Reef Marine Park Authority (Australia)
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs (a software tool)
IUCN	International Union for the Conservation of Nature
km	kilometre
LRMP	Land and Resource Management Plan (BC)
m	metre
MaPP	Marine Planning Partnership for the North Pacific Coast (BC)
MCZ	Marine Conservation Zone (United Kingdom)
MLPA	Marine Life Protection Act (California)
MMA	marine managed area (general term sometimes used in the US and elsewhere)
MPA	marine protected area
MPAIT	Marine Protected Area Implementation Team (BC)
NGO	non-governmental organization (usually environmentally oriented)
NM	nautical mile
NMCA	National Marine Conservation Area (Parks Canada)
NSB	Northern Shelf Bioregion (BC)
PA	Precautionary Approach
PNCIMA	Pacific North Coast Integrated Management Area (BC)
SD	standard deviation
UK	United Kingdom
US	United States
VEC	Valued Ecosystem Component (DFO)
VMEF	Valued Marine Environment and Feature (Province of BC)

I. Foreword

This report focuses on the scientific literature and related practices from marine planning processes worldwide to inform the development of an MPA network in British Columbia's (BC's) Northern Shelf Bioregion. Encompassing the North and Central Coasts of the province, Haida Gwaii (Queen Charlotte Islands) and several First Nation territories, local and traditional expertise will be critical to the success of this endeavour. The recommendations made in this report are meant to complement, not replace, engagement of local communities, stakeholders, and governments.

Marine protected areas (MPAs), despite having been with us for several decades, are still tricky to establish, with their ultimate outcomes not always matching initial good intentions. A network of MPAs, i.e., an ecologically coherent placement of several complementary MPAs together in a region that function as a group, is much more challenging still. The 16 Canada-BC MPA Network Design Principles are a step in the right direction. The implementation guidance in this document concerns the subset of those principles that are more ecological and quantifiable. While it is tempting to seek hardened rules, the inflexibility of such rules would almost certainly lead to disenchantment and conflict. The somewhat flexible recommendations provided here are nevertheless based on good practices found in the literature, on the water, and through hard-learned experiences.

The Northern Shelf Bioregion is a varied seascape, ranging from deep narrow glacial-fed inlets to current-swept passages to broad continental shelf waters, gyres and upwellings. Each seascape brings its own scale and ecology, and these differences should be reflected in MPA network planning. For example, a relatively small MPA in an estuarine inlet may be entirely appropriate, whereas that size would not adequately protect a typical deep-sea canyon. In this light, our recommendations necessarily come with ranges. For example, the minimum recommended size of MPAs ranges from 5 to 150 km^2, which, rather than being intentionally vague, is meant to take into account the varying scale of the planning region. Correct and workable implementation of this and other recommendations will depend upon conscientious and responsible interpretation by the planning process participants.

The cultural landscape of the region is likewise varied, and will also need to be considered at a scale fit for purpose. Federal, provincial, First Nation, and municipal implementation will require a multi-tiered cooperative approach. The social, economic, and cultural principles (i.e., 6-11, described below) bring with them a plethora of considerations, any one of which could cause the process to stumble or even fail if not addressed. Trust will be paramount so that when inevitable mistakes and oversights are made there will be the necessary good will and effort to overcome them.

Valuable preparatory work has already taken place in BC, some of which has fed into previous planning processes. The Northern Shelf Bioregion brings with it a BC and Canadian context of natural, cultural, legal, and regional planning histories; thus, it is not a blank slate, but a rich tapestry worthy of completion. As practitioners who have worked with, and learnt from, other marine planning processes the world over, we see BC's Northern Shelf Bioregion process as a compelling opportunity to safeguard the unique values held in the region, the likes of which have already been lost in many other lands and cultures. We wish all participants the best of success.

II. Executive Summary

With the vision of "an ecologically comprehensive, resilient and representative network of marine protected areas that protects the biological diversity and health of the marine environment for present and future generations", the Canada-BC MPA Network Strategy was developed (Canada-BC, 2014, p. 9). As part of that strategy, 16 Canada-BC MPA Network Design Principles were created jointly by federal and provincial governments, which included a ten month consultation period (ibid., 2014).

The Marine Protected Area Implementation Team (MPAIT) is a federal-provincial technical working group responsible for coordinating marine protected area network planning and implementation in Canada's Pacific waters.[1] In August 2014, the MPAIT issued a Statement of Work to develop guidance on applying Canada-BC MPA Network Design Principles for the Northern Shelf Bioregion[2] (NSB), with a particular focus on those of quantitative scientific nature: #2, 3, 5, 6, & 16. (Four related principles with some scientific considerations are also discussed in this report, though recommendations are not made: #4, 7, 8, & 12.) The remainder of the principles, though still important for MPA design and implementation, were not included in this scope of work.

This document has undergone several rounds of internal review, two separate rounds of external peer review by recognized experts (3 & 3 persons, respectively), reviews by MPAIT members (10 reviews), and has been the topic of discussion at a bespoke expert review workshop, 3-4 February 2015, organized by MPAIT. Comprehensive in its coverage of a broad range of topics, this report is necessarily an overview. Some of its recommendations, if accepted for implementation, will need to be refined in follow-up work, with additional examples from the literature and planning processes elsewhere.

The Canada-BC MPA Network Strategy uses the IUCN definition of an MPA, which includes a broad range of management measures. Principles directly related to management concerns fall outside this scope of work. Determining appropriate management measures will require a site by site consideration of existing human uses, their ecological impacts, and the trade-offs involved (Principles 6-8, below). Designing an *effective* MPA network is already complicated by external non-point stressors such as climate change, and becomes much more so if management measures only partially protect species and habitats. For this reason, the ecological design recommendations within this report generally presume that the MPAs will be designed to fully (or nearly so) protect the species and habitats within them. As discussed under Principle 5, weaker or stronger levels of protection will drive the design of larger or smaller MPA sizes, as the case may be, in order to achieve similar ecological objectives. Reflecting the literature, strong management measures (e.g., no-take areas) are shown to be much more effective in meeting such objectives (e.g., Edgar et al., 2014).

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[1] At the time of writing, MPAIT is undergoing a re-structuring to include First Nations, and will be renamed.

[2] This planning region is comprised of Haida Gwaii (Queen Charlotte Islands), North and Central Coasts of BC, and the northeast corner of Vancouver Island, extending from the inlets out to the base of the continental shelf slope: http://www.dfo-mpo.gc.ca/oceans/publications/dmpaf-eczpm/img/framework2011_fig1.jpg.

Our recommendations under Principle 6 (inclusion of the full range of human uses) presume that there will also be a variety of management measures available to address mitigating impacts to existing human uses. This suggests that no-take reserves, while an important part of the NSB MPA network, should not be the only management option. Existing MPAs and other spatial protective measures should also be taken into consideration (per Principle 14). We note that MPAs designed to meet community goals can achieve greater compliance and subsequent conservation success than regimes designed only for biodiversity conservation (McClanahan et al., 2006). Ultimately, the management of the MPA network is inextricably linked to the network's ecological objectives.[3]

In virtually all the literature reviewed, comprehensive and inclusive stakeholder engagement is part of recommended practices. However, in the five real-life processes we considered in greater detail (summarized in Appendix 1), none had outcomes that pleased all stakeholders, with some processes facing considerable, and at times acrimonious, opposition. No MPA process should thus expect to please everybody, and evidence from other parts of the world indicates considerable political will is required to move forward with implementation.

Throughout this report, we emphasize the need to reflect the scale and the ecology of the features under consideration for protection. The physical and biological diversity of the Northern Shelf Bioregion suggest that a broad range of MPA sizes, spacing, and approaches will be necessary. We argue against simplistic across-the-board targets, and instead recommend that the spatial extent of protection reflect the ecological context of the feature (e.g., its spatial distribution, rarity, role in supplying ecosystem services, etc.) and the level of threat it is facing. For example, keystone species or species and habitats under threat should receive greater percentage protection than common species or species and habitats that are not particularly endangered.

While our recommendations reflect the literature, they are sometimes more flexible and less stringent than commonly called for. For example, while we recommend an overall MPA network footprint of 20%, the recent IUCN World Parks Congress declaration calls for 30% no-extraction areas (IUCN, 2014), and experts often call for more than that (MPA News, 2015). Likewise, we allow for the possibility of smaller MPAs than commonly recommended, as well as wider spacing. In all cases, our rationale has been to balance practices suggested internationally with the current state of marine ecosystems at home. In general, the NSB is fortunate to still have a large degree of ecosystem health, as compared to, say, European waters. That said, the NSB coast and waters are likely to become further developed, and hence under greater pressures over time. One should not become complacent, as underlined by several NSB stocks that are in decline. We encourage the development of a comprehensive NSB MPA Network as soon as possible.

Six of the 16 Canada-BC MPA Network Design Principles can be characterized as quantitatively scientific in nature (ecology with some socio-economics). The top six key recommendations for each of these are

[3] At the time of writing, the NSB MPA Network Objectives are still in draft format subject to further revisions, and for that reason will not be quoted directly in this document.

summarized below. Full text of these *Key Recommendations*, as well as *Additional Recommendations*, and discussion of other related Principles can be found in the main body of the report.

Principle 1: Include the full range of biodiversity present in Pacific Canada

1. Divide the Northern Shelf Bioregion into sub-regions that reflect the network's ecological objectives, while taking into account management and logistical realities.
2. In order to track progress in the protection of the full range of biodiversity, lists of "representative" (indicative) species and habitats for the NSB will need to be developed.
3. Use credible species-habitat classification systems where they exist. More than one can be applied in the same (sub-) region to highlight different aspects of biodiversity, but those that have been verified with biological data or local knowledge should be prioritized.
4. Replicate feature types and classification classes 3-5 times in each sub-region where they occur.
5. Targets for features should vary according to the rarity of the feature and the threats it faces, and could range from < 5% to 100%.
6. The minimum recommended footprint of the NSB MPA network is 20% of the planning region. Footprints across sub-regions should be approximately the same.

Principle 2: Ensure ecologically and biologically significant areas (EBSAs) are incorporated[4]

1. The existing NSB EBSAs identified by DFO should each be reviewed by scientific and local experts for inclusion in the MPA network based on the network objectives. Decisions (for or against) and rationale thereof should be documented and attributed.
2. Other designations, such as *Valued Ecosystem Components* (DFO) and *Valued Marine Environments and Features* (Province of BC), should also be used to inform the selection of MPA sites.
3. Identification (or estimation) of species and habitats not covered by existing designations is recommended, with particular consideration given to:
    a. spawning, breeding, nursery, rearing, foraging migration, and seasonal refugia;
    b. intertidal, shallow nearshore, and deep offshore habitats, and processes.

    These newly identified areas should also be reviewed for possible inclusion (or parts thereof) in the MPA network, based on the network objectives.

4. To facilitate management considerations, sub-divide large identified areas into smaller sub-units based on the network objectives.
5. Identified areas not included in the final MPA network should not be forgotten, but instead be listed as part of the description of the NSB's recognized ecologically valuable places.
6. Use of local and traditional knowledge in the identification of EBSAs and EBSA-like areas is recommended.

[4] For a discussion of EBSAs and their meaning in this report, please see the main text, under Principle 2.

Principle 3: Ensure ecological linkages

1. The spacing and configuration of an MPA network should reflect the ecological objectives of that network, such that sites for species' life history stages and habitat patches of particular interest are close enough to conceivably be ecologically connected.
2. In general, a representative MPA network should be well distributed, alongshore and offshore.
3. MPA size and spacing should reflect the predominant geography, oceanography, and scale of the local ecosystem into which sites are placed.
4. Generic MPA spacing should not exceed nine times the square-root of the average size of the neighbouring MPAs; i.e.,

   $$\text{MPA Spacing} \leq 9\cdot((\text{Area}_1 + \text{Area}_2)/2)^{0.5}$$

5. Same or similar habitats in close proximity to one another (e.g., rocky reefs and islets < 5 km apart) are likely to be a single ecological system, and if protected, should be treated as either a single larger MPA or as a cluster of ecologically connected MPAs.
6. When known, the spatial distribution of species' life history stages, including the movement of adults (foraging and feeding, breeding, migratory behaviours), should be considered to be protected as an ecologically connected MPA cluster.

Principle 5: Ensure maximum contribution of individual MPAs

1. MPA shape should attempt to capture the locally dominant ecological processes and features, in accordance with the MPA network objectives.
2. An uncertainty factor should be included as part of an MPA's overall shape and size calculation.
3. The NSB network should contain MPAs across a broad range of sizes.
4. MPAs, at a minimum, should be 5 km^2 to 150 km^2 in size, depending on their location and conservation objectives. (*Examples of implementation provided in the full report text*.)
5. The majority (more than half) of MPAs should be at least 50 km^2.
6. MPA and protected habitat patch size should take into account anticipated management measures, such that ecological function is preserved:
   a. Under management that will allow some limited extractive activities (IUCN category IV), or otherwise negatively affect species or habitats, affected areas should generally be at least two times as large as outlined above; and
   b. Under management that will allow sustainable use (IUCN category VI), affected areas should generally be at least four times as large as outlined above.

Principle 6: Recognize and consider the full range of uses, activities and values supported by marine environments

1. Before collecting data on the range of uses, activities and values in the NSB, first ensure there is a shared understanding of the planning process, its objectives, and management options.
2. Incorporate traditional, local, and stakeholder knowledge concerning usage of the marine and nearshore environment of the NSB to produce fine resolution spatial datasets (location, relative importance, and intensity) of:
    a. human commercial and recreational activities,
    b. culturally and historically significant areas, and
    c. spiritual sites.
3. Identify community-based conservation initiatives and integrate local knowledge for possible inclusion of these sites in the MPA network.
4. Incorporate non-market values into the MPA process, balancing these with conservation and economic concerns.
5. As that MPA implementation may initially impact some local economic opportunities, identify opportunities for future and alternative uses both within proposed MPA sites and the surrounding region, and develop a displacement policy for those that are impacted by development of MPAs.
6. Use optimization (e.g., Marxan) and decision support tools (e.g., InVEST) to integrate ecological, social and economic considerations into marine spatial planning processes for MPA design.

Principle 16: Take a precautionary approach

1. Avoid making irreversible decisions that could lead to substantive or irreversible harm to the environment (species and habitats).
2. Identify critical knowledge gaps so the appropriate decision-making strategies can be applied, and research can be applied in filling these gaps.
3. More precaution will be required in the face of more significant knowledge gaps. Build in safety factors (e.g., buffer zones) in calculations of MPA network design and the management of human activities within, and outside of, the network.
4. While some MPAs should be seen to improve human well-being, not all of them need have this objective. Some should be established solely for reasons of ecological precaution.
5. Given that a key pitfall involves achieving an acceptable balance between using best available evidence and precaution, an attempt should be made to develop agreed minimum standards for acceptable risk at the start of the MPA process.
6. Treat the MPA Network Design Principles as a package, which as a whole contain several elements of the precautionary approach. Do not restrict implementation to a subset of Principles.

In the body of this report, selected Canada-BC MPA Network Design Principles are discussed, including pitfalls to be avoided, and several recommendations are made, based on an extensive review of the literature (159 references) and existing practices. In **Appendix 1**, at the end of this document, examples of implementation rules developed in five other planning processes are summarized. Further, a detailed literature review (95 papers examined), organized according to the 16 MPA Design Principles is in **Appendix 2** (separate document). In **Appendix 3,** the *Sidney Consensus* provides a succinct set of principles for ecosystem-based management, developed by academia, federal government, First Nations, industry, provincial government, and NGOs in BC.

This report is the first attempt to provide guidance on implementation of (some of) the recent Canada-BC MPA Network Design Principles. We emphasize the need to regularly monitor, review, re-evaluate, and adapt as experience is developed and new information becomes available.

III. Introduction

British Columbia's coastal and maritime waters are graced with rich cultures and traditions associated with long-term sustainability, natural resources and biodiversity. Not wishing to lose this natural and cultural heritage, the *Canada – British Columbia Marine Protected Area Network Strategy* was developed to "protect its richness for present and future generations" (Canada-BC, 2014, p.2). The strategy contains 16 design principles covering ecological; social, economic, and cultural aspects; and general implementation. The MPA Network Principles are necessarily broad and vague (e.g., "ensure ecological linkages") to include the range of implementation possibilities; therefore, technical guidance and stakeholder input are required to enable their regional application. The primarily scientific (ecological with some socio-economic) guidance in this report addressing the six most quantitative principles should be seen as just one component of the approach that will be required to address all 16 Principles.

What is an MPA?

In this report, we follow the Canada-BC MPA Network Strategy (2014, p. 7):

For the purposes of this Strategy, the term 'marine protected area' will be used as a single, general umbrella term that is applied to the range of different marine habitat protection tools available under federal and provincial legislation. In addition, the International Union for the Conservation of Nature / World Commission on Protected Areas (IUCN/WCPA) 2008 definitions of a protected area and a protected area network have been adopted both nationally and regionally for developing networks of MPAs. These definitions are:

MARINE PROTECTED AREA: "A clearly defined geographical space recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values".

MARINE PROTECTED AREA NETWORK: "A collection of individual marine protected areas that operates cooperatively and synergistically, at various spatial scales, and with a range of protection levels, in order to fulfill ecological aims more effectively and comprehensively than individual sites could alone."

The Marine Protected Area Implementation Team (MPAIT) is a federal-provincial technical working group responsible for coordinating marine protected area network planning and implementation in Canada's Pacific waters.[5] In August 2014, the MPAIT issued a Statement of Work to develop guidance on applying the network design principles identified in the Canada-BC Marine Protected Area Network Strategy in the Northern Shelf Bioregion[6] (NSB), with a particular focus on those of a scientific and

[5] At the time of writing, MPAIT is undergoing a re-structuring to include First Nations, and will be renamed.

[6] This planning region is comprised of North and Central Coasts of BC, extending from the inlets out to the base of the continental shelf slope: http://www.dfo-mpo.gc.ca/oceans/publications/dmpaf-eczpm/img/framework2011_fig1.jpg.

quantitative nature, in **bold** below.[7] Four other related principles with some scientific considerations are also discussed, though creating recommendations for these fell outside the scope of work (underlined below). The remainder of the principles were not included in this scope of work. When considering the six bolded Principles, we have generally interpreted them broadly, going beyond strictly scientific considerations to consider some possible policy implications as well.

ECOLOGICAL NETWORK DESIGN PRINCIPLES

1. ***Include the full range of biodiversity present in Pacific Canada*** (representation and replication).
2. ***Ensure ecologically or biologically significant areas are incorporated*** (EBSAs).
3. ***Ensure ecological linkages*** (connectivity).
4. *Maintain long-term protection.*
5. ***Ensure maximum contribution of individual MPAs*** (size, spacing, shape).

SOCIAL, ECONOMIC, AND CULTURAL PRINCIPLES

6. ***Recognize and consider the full range of uses, activities and values supported by marine environments*** (spatio-temporal intensity of human activities, cultures and values, ecosystem goods and services, costs of inaction).
7. *Maximize the positive* (identify opportunities for sustainable socio-economic activities, cultural and spiritual values).
8. *Minimize the negative* (network design cost, user conflict, balance conservation with social and economic opportunities, economic analyses).
9. *Enhance management effectiveness and compliance to maximize benefits and minimize costs.*
10. *Work with people* (balanced, open, inclusive, transparent, providing opportunities for meaningful involvement, stakeholders, & partnerships with First Nations, local authorities, coastal communities, resource users).
11. *Respect First Nations' treaties, title, rights, aspirations and world-view.*

GENERAL OPERATING PRINCIPLES

12. *Foster ecosystem-based management.*
13. *Apply Adaptive Management.*
14. *Build on existing MPAs, other management tools and marine planning initiatives.*
15. *Include a full range of protection levels.*
16. ***Take a precautionary approach.***

Note that Principles directly related to management fall outside this scope of work. Reflecting the literature, **the ecological design recommendations within this report generally assume that the MPAs will be designed to fully (or nearly so) protect the species and habitats within them**. Determining appropriate management measures will require a site by site consideration of existing human uses, their ecological impacts, and the trade-offs involved (Principles 6-8, below). Existing MPAs and other spatial protective measures should also be taken into consideration (per Principle 14).

[7] Political, process, and management issues, will be considered separately from this report.

There is a diversity of good practices and guidance regarding the establishment of MPA networks. The choice of methods will largely hinge on the social, political, traditional, cultural, economic, and ecological realities of the NSB. There are also pitfalls to be avoided, seldom covered in the literature, which we will strive to point out. Although getting started with good guidance is clearly advantageous, it would be unrealistic to expect to get the myriad of variables correctly balanced in the first implementation. We therefore emphasize the necessity of an iterative approach comprised of regular monitoring, review, and adaptation as new information and insights become available, allowing a robust and resilient MPA network in the NSB to be established and maintained.

Background

Government-led marine conservation and planning in BC extend back several decades. Most important was the establishment of a series of marine parks within the Provincial Park system. However, such sites were protected largely on an *ad hoc* basis, often with objectives outside of conservation, such as the protection of anchorages for recreational boaters. This resulted in a large number of marine parks that still exist to this day, but they are generally small, have weak protective mandates, and were not conceived as parts of a functioning ecological network (Dearden, 1985, 1987). Nonetheless, some areas with considerable conservation value, such as Desolation Sound were afforded some protection during these early years (Dearden, 1986). Several provincial ecological reserves were also established in the marine environment with a strong protective mandate[8], though they too are small, and a proposal for a federal marine park for the Strait of Georgia was developed in the mid-1960s though never implemented.

More systematic conservation planning came to the fore in the late 1990s and into the early 2000s with the iterations of the Central Coast and North Coast Land and Resource Management Plan (LRMP) processes. As part of that work, the Coast Information Team (CIT) produced ground breaking Marxan analyses of shoreline and marine waters (CIT, 2004; Ardron, 2008). Much of the approach taken then, more than ten years ago, remains relevant today. More recently, the Pacific North Coast Integrated Management Area (PNCIMA), and the on-going Marine Planning Partnership for the North Pacific Coast (MaPP) have added local and regional insights to the various social and political considerations. The seven-year (2006-2013) BC Marine Conservation Analysis (BCMCA), conducted outside a formal government process, deserves special mention given its instrumental role in assembling available province-wide marine data sets and stakeholder trust and involvement (BCMCA, 2012; Ban et al., 2013). Also, an InVEST[9] analysis of ecosystem services was undertaken on the west coast of Vancouver Island (Guerry et al., 2012). In this rich context of previous analyses, we would like to highlight the pertinence of Principle 14 (*Build on existing MPAs, other management tools and marine planning initiatives*).

Valuable work continues to flow from academic researchers, non-governmental organizations (NGOs), First Nations, Provincial, and Federal levels of government. The recently released report on MPA design

[8] However, reserves designated by the Province require the cooperation of federal and First Nation governments to ensure protection from the full range of possibly harmful activities.
[9] http://www.naturalcapitalproject.org/InVEST.html accessed January 2015.

commissioned by the Kitasoo/XaiXais First Nation and Coastal First Nations-Great Bear Initiative Society is a case in point. It provides helpful guidance complementary to this report and is recommended reading (Burt et al., 2014).

Literature Review

Our literature review (**Appendix 2**) examines each of the Canada-BC MPA Design Principles (henceforth, simply *Principles*). Relevant passages from about one hundred papers and reports on MPA network design were aggregated from a broad spectrum of researchers, practitioners, and civil society. The ecological Principles (Section A) were further sub-divided according to the Convention on Biological Diversity's (CBD) MPA network guidance and *ecologically or biologically significant area* (EBSA) criteria, to separate key components implicit in each broad ecological Principle. The CBD criteria were chosen due to their universality, having been adopted by Parties to the CBD in 2008 (Decision IX/20). Canada was very active in development of the CBD EBSAs, which were based on the DFO EBSA framework (Dearden & Topelko, 2005; Dunn et al., 2014).

In our reading of the literature, most of the guidance remains fairly general in nature. This is not surprising, since location-specific considerations must consider the scale of the physical environment and its relevant habitats, species, and ecological processes as well as significant differences in cultural and socio-economic settings. However, the generality of the literature often also reflects the lack of scientific consensus on critical questions, which shall be discussed further in this report. These include, for example, overall percentages to be protected, minimum patch sizes, and so forth, which in addition to varying from place to place, demand comprehensive high quality data and analysis before such quantitative targets can be estimated.

Ecological realities should be the first consideration in developing MPA networks. Given that in many instances data are seldom available, "rules of thumb" are typically developed to best approximate regional conditions (Carr et al., 2010). In a few cases, specific species and habitat targets have been modelled using available (but still limited) data to infer species-area curves (e.g., Natural England & Joint Nature Conservation Committee, 2010). Using the Canada-BC Principles as the framework for this report, we discuss these critical issues as they arise.

In virtually all the literature reviewed, comprehensive and inclusive stakeholder engagement is part of recommended practices. However, in the five real-life processes that we considered in greater detail (summarized in Appendix 1), none had outcomes that pleased all stakeholders, with some processes facing considerable, and at times acrimonious, opposition. No MPA process should thus expect to please everybody, and considerable political will has been needed to move forward with implementation.

Reported practices also reflect the varying social and political contexts of MPA designation. In areas where marine resources are more heavily exploited there has been generally greater opposition to MPAs. Hence, there is a tendency to establish more and larger MPAs in less-used areas and fewer smaller ones in areas of high human activity. In some cases this avoidance of human conflict has come at the expense of ecological values, producing "residual" protected areas (Devillers et al., 2014). The line between an existing practice based on implementation expediency and *a good practice (or best practice*[10]*)* is at times a hazy one, especially when it is acknowledged that taking stakeholder concerns into account is in itself usually considered to be good practice (Sumaila et al., 2000).

What is recommended in the literature is not always achieved in implementation. Guidelines from five well-known international planning processes (Appendix 1) can be taken as an indication of how ecological, social, cultural, economic, and political realities must be balanced in practice. While each of these cases had ecological shortcomings and social controversy, they nonetheless demonstrate a pragmatism that is both informative and inspiring. The guidance developed in this report for NSB builds on both the theoretical (ideal) literature, as well as from actual practices.

IV. Principles: Overview, Discussion and Recommendations

In this section, the official text for selected Principles is first presented in italics (Canada-BC, 2014), followed by a discussion of each. Many references will not be re-stated, and the reader is directed to Appendix 2 for a full listing of relevant points and their associated references. The Principles in bold are the ones that we were asked to concentrate our efforts on. For those not bolded (instead underlined), but still with ecological aspects, we outline some issues relevant to the BC context. For those Principles outside the remit of this report (9-11 and 13-15), some relevant literature is included in Appendix 2, which also contains a section on considerations not captured by the 16 Canada-BC Principles.

We have developed recommendations for each priority Principle. However, recognizing the need for these to be succinct and tractable, they have been further sub-divided into *Key Recommendations*, and *Additional Recommendations,* with the aim of not having more than six Key Recommendations for any given Principle. Only the Key Recommendations are listed in the Summary (section V) at the end of the report, and the Executive Summary above. However, **we wish to draw attention to the value of the Additional Recommendations** as well.

The recommendations in this report generally fall somewhere in between *Strategic Conservation Objectives* and *Operational Conservation Objectives*, as defined by DFO (2012a), and could help inform their development.

> "Operational Conservation Objectives are more specific and measurable than Strategic Conservation Objectives described above. In the above example of unpacking the Strategic Objective of 'protect threatened or vulnerable species', Operational Conservation Objectives would specify parameters (such as abundance, area of distribution, biomass, or other factors relevant to viability of the species) for each threatened or vulnerable species identified through a Strategic Conservation Objective associated with protection. With Operational Conservation Objectives the unpacking process has reached a level of specificity that should directly guide the National Capital Region

[10] In this report we prefer the term *good practices,* which suggest that there is more than one way to achieve desired outcomes. The term also reflects an ongoing development of solutions that have not yet hardened into widely agreed-upon *best practices.*

Guidance on the Formulation of Conservation Objectives and Identification of Indicators, Monitoring Protocols and selection of suitable indicators and positioning of appropriate reference points. Consequently, Operational Conservation Objectives are needed to guide monitoring and evaluation of overall MPA network effectiveness, and the effectiveness of individual MPAs relative to their individual objectives" (ibid., pp. 5-6).

Most of the recommendations have been built on existing "rules of thumb" using existing studies, which provide some necessary planning flexibility that would otherwise be lost. They are a strategy that can only be recommended in the absence of better data, and as such should be seen as part of taking a precautionary approach (Principle 16). However, we would strongly recommend use of existing quantitative data housed by various Canadian and British Columbian institutions and researchers, as well as further empirical studies to refine / verify / falsify them. In the meantime, we put them forward as stand-ins until better quantitative methods can be established.

Ecological network design principles

"To protect and maintain marine biodiversity, ecological representation and special natural features" is the first goal of the Canada-BC MPA Network Strategy (2014; see box below). Highlighted as being of primary importance, it is the only one of the six goals that must be included for a designation to be considered an MPA (pp. 8-9). The Ecological Network Design Principles (1 through 5) that arise from this goal therefore warrant particular attention. While best informed by the social and economic Principles and the context of the region, the ecological Principles are fundamental for an area to qualify as an MPA that is recognized by BC and Canada.

Canada-BC MPA Network Goals

1. To protect and maintain marine biodiversity, ecological representation and special natural features.
2. To contribute to the conservation and protection of fishery resources and their habitats.
3. To maintain and facilitate opportunities for tourism and recreation.
4. To contribute to social, community, and economic certainty and stability.
5. To conserve and protect traditional use, cultural heritage and archaeological resources.
6. To provide opportunities for scientific research, education and awareness.

"Goal 1 is of primary importance." (Canada-BC, 2014, p. 9)

1. Include the full range of biodiversity present in Pacific Canada

Representation & Replication: Represent each habitat type in the overall MPA network. For example, rocky reef habitat, eelgrass meadow, intertidal mudflat, persistent gyres or eddies, or representation within a hierarchy of ecological scales (e.g., representation of rocky reefs within a broader biogeographic classification).

The degree of replication should be assessed at a bioregional (or finer) scale(s) in an effort to safeguard against catastrophic events or disturbances and to build resilience in the overall MPA network.

Overview

Representativity: arguably the best-known and globally accepted MPA network criterion,[11] implementation can nevertheless raise difficult technical and scientific questions; namely, how representative spatial features (i.e., species, habitats, and ecological communities) are selected and how they are delineated from one another. The decision of whether an individual occurrence of a species is "representative" or not, points out the difficulty of applying this Principle's official text (quoted above), and the necessity of establishing clear guidelines. Finally, a solid line from a classification scheme on a map is not necessarily a line in the water.

Nevertheless, in order to understand, monitor, and assess progress towards meeting this Principle's main goal (i.e., including the full range of biodiversity), it will be necessary to ensure the individual occurrences in aggregate (throughout the MPA network) establish a "representative" selection of indicative species and habitats. For the purposes of this document, we use an ecological interpretation of the term, and will not be looking at other possible interpretations. The OSPAR definition of representativity, used for MPA planning in the north-east Atlantic can be applied to the NSB equally as well:

> "[An area that] contains a number of habitat / biotope types, habitat complexes, species, ecological processes or other natural characteristics that are typical and representative for the OSPAR-Area as a whole or for its different biogeographic units." (OSPAR, 2003).

However, as the above definition highlights, representativity proper still covers a very broad range of possible species and habitats. Because it is logistically difficult and expensive to survey diverse marine habitats and biota at high resolution (e.g., 1:5000) over large spatial extents (e.g., a bioregion), bio-physical classifications are commonly used as a surrogate. Bio-physical classifications use environmental variables to approximate known habitats or species distributions, calibrated using biological observations when available. Unique or unusual features can be captured separately, often through the use of local and expert knowledge, and can be located within an otherwise representative habitat (see EBSAs, below).

[11] e.g., §32(c) of the 2002 Johannesburg Plan of Implementation of the World Summit on Sustainable Development. Accessed Nov. 2014: http://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/WSSD_PlanImpl.pdf

DFO (2013a) reviewed the key elements of a hierarchical marine ecological classification system to support the development of a network of MPAs at regional scales, and coastal zone management and planning activities at local scales. Twenty BC-based case studies were reviewed along with a comparative literature review of global applications to better understand the types of models, expert systems, and classification systems used to describe species and habitat diversity in the pelagic and benthic realms, and to understand information / data requirements and gaps. The review revealed that:

1. species and habitat diversity mapping in the Pacific region tends to consist of one-off, single-species based projects using relatively disparate data sets;
2. no single habitat classification system has been used in the benthic or pelagic realms;
3. a few different species distribution models have been used in the region with no clear guidance on 'best' practices or structured application;
4. relatively little research has been directed at pelagic realm diversity; and
5. large gaps in fully interpreted multi-beam acoustic data are limiting descriptions of benthic habitat types and diversity.

The authors concluded that it will be necessary to apply hierarchical classification approaches to generate sufficient data to achieve the goal of subdividing bioregions into smaller meaningful biodiversity units for meeting representation objectives, and that at finer scales of resolution within the classification hierarchy, species composition data should receive increasing attention compared to abiotic data such as bathymetry and oceanographic processes. However, as is noted in a 2012 Canadian Science Advisory Secretariat report:

> "In cases where these [biological] data are not available, geophysical and oceanographic factors may be used where there is reason to believe these factors can discriminate among habitat and community types. When biological data become available, they should be used to validate or adjust boundaries of the biogeographic unit(s)" (DFO, 2012b).

The above-quoted report concludes that for a network to be representative, three requirements must be met:

(i) an accepted biogeographic classification system to guide what biogeographic units of the bioregion are to be represented in the network to ensure the full range of ecosystems in the bioregion are captured;
(ii) an accurate and informative map of the bioregion relative to that classification system to guide where to select areas so that they represent the intended biogeographic units; and
(iii) a decision that the areas selected adequately represent the biogeographic units to guide how much of each biogeographic unit to include in the network (ibid., p. 2).

<u>Replication:</u> replication helps to ensure that a) more than one example of an ecological community is protected; b) there are 'back-up' areas should one place be hit by a disaster; and c) uncertainty and spatial variation are to some extent captured. Arguably the most straight-forward criterion to test, it hinges on the assumption that the given representative habitat class is both meaningful and consistent.

Robinson et al. (2011) point out that at the scale of habitats, different examples (patches) of the same habitat may not necessarily represent the same biodiversity (i.e., habitat heterogeneity), and hence replication can be complicated by inherent ecosystem properties such as environmental gradients (e.g., freshwater inflow) not accounted for in the classification system.

Although representation and replication can go some distance in achieving Principle 1, and building overall ecological resilience, it cannot be assumed that including (and protecting) the full range of biodiversity will be addressed with just these two criteria. The biological and ecological considerations of Principles 2 and 3, below, are also required.

BC and NSB context

Physical classifications in Pacific Canada began with the work of Harper et al. (1993) eventually leading to the creation of the five *bioregions* in Pacific Canada, as defined in the *National Marine Conservation Areas Act* (Canada, 2002). More recently, the Canadian Science Advisory Secretariat (DFO, 2009) proposed a framework and principles for the biogeographic classification of Canadian marine areas that has become the basis for the designation of the NSB planning region. Finally, in 2013 DFO further elaborated upon a framework through which the Pacific regions could be further sub-divided into ecologically meaningful sub-bioregion scale units, using a prototype Pacific marine ecological classification system (PMECS) (DFO, 2013a). However, implementation of this framework has not been completed.

Through the Province of BC, Zacharias et al. (1998) extended the work of Harper et al. (1993), leading to 619 *ecounits* based on the spatial intersection of classified information on wave exposure, depth, relief, currents, and substrate. Known as the BC Marine Ecosystem Classification, the intent was to emulate the terrestrial Ecoregion Classification System, first adopted for the British Columbia landscape in 1985.[12] The BC Marine Ecosystem Classification ecounits were not widely adopted, in part because the units had not been empirically validated and some ecounits did not correspond to local and expert knowledge. However, the underlying classified data, particularly substrate, were used in other classifications and analyses of the Pacific Canadian shelf.

An alternative, coast-wide classification based on Southwood's (1988) ecological theory of habitat templates has undergone several revisions since Gregr and Jamieson (2008) adopted the approach developed on the Canadian east coast by Kostylev and Hannah (2007). The challenge in implementing this template is the derivation of the necessary physical layers (including bottom type, temperature, roughness, energy). The most recent version of this classification will soon be available as a DFO technical report (Gregr et al., in review) includes a sediment model to create a comprehensive grain size map for the BC shelf. The habitat template describes the spatial distribution of potential benthic habitats in the deeper (i.e., > 20 m) regions of the Canadian Pacific Shelf. It correlates better with benthic community structure than linear geographic distance, and is negatively correlated with

[12] http://www.env.gov.bc.ca/ecology/ecoregions/.

biodiversity. The classification may be useful for supporting analyses of representativity, and unique or rare features *sensu* EBSAs (see below).

Parks Canada studies

Parks Canada has conducted two biodiversity representativity analyses in BC that focused on benthic and pelagic physical features rather than biological communities per se, because the former are map-able, spatially comprehensive, and lend themselves to a formal, repeatable set of rules (e.g., classification). Consequently, in all the Parks Canada studies, physical habitat diversity was assumed to be a surrogate for biodiversity. Robinson and Royle (2008) used a proportional representation analysis to assess how well the proposed southern Strait of Georgia Natural Marine Conservation Area (NMCA) represented select elements of biodiversity in the Strait of Georgia Natural Marine Region: (i) pelagic habitats seaward of the kelp zone (water column), (ii) shoreline habitats (datum to about –5 m), (iii) subtidal geologic regions (> 20 m), and (iv) benthic subtidal habitats (from datum to > 1000 m). The authors found that about 58% of the four biodiversity elements considered in the region were represented by the proposed NMCA, and that it would be unrealistic and impractical to assume that any one area alone proposed as an NMCA could fully represent the biodiversity of the region.

Robinson and McBlane (2013) conducted an oceanographic (pelagic) representativity analysis by considering if Pacific Canada marine waters can be subdivided into major upper ocean sub regions with recurring physical oceanographic processes and potentially different marine plankton diversity. The methodology included GIS-modelling, expert opinion, classification systems, and regionalization approaches. The analysis was restricted to the upper ocean (~20–30 m depth) and to oceanographic processes linked to enhancing nutrient supply to surface waters. It was assumed that each ocean sub-region has a suite of recurring and enduring physical oceanographic processes that distinguish itself from its neighbour, and that the oceanographic processes result in lower trophic level properties (e.g., primary production) that influence the organization and production of higher trophic levels, such as fish, seabirds and marine mammals. Importantly, because many physical and chemical oceanographic processes can change markedly from season-to-season and year-to-year, it was necessary to simplify the analysis by considering ocean processes that occurred during the summer only (mid-June to mid-September). This study highlighted a key difference between pelagic and benthic ecosystem representation analysis in that the former is highly dynamic in space and time, and thus presents significant challenges for mapping and representation studies.

An MPA strategy with an objective to protect all biodiversity in a region will also need to consider pelagic species, as well as those in nearshore ecosystems. Many pelagic species are highly mobile both seasonally and inter-annually, which makes them difficult to protect in singular MPAs, except for known “bottlenecks” in their life history. In contrast, nearshore ecosystems are typically occupied by either sessile or early life stage organisms with limited mobility. Thus, nearshore and inter-tidal classification are also likely to be critical to a representative MPA approach.

The complexity of the nearshore requires a higher resolution analysis, thereby imposing enhanced quality and processing requirements on the available data sets. An alternative analytic framework may also be warranted ecologically, as the nearshore often represents a more dynamic high energy environment that is home to a variety of commercial invertebrate species, as well as early life history stages of many commercial marine fishes. It is also the zone where terrestrial impacts can have greatest effect. Thus, any discussion herein relating to how the relative intensity of stressors can inform MPA design is potentially even more relevant in the nearshore. An approach has recently been developed (Gregr et al., 2013) to classify the nearshore (from high water line to 50 m depth) according to bottom type. The classification provides a spatial framework of physical data to which biologically relevant data can be assigned. This approach is currently being applied to Pacific Canada's entire coast, with the Central Coast region and Haida Gwaii expected to be completed in 2015.

Any classification that has not explicitly had its biological relevance groundtruthed will at best identify only potential habitats, which in turn are an unproved (typically unexamined) proxy for biodiversity. Local knowledge should be a component of any credible groundtruthing exercise, of which First Nations peoples would be valuable contributors. Since biodiversity is a function of species distributions, the question of biodiversity is best addressed with biological data, when available. In the context of the Canada-MPA Principles, this fits in the next Principle (EBSAs).

Pitfalls to be avoided

Mapped habitat classification systems are a coarse approximation of ecological community distributions across a planning area based on abiotic surrogates. How well they actually capture the region’s ecology and biology is seldom tested, and there are a number of ways they can go wrong. First, the simplifying assumptions behind the model could be inaccurate or incorrect (e.g., assuming a uniform suitability ‘envelope’ for ranges of physical variables, where the response may in fact be non-linearly differentiated within those ranges). Second, the abiotic data used in the classification system may be spatially too coarse (or inaccurate) to faithfully represent fine changes in biodiversity. Third, key data that might be important for determining biological distributions (e.g., dissolved oxygen) may not be available. Fourth, overextended classification systems may leave fragments or “slivers”. Because over-classified fragments tend to be unusual or even one-of-a-kind (misinterpreted as “unique” or “rare”), they can exert a strong influence on the selection of MPA sites in order to meet their targets. Finally, the resulting mapped ecological classes may differ depending on what classification systems or abiotic data are used, leading to a variety of possible (often valid) interpretations of a given region’s ecological communities, which can complicate implementation and interpretation.

More fundamentally, another pitfall to be avoided is to think that a good classification is essential, and warrants delaying the implementation of the MPA network. As illustrated in California (Appendix 1), a broad along-shore and offshore distribution of MPAs, combined with a basic list of indicative habitats, will go a long way towards representing different kinds of features, even if information isn’t perfect or is missing altogether.

Implementing representativity also requires the setting of targets. Common practice is to set a single value (say, 20%) for all representative habitats (and sometimes species distributions as well). While expedient, this is not considered good practice. The assumption behind such across-the-board target setting is that the MPA network will function like a miniature version of the larger planning region. However, there is no evidence to support such an assumption. On the contrary, very common habitats are seldom in need of the same level of protection as less-common or unusual habitats. Less-common habitats are much more reliant on existing patches as stepping stones to stay connected to one another; whereas more common habitats can suffer some holes in their fabric without a loss of ecological coherence (Johnson et al., 2008). From a management perspective, across-the-board targets can result in a great deal of time and money being spent protecting very common habitats. For example, a fixed percentage of a common class, say *deep-mud*, can translate into millions of hectares of protected mud. An alternative approach might be to set a range of targets that reflect the continuum of rare to common, unthreatened to threatened habitats. In such a fashion, limited resources will be better directed to ecological communities most in need of protection and adequate representation in an MPA network.

Regarding threatened and endangered species, IUCN's Species Survival Commissions, and COSEWIC (Committee On the Status of Endangered Wildlife In Canada) specify minimum population abundances, number of populations, and extent of occurrence and area of occupancy that could be useful to inform decisions on targets for these species. However, for the vast majority of non-threatened species and habitats, no such guidance yet exists.

Target setting comes with other issues as well. Given pervasive data gaps, expert opinion is often called upon. However, experts may have very different interpretations of what is being asked of them and can come up with radically different answers. This turned out to be the case for the BCMCA when setting species-related targets. In the end, the BCMCA team had to largely set aside the targets derived from expert workshops and instead set a fixed range of targets based on their own best judgement (Ban et al., 2013). There may be legitimate reasons why bird experts, say, set different targets than cetacean experts; i.e., the possibility that these species groupings could indeed require radically different amounts of their respective habitats. However, in the case of the BCMCA, the main issue was that most experts wanted all or almost all of their species protected (Ban, pers. comm., Mar. 2015).

Setting across-the-board targets avoids the perception of favouritism or other political motivations, treating all habitats and species "the same", but in doing so fails to capture meaningful differences in the species-specific spatial requirements of habitats and their ecological communities.

Key Recommendations

Sub-regions

1. Divide the Northern Shelf Bioregion into sub-regions that reflect the network's ecological objectives, while taking into account management and logistical realities.

Commentary: As recommended by the Canadian Science Advisory Secretariat report that developed the Canadian Bioregions, including the NSB, "…subdivision of larger biogeographic units should consider bathymetry and oceanography as well as food web structure and benthic communities" (DFO, 2009a, p. 2) and that, "…their geographic scale should receive strong consideration" (ibid., p. 13). Later works (DFO, 2102a, 2012b, 2013a) have laid out various considerations for how this could be achieved. Sub-divisions should be based on both physical and biological considerations, and should be of a scale fitting the ecology, with smaller units likely to be closer to shore than offshore ones (DFO, 2009, p. 14). "All available ecological information and data (including experiential / traditional knowledge) should be taken into consideration…" (ibid., p. 15).

As noted in DFO (2013a), hierarchical classifications require "knowledge of management objectives and their associated spatial requirements." Therefore, the sub-division of the NSB should reflect the realities of both its ecology and its management objectives. Additionally, the logistics of holding stakeholder consultations and workshops can also influence where the final lines are drawn. However, in our view, ecology should hold primacy, with management objectives and logistics holding secondary and tertiary considerations, respectively.

Previous provincial classification systems, analyses, and planning processes have generally treated Haida Gwaii (Queen Charlotte Islands), the North Coast, and Central Coast separately, recognising their relative ecological, social, and traditional differences. First Nation delineations also highlight these different sub-regions (apropos Principle 11), which could be considered, consistent with Principle 10, to further characterize and guide planning within the NSB.

Historical differences in data collection and analysis also suggest it may be analytically expedient to separate the three sub-regions to avoid issues concerning different survey and sampling methodologies, different contractors, and sample bias. While outside the scope of our work to sub-divide the NSB, we note that the northwest section of Vancouver Island is somewhat problematic. Sharing much ecologically in common with the rest of the west coast Vancouver Island, it could be a separate sub-region, albeit much smaller than the others in the NSB. Alternatively, to keep the scales consistent, it could be incorporated as part of one of the others.

Regardless of what sub-regions are decided upon, all of the recommendations in this report would still apply to each sub-region.

<u>Representativity</u>

2. In order to track progress in the protection of the full range of biodiversity, lists of "representative" (indicative) species and habitats for the NSB will need to be developed.
    - As a starting point, we recommend reviewing the species and habitats used by the LRMP, CIT, PNCIMA, BCMCA, and MaPP processes,[13] as well as the methodologies for identifying *valued components* (BC Environmental Assessment Office, 2013) and *ecologically significant species and community properties* (DFO, 2006).

[13] Acronyms: please see list on page 4.

Commentary: As stated under Goal 1 of Canada-BC MPA Network Strategy (2014), "Ecological representation (or representativity) means *protecting relatively intact, naturally functioning examples of the full range of ecosystems and habitat diversity found within a given planning area*. Establishing a network of MPAs that captures examples of all habitat types will ensure that the finer-scale elements of biodiversity and physical characteristics are also protected" (p. 10, italics in original). Note that representativity in this sense is meant to include everything ("the full range") in the region. Therefore, any list will necessarily be incomplete. However, in order to monitor progress in meeting this Principle, such a list, incomplete though it will be, will nevertheless be necessary.

It is outside of this contract to suggest exactly *which* species and habitats should be considered as candidates for a representative list of the NSB. However, there has already been a lot of good work done on this topic in the region. We therefore suggest compiling this previous work for consideration. We note, however, that previous processes have included few marine fish and invertebrate species as part of planning targets, focussing instead on the available data for anadromous species (e.g., salmon, eulachon), mammals, and seabirds. Therefore, additional fully marine fishes may need to be added to existing lists, where data permit; e.g., from DFO fisheries-independent surveys.

Classification

3. Use credible species-habitat classification systems where they exist. More than one can be applied in the same (sub-) region to highlight different aspects of biodiversity, but those that have been verified with biological data or local knowledge should be prioritized.

Commentary: As noted above, the variety of possible approaches taken to classify data can lead to a variety of possible (often valid) interpretations of a given region's ecological communities. Each classification will bring with it strengths as well as "blind spots", and hence using them together can provide for a more comprehensive view of representativity than using any single system alone. However, as stressed throughout this section, much hinges on the quality of data, and those systems that use field validated data should be given preference, possibly through greater weighting.

Replication

4. Replicate feature types and classification classes 3-5 times in each sub-region where they occur.

Commentary: Replication assumes a minimum of two examples (of ecologically sufficient size) of each representative feature in a given bio-geographic region (where the features exist). Ensuring more than two examples is a self-evidently better practice, all other things being equal, and consistent with the precautionary approach (Principle 16). Furthermore, places subject to elevated risk require more area to be protected, either in singular MPAs or multiple sites, to ensure that conservation objectives have a better likelihood of being met where the chance of catastrophe is higher than normal (Allison et al., 2003). Three or more examples are commonly recommended (e.g., in the UK and California; Appendix 1).

Choosing the unit of replication can be tricky. Usually it is a class from a biophysical classification system or sites of features (i.e., species and habitats) that are typical for the (sub-) region. The lines can become murky, however, such as when considering fish stocks. In that case, small stocks (such as singular runs of salmon) would need to be grouped together before being replicated (e.g., at the level of estuaries for marine features, or (sub-) watersheds on land), whereas large stocks (such as herring and their spawning beaches) could be treated as single features with replicates (e.g., more than one spawning beach).

Because the characteristic habitats of the NSB vary much more widely in size than those in many other regions, we have added some further considerations in Additional Recommendations 8-12.

<u>Targets</u>

5. Targets for features should vary according to the rarity of the feature and the threats it faces, and could range widely from < 5% to 100%.

Commentary: Some features will need more or less percentage protection than others, as discussed above. Avoid the trap of treating everything as “the same”; they are not. This is particularly relevant when considering representation of species at risk, where targets may have to include 100% (or nearly so) of the species’ habitat.[14] Appropriate protection of representative features will require considering each one’s distribution, ecological role, rarity versus commonness, histories of depletion, and possible future threats or changes, as well as the pressures it currently faces.

For each feature –species or habitat– it is good practice to explore a range of targets and see how they affect the overall MPA network configuration. Numerical targets can be very contentious, and expert agreement can be hard to attain. A less difficult approach is to first set relative targets using relative wordings (e.g., low through medium to high). A typical representative feature should by default get the medium target label. Highly endangered or unique features should get the high (or very high) label, and widespread very common features should get the low (or very low) label. After all the features in a region have been assigned relative word targets, a range of numerical values can be assigned to each of them. This second step will also require some discussion and exploration, but is more likely to reach expert agreement than trying to get to numerical targets in one step. Choosing an exact value for any particular feature can be difficult, and one approach to finalising numbers is to look at the overall size (footprint) of the network. If a software support tool is used, then different target ranges can be run using various values for what is the anchoring “medium” value, until the desired overall footprint of the MPA network is found. Individual targets should be re-checked to ensure that they are (mostly) protected within the range set by experts, local knowledge, etc. If not, then the “medium” value will have to be incrementally raised, and the analysis re-run, until a good overall balance between individual feature protection and the overall network footprint is found.

6. The minimum recommended footprint of the NSB MPA network is 20% of the planning region. Footprints across sub-regions (Recommendation 1, above) should be approximately the same.

[14] However, species subject to the *Species at Risk Act* may require 100% protection, regardless of whether they occur in MPAs.

Commentary: This "footprint" recommendation is intended as a precautionary measure, on the assumption that the data for a full set of science-based species and habitat targets (Recommendation 2, above) will not be available. As emphasised throughout this report, however, when good biological / ecological data are available, they should be used and take precedence over simplistic rules of thumb, like this one. Likewise, local knowledge can also aid in the setting of individual species and habitat targets, as discussed above. However, invariably there will be gaps in knowledge. Setting overall network-scale footprint targets is controversial because they can miss important nuances and elements of good network design, as outlined in this document. Nevertheless, they are commonly used as a convenient indicator that meaningful protection has perhaps been achieved.

As pointed out in the OSPAR Commission's background report on MPA network design (2007, p.18), in the literature a variety of network sizes generally ranging from 10% to 50% have been suggested as being effective as a conservation and fisheries management tool (Gerber et al., 2003; GACGC, 2006; Rodwell & Roberts, 2004; MRWG, 2001; NRC, 2000; Roberts & Hawkins, 2000; Ballantine, 1997; Carr & Reed, 1993; Ballantine, 1991), with an emphasis on larger numbers generally coming later. Based on recent literature (later than the 1990s), a range of 20% to 40% overall protection is within a typical recommendation. A recent IUCN World Parks Congress declaration calls for 30% no-extraction areas (IUCN, 2014), and experts often call for more than that (MPA News, 2015). In practice, this is not often achieved, but there are some notable exceptions, such as Great Barrier Reef Marine Park, which set a minimum target of 20% of each habitat type to be protected, and in the end fully protected 33% of the whole region.

We could find no advice in the literature on how to adapt global targets for use in a regional context. Our rationale in selecting a lower than commonly recommended footprint has been to balance practices suggested internationally with the state of marine ecosystems at home. In general, the NSB is fortunate to still have a large degree of naturalness and ecosystem health, as compared to, say, European waters. We view 20% as an ecologically meaningful minimum value at the low end of the commonly prescribed range, chosen for the NSB due to the relatively low human pressures and low population density compared to other places globally. Additionally, we note that studies that model overall protection usually assume high mortality rates in areas outside of the MPAs, higher than what might be expected in the NSB.

In their recent study of BC's Central Coast, Burt et al. (2014) suggest a 30% overall footprint, noting in their decision Jessen et al. (2011), which relied heavily on expert advice. On the other hand, preliminary modelling using Ecopath with Ecosim to restore the BC North Coast ecosystem back to 1950 levels suggested that a much larger area may have to be closed (Ainsworth & Pitcher, 2010). This highlights that there are various opinions and results. In this light, we fully acknowledge that we may be recommending too little. To this criticism, we would remind the reader that the Recommendation (i) is not intended to be taken in isolation, (ii) is intended to be a *minimum* value, (iii) that if the network objectives and the Principles as a whole dictate a larger network, then this recommendation should not be misconstrued to hinder that; and (iv) that in ten or twenty years, once the efficacy of the MPA network is better understood, it will likely be easier to expand the system than it would be to contract it.

Finally, setting a larger target could direct a disproportionate amount of attention to this one recommendation.[15] In the end, it should be expected that the other recommendations should lead to an ecologically meaningful footprint. This one recommendation, in bundling together many considerations, can at best be seen as a first, but incomplete, indicator of success.

When considering global MPA coverage, the CBD's 2010 Aichi Target 11 of (at least) 10% comes to mind.[16] However, it is worth recalling that discussions for this target began with scientifically suggested values exceeding 20%. Subsequent political negotiations during the tenth Conference of Parties reduced that value to 10%, mainly because less than 2% of the marine environment had been protected at that time (pers. obs. of one of the authors – JAA). The corresponding CBD land target of (at least) 17%, on the other hand, reflects the greater terrestrial conservation that had already been achieved, which exceeded 10% at the time of negotiations. Both are ultimately politically negotiated targets, and the lower marine threshold of 10% versus 17% for land cannot be said to be scientifically justified. Rather, the lower marine value reflects the weaker state of marine conservation at the time it was negotiated. Because Canada is a Party to the CBD, Aichi Target 11 will need to be integrated into Canadian protected area outcomes, certainly. However, meeting this target does not preclude using a variety of targets for individual species and habitats, nor does it preclude aiming higher in the marine realm for a footprint that better reflects scientific literature and opinion.

Additional Recommendations

<u>Replication</u>

7. Replication: Rare, threatened, and endangered species and habitats at risk, may need more replicates than common features, as per the network objectives.

Commentary: Other obligations and existing protective measures, such as through the Species at Risk Act, should also be taken into account.

8. Very large patches (approx. two standard deviations above the mean size) may need only 1 or 2 examples, while very small patches (approx. 2 SD below the mean) may require more than 5.
9. Very broad habitat classes will need more replicates than narrowly defined ones (in order to capture the range of biodiversity within each broad class).
10. Classification systems and species distribution models based on weak or questionable data will also need more replicates (to better ensure that what is intended to be protected is actually so).

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[15] Responses to date, e.g., at the expert review meeting, indicate that it already attracts considerable attention.

[16] CBD Aichi Target 11 states: "By 2020, at least 17 per cent of terrestrial and inland water areas and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape."

Classification

11. Biophysical classification systems should be validated using independent biological and physical data.

Commentary: the development of biophysical classifications system(s), while helpful, should not be seen as essential to moving forward on MPA network development. Their creation can be very labour- and data-intensive, and much can be achieved using simpler indicative systems that include depth, distance offshore, and already well-described and mapped habitats.

12. To ensure consistency with DFO (2009), the sub-biogeographic regional representation framework should consist of two major realms: pelagic and benthic. To that, we would recommend that a littoral / inter-tidal / shoreline zone also be added.

Commentary: BC's Shorezone Units could be aggregated for shoreline classes (c.f. CIT, 2004). Pelagic classifications are in general at a much broader scale than benthic ones, reflecting the scale of the processes they intend to capture, and should account for seasonal and annual variability. Separate winter and summer classifications, for example, could be appropriate. As noted in DFO (2102b), "Inshore areas are often significantly different than offshore areas due to differences in anthropogenic and naturally-induced pressures as well as differences in community structure. Due to such differences, it is recommended these environments be considered separately when selecting the appropriate scale for incorporating representativity in the MPA network" (p. 2).

13. In any classification system, small and unusual classes should be carefully scrutinized, especially in systems that have many classes. If found to be questionable, they can be merged into neighbouring classes.

Commentary: As noted in DFO (2012b), "Classification below a scale for which not enough data are available to create an accurate classification should be avoided. As long as sufficient data are available, the stopping rule for selecting the scale of subdivision at which to incorporate representativity within the network should be at the scale that most appropriately shows the patterns of community structure thought to be produced by the ecological functions characteristic of the bioregion" (p. 2). In this light, unusually small and fragmented classes should be reviewed for (i) data accuracy, and (ii) their relevance with regard to community structure.

14. If a multi-variate classification is not used, broad but ecologically meaningful depth classes (e.g., 0–10m, 10–50m, 50–200m, 200–1000m, > 1000m), and broad geographic and geomorphic categories should still be applied (e.g., inlets / fjords, passages / mostly enclosed waters, continental shelf, and continental slope); as well as smaller readily identified geomorphic features such as rocky reefs, plateaus, canyons, and sills (for the benthic realm); and oceanographic upwellings, temperature / salinity fronts, and gyres (for the pelagic realm).

Commentary: Simple feature-based classifications have already been used in BC for the CIT analyses (2004) as well as in the Californian MLPA process that focussed separately on 5 depth zones and 10 habitat types. This demonstrates a way forward when full, ecologically sound classifications are not available, if they are viewed as unreliable, or do not correspond to local knowledge. Their simplicity is in many ways an asset, reducing issues concerning data accuracy and variability. However, their scale is necessarily coarser than more data-intensive approaches.

2. Ensure ecologically and biologically significant areas are incorporated

Protection of Unique or Vulnerable Habitats: Design networks to include biophysically special and unique places.

Protection of Foraging or Breeding Grounds: Design networks to include important areas for breeding, feeding and high aggregation.

Protection of Source Populations: Design networks to include important sources of reproduction (e.g., nurseries, spawning areas, egg sources, etc.).

Overview

The multi-facetted designation of an *ecologically or biologically significant area* (EBSA) generally refers to either the first definition developed by DFO, or the one later adapted by the Convention on Biological Diversity (CBD). The criteria for both, while not the same, are largely compatible with one another (Gregr et al., 2012). The CBD EBSA criteria include (Decision IX/20, Annex 1):

i. Uniqueness or rarity,
ii. Special importance for life history stages of species,
iii. Importance for threatened, endangered or declining species and habitats,
iv. Vulnerability, fragility, sensitivity, or slow recovery,
v. Biological Productivity,
vi. Biological diversity, and
vii. Naturalness.

Each of these criteria is further explored in Appendix 2, the literature review table.

Reflecting advice received at the MPAIT review workshop (3-4 Feb. 2015, Richmond, BC), the definition of EBSAs used here includes, but is not limited to, areas identified through the CBD or DFO EBSA approach. Whereas Principle 1 emphasizes a representative approach to capture a broad range of biodiversity, this Principle focuses squarely on places of particular importance to particular species populations, and can thus be seen as the means to ensure that places critical to persistence of the NSB's marine biodiversity are included in the MPA network.

The importance of *focal species* in maintaining healthy ecosystems has long been discussed in terrestrial conservation (Lambeck, 1997), and may also be applicable in the marine environment (Heithaus et al., 2008; Olds et al., 2014). For example, there is evidence that MPAs are essential to conserving long-lived groundfishes, such as rockfishes (Berkeley et al., 2004; Hixon et al., 2014), which may also be important predators that affect community structure. Given the cultural, economic and ecological significance of rockfish to British Columbians, and particularly to First Nations, identifying places important to rockfishes (e.g., DFO's Rockfish Conservation Areas) may serve the dual objective of providing specific ecological restoration targets for MPAs (e.g., rebuild old-age structure to historical levels preceding current exploitation levels), and of demonstrating to the public the value of how MPAs provide long-term protection to iconic species esteemed by British Columbians.

Developing a classification that encompasses a range of species can be approached in one of two ways. Gregr et al. (2012) articulate the difference between physiographic and zoological (i.e., species-based) classification methods. Physiographic methods can be considered a bottom-up approach, where a physical classification is presumed to have ecological relevance. Such approaches have the advantage that physical data are often comprehensive, but face the subsequent challenge of demonstrating biological relevance. Species-based approaches illustrate biological relevance by definition, and important areas for individual species are generally defined using habitat suitability models. However, these methods are time consuming and data intensive. They are also challenged by a limited understanding of ecological processes, and a lack of methods to quantitatively integrate individual models into an overall classification. Thus, integrated zoological classifications continue to be based largely on expert opinion (Gregr et al., 2012).

BC and NSB context

The above dilemma is well illustrated by the DFO EBSA process in Pacific Canada. Clarke and Jamieson (2006a, 2006b) surveyed regional experts for the identification of important areas for 40 species in the PNCIMA region. They found that when considered in aggregate, the entire region is of importance to one or more species. Integration of the individual areas proved problematic, plagued not only by variable confidence in the individual species layers, but also by concerns on how to weight the various data layers (a variation of the target problem described above). Ultimately, expert-derived, physiographic features were used to recommend a total of 15 EBSAs (one of them multi-part) based on how well they corresponded to the original identified areas. Upon review as part of the Canadian Scientific Advisory process (DFO, 2013b), the 18 sites were advanced as DFO EBSAs. However, the review also highlighted the uncertainty associated with the area boundaries, noted several scaling challenges, and recommended future revisions based on more quantitative methods. Jamieson and Levesque (2014) subsequently modified three of the previously identified EBSAs in the PNCIMA region, and added two more focused on the nearshore that were not considered in the first pass. This experience highlights two fundamental challenges for MPA design: first, how to select and organize the species of concern, and secondly, how to balance the zoological and physiographic aspects into a unified classification.

Identifying species of interest has been a challenge in BC for some time, dating back at least to the beginning of the PNCIMA process. However, as part of their recent efforts at developing a risk assessment framework, DFO has compiled an extensive list of species (i.e., Valued Ecosystem

Components – VECs; e.g., DFO 2014). The technical report underlying this science advice is still in review (M. O., personal communication); however, the draft could likely be made available to the MPAIT team.

While such a comprehensive list of species may be unwieldy for MPA designation, we suggest it provides an excellent starting point from which keystone, umbrella, and indicator species (*sensu* Simberloff, 1997) could likely be identified. Working from a short-list of key species would presumably obviate the need for ranking and could also simplify the integration of zoological and physiographic classifications (Principle 1).

Valuable areas for conservation in Pacific Canada (Valued Marine Environments and Features – VMEFs) comprehensively described by Dale (1996) represent one of the earliest pieces of work to support MPA design in the region. Dale (1996) defined 27 types of VMEFs for conservation that, perhaps not surprisingly, align well with the various subsequent EBSA criteria despite predating them by almost a decade. These VMEFs provide an excellent starting point for deriving an empirically-based physiographic classification. However, an adaptable methodology to relate these various identified areas in the NSB does not exist. Potential methods include an iterative approach proposed by Gregr et al. (2012) based on sufficiency thresholds for important areas; or a blended data- and expert-driven methodology, as was used to identify candidate seamount EBSAs in the North Pacific (Clark et al., 2014).

Nevertheless, a fully empirical classification is likely still some distance away, given the lack of information on species distributions, and their ecological needs. Until then, we recommend that the implementation of this Principle take into account the expert-driven work that has already occurred, as outlined above, including the on-going DFO-EBSA process.

Pitfalls to be avoided

EBSAs should not be confused with MPAs. Though some (parts) of them will become MPAs, not all MPAs will be EBSAs, and not all EBSAs will be MPAs.

EBSAs are a description of key areas likely to require enhanced protection of various kinds, but management measures need not be spatial in all cases. Some EBSAs can be very large (e.g., upwelling areas) and unless stakeholders are clear that these are not *de facto* MPAs, serious misunderstandings can ensue.

EBSAs should be seen as one way to focus discussions spatially within the planning region. While not necessarily MPAs, they are by definition ecologically important and therefore critical for informed discussions. The challenge with EBSAs is to neither misinterpret them as *de facto* MPAs, nor to discard them as being irrelevant to MPA planning.

The first EBSAs identified as part of the MPA process are unlikely to be comprehensive.

EBSAs are challenging to identify. Both our understanding of them and their true distribution will evolve over time. As such, good monitoring regimes and a rigorous active adaptive management approach will be necessary to allow the MPA network to adjust to new knowledge as it becomes available.

Attempting to capture dynamic behaviours and processes in static boundaries can, in some instances, lead to only partial protection. Some important areas, particularly for pelagic (i.e., mobile) species, are variable both seasonally and inter-annually, which could require management regulations that reflect this variability, including perhaps a dynamic element to the MPA's boundaries or its management.

Vulnerable marine ecosystems

As a result of the UN General Assembly's decision 61/105 (UNGA, 2006), *vulnerable marine ecosystems* (VMEs) in the world's oceans beyond national jurisdictions are to be protected from bottom fishing activities. Their suggested criteria, developed through a series of UN Food and Agricultural Organisation (FAO, 2009) expert meetings, bear more than fleeting resemblance to EBSAs, in part due to some of the same experts being involved (for a comparison of criteria, see Table 1 in Ardron et al., 2014). Although VMEs are restricted in their application to just bottom fisheries, there is much regarding their identification and designation that can also be applied to EBSAs as well. Ardron et al. (2014) outline VME identification methods in use worldwide, and from these suggest a systematic 10-step approach.

1. Comparatively assess potential VME indicator taxa and habitats in a region.
2. Determine VME thresholds.
3. Consider areas already known for their ecological importance.
4. Compile information on the distributions of likely VME taxa and habitats, as well as related environmental data.
5. Develop predictive distribution models for VME indicator taxa and habitats.
6. Compile known or likely fishing impacts.
7. Produce a predicted VME naturalness distribution (areas of low cumulative impacts).
8. Identify areas of higher value to user groups.
9. Conduct management strategy evaluations to produce trade-off scenarios.
10. Review and iterate, until spatial management scenarios are developed that fulfil international obligations and regional conservation and management objectives.

Each of these steps is further explained in Ardron et al. (2014). While the details can vary from application to application, there is general agreement that taking a systematic approach to conservation planning is best practice.

Key Recommendations

1. The existing NSB EBSAs identified by DFO should each be reviewed by scientific and local experts for inclusion in the MPA network based on the network objectives. Decisions (for or against) and rationale thereof should be documented and attributed.
2. Other designations, such as *Valued Ecosystem Components* (DFO) and *Valued Marine Environments and Features* (Province of BC), should also be used to inform the selection of MPA sites.

Commentary: It is beyond the scope of this project to analyze the existing EBSAs and other similar designations for their possible inclusion (or parts thereof) in the NSB MPA network. However, we suggest that any assessment process be transparent and accountable. Because the Pacific EBSA identification was one of the first in Canada, it has many features of learning by doing (note the caveats in DFO, 2013b). In this light, the NSB represents an opportunity to review and refine the 18 original and 2 additional proposed EBSAs for possible inclusion in the MPA network. Additionally, the underlying EBSA data could be used to inform the delineation of MPA boundaries according to the Network Objectives. With the benefit of hindsight, other areas previously not considered as official EBSAs should be considered in the NSB process.

3. Identification (or estimation) of species and habitats not covered by existing designations is recommended, with particular consideration given to:
   a. spawning, breeding, nursery, rearing, foraging migration, and seasonal refugia;
   b. intertidal, shallow nearshore, and deep offshore habitats, and processes.

   These newly identified areas should also be reviewed for possible inclusion (or parts thereof) in the MPA network, based on the network objectives.

Commentary: As was emphasized at the Feb. 2015 expert review workshop, the results from the DFO EBSA process are not yet comprehensive, and hence new areas could, and likely will, be identified, through a variety of means.

4. To facilitate management considerations, sub-divide large identified areas into smaller sub-units based on the network objectives.

Commentary: Some of the larger EBSAs may have portions that are amenable to spatial protective measures, including MPAs, and these should be sub-divided according to management needs. Doing so may require returning to the underlying data sets to determine the spatial extent of species and habitats to be protected.

5. Identified areas not included in the final MPA network should not be forgotten, but instead be listed as part of the description of the NSB's recognized ecologically valuable places.

Commentary: Places not selected as MPAs can nonetheless be held as "understudies" should there arise issues with selected sites. In any case, these ecologically important places will likely require enhanced management measures.

6. Use of local and traditional knowledge in the identification of EBSAS and EBSA-like areas is recommended.

Commentary: As EBSAs are meant to capture exceptional biological or ecological areas, local knowledge can go far in identifying such places that are often well-known by those who live and work on the sea. Previous EBSA assessments in BC have relied exclusively on scientific expert knowledge. It is likely that local and traditional expertise would bring to light additional places.

3. Ensure ecological linkages

Connectivity: To the extent possible, consider the dispersal dynamics, the home range(s) of marine organisms, and the distribution of marine habitats over space and time, especially when assessing replicates and when determining the spacing of individual MPA sites within the network.

Overview

Connectivity, although widely prescribed as an essential element of MPA networks, is paradoxically one of the most difficult concepts for ecologists and modellers to unravel. Connectivity in MPA design is customarily interpreted as having two parts: (i) connectivity over life history stages; i.e., that larval, juvenile, and adult stages each have protected habitats that are ecologically linked; and (ii) larval dispersal from one protected area to another, including the identification of “sources” and “sinks”. This second part is most commonly focussed upon in the literature; however, its importance to MPA planning in BC remains unclear. In BC’s waters, many fish larvae are widespread, as illustrated in earlier DFO ichthyoplankton surveys (e.g., Mason et al., 1981), but studies of their distributional patterns, including possible sources and sinks are few. A third critical, but often overlooked, aspect of connectivity is the usually seasonal movement of adults among foraging, spawning, and overwintering areas.

In their thorough treatment of connectivity, Cowen and Sponaugle (2009) describe the state of the art and highlight a variety of issues concerning variability that stand in the way of better connectivity (mainly larval) modelling:

- Ocean and tidal currents will usually differ at different depths, and can flow in opposite directions;
- Spawning characteristics of different species, including when and under what conditions larvae enter the water column, will differ;
- Larval time in the water column differs across species;
- Larvae vertical location in the water column will vary across species;
- Vertical movements of larvae, and other micro-scale swimming characteristics that affect their dispersal are poorly understood;

- Habitat suitability for settlement of larvae varies across location and species;
- Migratory behaviour and normal ranging of juveniles and adults will differ;
- Predator-prey interactions (eggs, larvae, juveniles and adults) will differ in different locations for different species; and
- Responses of species across life history stages to environmental variability, cycles, and climate change will vary.

Such connectivity considerations are difficult to examine in the field. However, in one study, larval dispersal distances ranging from 15 to 184 km were measured, including recruitment from MPAs (Christie et al., 2010). In another study, looking at genetic parentage, reserves which accounted for just 28% of the local reef area produced approximately half of all juvenile recruitment to both reserve and fished reefs within 30 km (Harrison et al., 2012). Such insights provide information with which to estimate the spacing of MPAs, and demonstrate that MPAs do provide valuable above-average larval exports.

BC and NSB context

Relatively little research has been undertaken on connectivity between MPAs in BC generally, or in the NSB in particular. An early modelling study of the NSB (Robinson et al., 2005) used a 3-dimensional oceanographic simulation model to understand larval connectivity between the proposed Gwaii Haanas National Marine Conservation Area (GHNMCA), and ten other proposed or existing marine protected areas in the NSB. The simulations were conducted using passive particles placed at three depths (2 m, 30 m and 100 m), and vertically migrating particles (5-40 m) for 30 days or 90 days in late winter. The model estimated that 2 and 30 m particles with a 30-day dispersal phase (e.g., representing invertebrates) and particles with a 90 day dispersal phase (e.g., representing fish) could disperse and be retained, on average, within 52–69 and 160–180 km from the source area, respectively. Hence, particle depth was an important determinant of dispersal distance. Overall, model results indicated that a high percentage of surface particles were dispersed from the proposed GHNMCA to non-MPA regions in central and northern Hecate Strait and along the west coast of the Queen Charlotte Islands, supporting the notion that MPAs can serve as important sources of invertebrate and fish larvae.

Another aspect of MPA spacing articulated by Robinson et al. (2011) is the influence of freshwater in the coastal ocean and its impact on environmental gradients, which ultimately drive biological diversity Their results indicate that at spatial scales of 100s of kilometres direct gradient factors such as temperature and salinity have the dominant effect on fish assemblage diversity, while at spatial scales of 1 to 10s of kilometres indirect and resource gradients become more important. The authors concluded that relying strictly on distance separation between eelgrass patches would not be useful, because in low gradient environments such as Gwaii Haanas (due to lack of river in-flow), meadows more than 60 km apart had only a few percent difference in species similarity, while in gradient rich regions of the west coast of Vancouver Island, fish assemblage diversity varied by as much as 25% over several kilometres. Therefore, physical distance separation was by itself not a useful predictor of changes in biodiversity. Given that the majority of the BC coast is influenced by freshwater run-off during spring and summer melt, the consideration of environmental gradients in MPA network planning is warranted.

Concerning larval dispersal, Burt et al. (2014) in their assessment of selected adults and larvae of the BC Central Coast found a typically wide range of values for times and distances, ranging from metres to hundreds of kilometres (§2.4, Appendices C & D). They report that about half of the species reviewed were limited in their movements (categories "no or very limited movement", < 0.05 km, or < 1 km), but that another 38% were highly mobile with movements from over 50 km to thousands of kilometres. The remaining 12% fell somewhere in between, ranging from 1 to 50 km (ibid., p. 20). Such a spectrum of dispersal distances underlines the difficulty of spacing MPAs based on larval connectivity (and also that MPAs are not the only management measure required). Clearly, no single spacing will suit all species; nevertheless, with about half the species having very short dispersal distances, it does suggest that for those short-dispersal species under threat, spacing may have to be closer than commonly prescribed; or alternatively, the individual MPAs would have to be large enough to allow for internal connectivity amongst communities. Burt et al. (2014) call for maximum MPA spacing of between 20 to 100 km, but do not specify where the shorter or longer distances should be applied.

MPA spacing in ecosystems that are significantly different from those in BC (e.g., tropical coral reefs) are at first glance irrelevant. However, given that larval dispersion distances vary greatly, no matter where one looks, strategies that have been applied elsewhere could still be applicable (c.f. Appendix 1). Some of these strategies have been captured in the recommendations below. Another approach includes minimum spacing requirements between like habitats (e.g., coral reefs, sandy areas, etc.). Use of these approaches in BC depends on the collection of connectivity data for typical NSB habitats and habitat-forming species (e.g., rocky reefs, kelp forests, etc.). Thus, in the recommendations below, addressing connectivity is mainly achieved through a generic spacing formula. Should habitat-specific connectivity information become available, the spacing requirements of these NSB habitats should be re-evaluated.

Pitfalls to be avoided

While connectivity is meant to apply to the full range of biodiversity within the NSB, some species will be under greater threat than others. When considering adult and larval movements, equally weighing the biological characteristics of commercial and non-commercial species can provide summary results that do not necessarily highlight the needs of those species most in need of protection. Not all species considered in literature reviews are equally protected by MPAs, nor are all species equally under threat (i.e., needing protection by MPAs). Many species will not be affected by fisheries or other dominant human activities that would be constrained within MPAs. Primary vulnerability (e.g., risk of being caught in fisheries) and secondary vulnerability (e.g., risk of loss of habitat or prey due to fishing) should be considered when selecting species upon which to build MPA connectivity requirements.

Additionally, some species / habitats may face localized pressures that are much more influential to their long-term viability than spacing per se. Some nearshore biogenic habitats such as eelgrass, for example, are more likely to be affected by disease, siltation and pollution associated with human development; hence, for some habitats, proximity to human settlement and local management measures are probably more relevant considerations than patch-to-patch spacing.

Although larval modelling and associated field validation serves an important role in understanding MPA connectivity, there may be more immediate value in documenting the movements of older life stages of fish, and other vertebrates like seabirds and marine mammals that don't have larval stages. For example, the seasonal movements of adult herring between spawning, foraging and overwintering or bottleneck areas should be considered within the context of a network of MPAs designed to protect them (thus feeding their many predators). Telemetry of seabirds also sheds light on the importance of connecting nesting areas with offshore feeding grounds. Ultimately, it is safe to say that a well-spaced, but non-circumspect placement of MPAs will capture larvae of the vast majority of marine fish and invertebrate species, but could fail at protecting key habitats of different older life history stages that are required to maintain those species within the bioregion.

Sub-regions under intense human pressures may require more closely spaced MPAs than those under lighter pressures. Although species mortality outside of MPAs is very unlikely 100%, simpler models often assume that it is. In reality, however, the magnitude of pressures outside the MPAs have varying effects on intermediate survival of species in-between MPAs and hence on their required spacing. If new or existing human activities were to increase (or decrease), for example, then MPA spacing should be re-considered, with regard to additional (or fewer) sites being needed in the network. MPA network design therefore should take into account the intensity of human activities and the efficacy of management occurring outside of the protected areas.

Spacing (and sizes) of the NSB MPA network may need to be adjusted as more (or fewer) human activities are added to the NSB.

Key Recommendations

Connectivity is perhaps the most vexing of the Principles to implement. Any single rule regarding MPA spacing is destined to be plagued by a multitude of exceptions. When considering MPA spacing, we have sought to refine this problem mainly by taking into consideration the size of MPAs and ecological connectedness.

Spacing

1. The spacing and configuration of an MPA network should reflect the ecological objectives of that network, such that sites for species' life history stages and habitat patches of particular interest are close enough to conceivably be ecologically connected.

Commentary: While this first recommendation may appear self-evident, there are currently very few representative MPA networks that take target species and habitats into account when considering the spacing of sites. Usually, general approaches meant to capture a broad range of species and habitats are applied instead. A network designed to protect only particular species or habitats will be narrowly focussed with sites chosen to specifically meet those objectives. However, a representative network, in capturing a range of habitat types, can lose sight of the ecological coherence of species of particular concern. For the recommendations that follow, it is suggested that the NSB MPA network should be designed to capture a wide range of the NSB's biodiversity (per Principle 1), while still containing ecologically connected "clusters" relevant for species and habitats of particular concern in the NSB.

2. In general, a representative MPA network should be well distributed, alongshore and offshore.

Commentary: This well-distributed guideline is adapted from the first (of three) initial tests for ecological coherence in the northeast Atlantic used by the OSPAR Commission (2008). When looking on a map, there should be no (or few) unusually large visual gaps; i.e., spaces missing an MPA.

3. MPA size and spacing should reflect the predominant geography, oceanography, and scale of the local ecosystem into which sites are placed.

Commentary: In practice, large MPAs will tend to be offshore and further apart (e.g., Great Barrier Reef), whereas smaller MPAs are more likely to be inshore and more closely spaced (e.g., in the Baltic Sea – about the same size as the GBR). The reasons for this are both ecological (i.e., broad scale features generally lie further offshore) and socio-economic (i.e., human activities tend to be concentrated closer to shore). To date, however, no single rule of thumb has captured this variability.[17] The simple formula below is our attempt to capture what have been, up to now, separate rules of thumb.

4. Generic MPA spacing should not exceed nine times the square-root of the average size of the neighbouring MPAs; i.e.,

   MPA Spacing $\leq 9 \cdot ((\mathrm{Area}_1 + \mathrm{Area}_2)/2)^{0.5}$

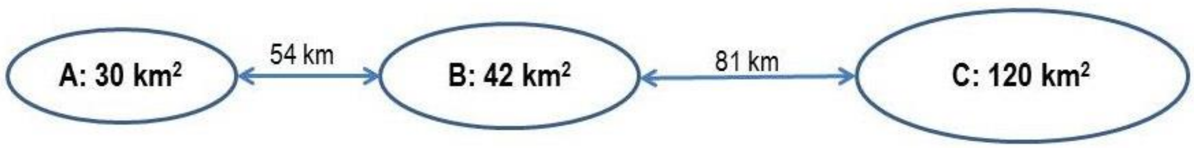
   a. This formula can also be used in reverse.[18] That is, if site locations were already decided upon, then their minimum sizes could be calculated based on their separation. As discussed under the next Principle, other considerations apart from spacing should also go into size calculations.
   b. For MPAs linking together life history stages, habitats, or ecological processes, see also recommendations 5 & 6 below.
   c. Particularly elongated sites (e.g., alongshore) or other unusual shapes may need special consideration to take into account relevant connectivity properties. In general, sites that have a high edge-to-area ratio are more "leaky" and will therefore require closer than generic spacing.
   d. The above calculation for spacing between two MPAs can be generalized for nearest-neighbour distances in a cluster of 'n' ecologically connected MPAs as follows:

$$\text{MPA Spacing} \leq 9 \cdot ((\mathrm{Area}_1 + \mathrm{Area}_2 + \ldots \mathrm{Area}_n)/n)^{0.5}$$

[17] However, OSPAR (2008) set up different guidelines for inshore, offshore, and high seas areas.
[18] That is, the square-root of the average area of the two neighbouring MPAs should be greater or equal to the spacing divided by nine.

Example of how to apply the MPA spacing rule

Consider the three MPAs A, B, and C shown here in a row, though in actuality they could be in another configuration (e.g., A & B could be along a shoreline with C further offshore). If A is 30 km^2 and B is 42 km^2, then the average area is 36 km^2 (i.e., (30+42)/2). Therefore, spacing should not exceed 54 km (i.e., 9 times the square-root of 36). Likewise, the separation between B and C should not exceed 81 km (i.e., $9 \cdot ((42+120)/2)^{0.5}$). Units should be consistent (i.e., km and sq. km, or miles and sq. miles) and distances should be measured as the fish swims, not as the crow flies.



Commentary: As discussed in Roberts et al. (2003), MPA networks need to take both site size and spacing into account, together. Spacing calculations in previous processes internationally implicitly reflect their typical scale; e.g., the Californian 50–100 km spacing rule was implicitly alongshore, since the planning area extended only 5.6 km (3 NM) offshore. The NSB is a much more complicated situation, where scales of features and processes vary considerably and inshore-offshore ecological connectivity can be significant. Therefore, a more sophisticated approach is required.

The above formula is not meant to model an ecological process; rather, it aims to generalize rules used in practice, capturing both the range of spacing and the corresponding range of recommended MPA sizes, linking the two (Table 1). Admittedly, these rules used in practice have been a blend of scientific and political considerations. Therefore, this generalisation should be seen in that light.

The constant can be seen as an indicator of precaution, whereby a lower value would indicate greater precaution. Using a constant multiplier of nine produces results that fall within the range of the three case studies considered that had explicit spacing and size rules (Appendix 1). Considering Table 1, if spacing is held to the average recommended maximum, our formula yields MPA sizes that are somewhat at the smaller end of the recommended spectrum; i.e., this rule is somewhat less stringent than ideal. If more stringency / precaution is desired, the constant could be reduced somewhat, say to eight (Table 1, column 7). If less is desired, it could be increased to 10 (column 5). Note that in all three scenarios, the size and spacing still stay within the range of values recommended in the case studies. It should be kept in mind that results from this rule of thumb are to be treated as a minimum requirement, not a target. It should be re-visited as more data specific to the characteristics of connectivity within the NSB become available. It is put forward here as a simple rule of thumb that reflects the broad range of scales within the NSB, on the one hand, and previous practices on the other.[19]

Table 1 Comparison of guidance from three MPA planning processes, and how they fit into our generalised rule. Results with a constant ("C") of 10 (less stringent), 9 (recommended) and 8 (more precaution) are shown. Note that all three constants still produce results that fall within the range of recommended practices (resultant MPA sizes are in km^2). Acronyms: GBRMP = Great Barrier Reef Marine Park (Australia); MLPA = Marine Life Protection Act (California, USA); MCZ = Marine Conservation Zone (United Kingdom).

Applied rules			Generalized rule				
	Min. size	**Max. spacing**	**Spacing used in formula**	**Resultant MPA size, C = 10**	**Resultant MPA size, C = 9**	**Resultant MPA size, C = 8**	**Example MPA, C = 9**
GBRMP (Aus.)	20 km min. dimension	200 km	200 km	400 km^2	494 km^2	625 km^2	~20 km x ~25 km
MLPA (USA)	5-40 km alongshore. Min area: 23-47 km^2. Preferred: 47-93 km^2	50-100 km	75 km	56 km^2	69 km^2	88 km^2	~12 km x 5.6 km (3 NM)*
MCZ (UK)	5 km minimum distance across and an average of 10-20 km	40-80 km	60 km	36 km^2	44 km^2	56 km^2	~5 km x ~9 km

*Note that Californian jurisdiction generally ends 5.6 km (3 NM) offshore.

[19] In their comprehensive study directed at developing MPA design criteria for BC's Central Coast, Burt et al. (2014) suggest a narrower range of MPA spacing and size values than previously prescribed for BC, and also what we are suggesting here. They acknowledge that smaller MPAs could be appropriate in some circumstances, but nevertheless fall back to the more constrained CA size rules (pp. 25, 28, 62). They also suggest more limited spacing than we do, citing a study concerning black rockfish (*Sebastes melanops*; pp. 26, 27, 29, 62). This study found the scale of dispersal for black rockfish to be 6–184 km per generation. That said, Rockfish Conservation Areas (RCAs) in BC are potentially already connected by demographically relevant dispersal within a generation, because the distance among reserves is already generally < 100 km (Lotterhos et al., 2014). Burt et al.'s decisions appears to have been strongly influenced by the Californian MLPA process, which for jurisdictional reasons, had no waters further than about 6 km offshore.

Ecologically connected MPA clusters

5. Same or similar habitats in close proximity to one another (e.g., rocky reefs and islets < 5 km apart) are likely to be a single ecological system, and if protected, should be treated either as a single larger MPA or as a cluster of ecologically connected MPAs.
6. When known, the spatial distribution of species' life history stages, including the movement of adults (foraging and feeding, breeding, migratory behaviours), should be considered to be protected as an ecologically connected MPA cluster.

Commentary: Known ecological linkages should take precedence over generic spacing rules when determining site locations. In some cases (e.g., bird nesting and feeding areas for some long ranging species) the spacing between ecologically connected sites could be much further apart than the generic formula would indicate, while in others it might be closer. Umbrella species and keystone species could be given greater emphasis, though this will depend on the assessment methods used (see also Principle 1, Recommendation 2).

Additional Recommendations

7. MPAs in areas of restricted water flow or exchange should be considered to be ecologically further apart (for aquatic species) from other sites than simple distance measurements would suggest.

Commentary: Fjords and inlets are likely to be ecologically connected internally, but less likely to be well-connected to adjacent inlets, hence biological exchange could be less than straight-line distances suggest. Similarly, regions of upwelling resulting from currents or bathymetric steering suggest that deeper sites along the continental slope could be important for the life history of some continental shelf demersal species, and that canyons, like inlets noted above, are best treated as being internally connected but less connected laterally than simple straight-line distances would suggest.

4. Maintain long-term protection [not an identified priority Principle for this report]

The benefits of MPA networks may be realized in a few seasons or it may take several decades. Therefore, management measures should be implemented on a permanent basis to better realize the benefits of protection.

Overview

This Principle is, in our view, primarily a management consideration that would better fit under *General Operating Principles*, rather than this section on *Ecological Principles*. Therefore, in Appendix 2 it was shifted to that section, between Principles 14 (build on existing MPAs) and 15 (include a full range of protection levels). However, there is an ecological aspect to this Principle; namely, determining what "long-term" might mean.

In what is arguably the most comprehensive long-term study of MPAs to date, Edgar et al. (2014) suggest that highly protected sites greater than ten years old are much more likely to show measurable improvement than younger sites. While there are caveats, the 10-year rule of thumb for an effective MPA provides a starting point. Naturally, species-specific results will range from less time for species with high reproductive turn-overs (e.g., Pacific herring, *Clupea pallasii*) to longer periods for others with late maturity and/or sporadic recruitment (e.g., rockfish, *Sebastes* spp.). Furthermore, damaged habitats and ecosystems can take much longer than just ten years to fully recover; corals and sponges common in the NSB, for example, are well known for their growth rates measured in centuries.

Long-term protection is contingent upon compliance with use restrictions that often require long-term surveillance, outreach, and enforcement activities. Without active surveillance and on-the-water management, MPAs are at risk of illegal, unregulated, and unreported fishing, and other extractive and ecologically harmful human activities. To understand whether MPAs are meeting their anticipated aims, long-term scientific monitoring is required. Remote sensing systems can contribute to the understanding, management and protection of the MPA network by improving the monitoring and prediction capabilities of numerous environmental processes such as climate change, depletion of natural resources, natural disasters, and the presence of (legal and illegal) human activities.

BC and NSB context

We note that communication, outreach, monitoring, surveillance and enforcement are hardly mentioned in the Canada-BC MPA Design Principles. However, the role of these activities is essential to the success of any MPA network.

While a regular review (e.g., every five years) of MPAs to ensure that they are meeting their objectives is a good practice, we would caution managers and stakeholders alike to not expect significant results early on (i.e., in the first review), given that it may take 10 years (or more) to be measurable. Expectations can potentially be refined by looking at the changes effected by MPAs in other jurisdictions (e.g., as in Edgar et al., 2014) or the effectiveness of BC's existing MPAs and Rockfish Conservation Areas – contingent upon the critical assumption that all parties are complying with the rules.

5. Ensure maximum contribution of individual MPAs

Size: Design individual MPAs to include sufficient area to meet the related site objectives and effectively contribute to network goals and bioregional objectives over the long term.

Spacing: Design MPA networks to reflect the spacing of habitats, cover the geographic range of habitats, and facilitate ecological connectivity between sites. Spacing should be assessed at multiple scales (i.e., bioregionally and coast wide) to best facilitate connectivity.

Shape: Design the shape of individual MPAs to the degree possible to follow ecological boundaries, avoid fragmenting cohesive habitats, and facilitate surveillance and enforcement.

Overview

Setting aside for the moment surveillance and enforcement considerations, the size and shape of individual MPAs can be influenced by four ecological considerations: (i) minimum viable patch sizes for a single species or ecological community; (ii) how “leaky” the MPA is (e.g., it's edge to area ratio); (iii) the survival rate of species outside the MPA (correlated to the magnitude of human pressures outside of the MPAs); and (iv) the number of replicates and other sites that are ecologically connected to the site in question (e.g., life history stages, larvae, trophic interactions).

The movements of adult species that do not range far from home may be adequately captured in a single MPA; whereas wide ranging or migratory species can be a challenge to protect using MPAs, requiring a focussed multi-site approach to identify life history bottlenecks and (seasonal) aggregations.

MPAs that capture a benthic / topographic feature in its totality are less likely to lose resident species than those that straddle a feature (e.g., a canyon or rocky reef). If the mortality pressure outside of MPAs is low, then it can be assumed that unprotected habitats can still offer some chance of survival as species move from one protected area to another. On the other hand, if anthropogenic pressures are high, then the sites will have to be bigger and more self-contained (i.e., using compact shapes that are less “leaky”). Singular sites, or those replicates separated by larger distances will likewise have to be larger and more self-contained than those that form part of a sub-regional constellation.

Added to the above ecological considerations are those that ensure effective management and compliance. For example, creating community-supported MPAs may have the benefit of increased local enforcement, as well as providing a sense of pride to the community.[20] Easy to follow boundaries based on prominent landmarks and straight lines are still to be recommended, even in this age of increasingly pervasive digital maps and plotters found on commercial and recreational vessels alike.

Here, we limit our discussion to the size and shape of MPAs, as the question of spacing to facilitate connectivity is considered above, under Principle 3.

[20] On the other hand, for communities that do not support a local MPA, non-compliance could set a poor example and behavioural precedent for other MPAs further away.

BC and NSB context

The widely varying geography and topography of the NSB will exert constraints on the shape and size of MPAs that other regions do not face. For example, minimum dimensions typically mentioned in the international literature, such as 5 km across, may not fit into some narrower NSB passages, smaller inlets and estuaries. Areas of high or extreme tidal currents are much more common in the NSB than many regions elsewhere, and represent physical "bottlenecks" that may require particular attention. In areas where depth changes gradually, such as Hecate Strait, there would be considerable value in capturing a range of depths in a single MPA extending offshore (Principle 1). In inlets, on the other hand, that drop off dramatically outside of their head, estuarine features and deep water features could conceivably be captured separately. The narrow continental shelf west of Haida Gwaii (Queen Charlotte Islands) suggests the importance of nearshore MPAs capturing not just the narrow shelf but also at least the upper half of the shelf slope. The various canyons and valleys reaching upward to the coast are better treated as single units than divided. Likewise, rocky reefs (including clusters of small islets and drying rocks) are better protected in their entirety, rather than being divided.

Pitfalls to be avoided

In order to reduce human use conflicts, there is a tendency to avoid protecting areas of high human use, or restricting MPAs to small sizes in such places. However, small MPAs are unlikely to be ecologically functional for many commercial and recreational species, save shellfish and some species of rockfish. If social and political considerations lead to MPAs that are smaller than biology would recommend, the deficit in ecological function will have to be made up through more stringent management measures outside of the MPA, and larger MPAs elsewhere in the region to protect those species and habitats.

Established Individual MPAs usually have site-specific objectives such as conservation of a particular red-listed species, or unusual habitat, among others. Ideally, the existing MPA will have been designed (shape and size) to meet those specific objectives; however, this is not always the case, and expanding or otherwise altering the boundaries of an existing MPA to better capture relevant features can help address the shortcoming. Per Principle 14, design factors of individual sites, such as size, shape and placement can be re-considered in the context of the larger network. Some MPAs, while originally designed for a specific purpose, could conceivably be expanded to more broadly capture network-level goals and objectives.

Other existing protected areas, while perhaps not ecologically ideal, may meet other societal goals for the bioregion, such as recreational usage, and their shape and size should reflect these values and uses. However, political MPA targets (e.g., 10% protection) will miss such differences, unless different legal designations are applied (e.g., *recreation areas* versus *ecological reserves*).

When considering the size and shape of existing protected areas in the NSB MPA network, consideration should also be given to their legal status, and if it may need revising.

Key Recommendations

Size of MPAs

1. MPA shape should attempt to capture the locally dominant ecological processes and features, in accordance with the MPA network objectives.

Commentary: Protecting one feature in its entirety is ecologically more parsimonious[21] than protecting two (or more) features partially, wherein 'leakage' will be greater and ecological effectiveness reduced. Notwithstanding the value of compact sites (#7, below), there are instances when sites may break that guidance when capturing a feature in its entirety; for example, elongated rocky reefs, shoreline features, ridges, troughs and canyons. Pelagic processes such as upwellings or fronts should be reflected in the orientation of the MPA; e.g., along a front, or around a gyre and its direction of travel. If only one example of a feature exists in a (sub-) region, and it is of socio-economic value, then this recommendation may have to be relaxed, with a spatial division of protection and sustainable use management.

2. An uncertainty factor should be included as part of an MPA's overall shape and size calculation.

Commentary: Spatially including an uncertainty factor is considered good practice here because it can address several issues in a straight-forward way, including *inter alia*: data uncertainty, variability of species distributions, protecting species that "wander over the line", protecting species and habitats from extractive users who wander over the line, simplification of boundary for enforcement reasons, and ecological edge effects more generally.

3. The NSB network should contain MPAs across a broad range of sizes.

4. MPAs, at a minimum, should be 5 km^2 to 150 km^2 in size, depending on their location and conservation objectives, as follows:
    a. For the protection of waters surrounding small "point" features such as singular haul-outs, rubbing beaches, singular seabird colonies, seamounts or estuaries, or "skinny" features such as herring spawn beaches, or tightly constrained features such as parts of narrow inlets or small lagoons, minimum sizes at the lower end of the range (e.g., 5-50 km^2) may be appropriate.
    b. For the protection of moderately sized features such as most representative habitats as well as complexes of species use areas (e.g., waters surrounding clusters of bird colonies, haul-outs and foraging grounds, and areas of increased biodiversity), minimum sizes in the middle of the range (e.g., 50–100 km^2) are more appropriate than smaller sizes.
    c. For the protection of larger features, especially offshore features, minimum sizes at the top end of range (e.g., 100–150 km^2) are most appropriate, and in some cases (e.g., for offshore pelagic features) could be significantly larger.

5. The majority (more than half) of MPAs should be at least 50 km^2.

[21] Here, the scientific meaning of the term is used (rather than "frugality"), in that it represents a simpler more direct approach to reaching the ecological goal.

Commentary: The geographic complexity of the NSB region warrants some added complexity in the guidance of placing sites within this physically complex region (as compared to many other regions covered in the literature). The 5–150 km^2 MPA minimum size guideline is necessarily broad to capture the diversity of the NSB, and should be considered alongside the subsequent guidelines that clarify appropriate usage. The 5 km^2 end of the spectrum is much smaller than is commonly proposed in the literature, but we believe is appropriate for a small minority of places in the NSB. However, we stress that the majority of MPAs should be at least 50 km^2, which reflects existing good practices. When circumstances allow, sites should preferably be larger in the range of 100 km^2 or more to increase their prospects of success (Edgar et al., 2014). As noted in the foreword, correct implementation of these broad ranges of minimum values will hinge upon a conscientious and responsible interpretation of the guidance by the planning process participants.

<u>Size adjustments according to level of protection</u>

6. MPA and protected habitat patch size should take into account anticipated management measures, such that ecological function is preserved:
   a. Under management that will allow some limited extractive activities (IUCN category IV), or otherwise negatively affect species or habitats, affected areas should generally be at least two times as large as outlined above; and
   b. Under management that will be for sustainable use (IUCN category VI), affected areas should generally be at least four times as large as outlined above.

Commentary: As discussed in the Introduction, and re-stated in the Executive Summary, many Recommendations in this report, including 1−5 under this Principle, presume highly protected areas. This particular recommendation considers two less-stringent IUCN park categories, based on the results of Ban et al. (2014). To achieve the same conservation result, no-take areas can be considerably smaller than partially protected areas. While this has been commonly accepted wisdom, supported by a number of anecdotal studies, Ban et al. (2014) recently quantified the differences through an extensive literature review. IUCN Category VI “protected areas with sustainable use of natural resources”, for example, had a predicted effectiveness score of 24% compared to 100% no-take reserves in the findings; i.e., about one quarter as effective. However, we note that the variability of the results is high (between 12% and 72% for the 95% lower and upper confidence intervals). Category IV parks, which have greater protection (“habitat / species management areas”) had a predicted effectiveness score in the study of 60%, again with high variability ranging between 34% and 89% (95% confidence intervals). The high variability suggests that individual situations can vary considerably and that perhaps there are other factors that this initial study did not consider (suggesting the benefit of follow-up work on this very management-relevant topic). Nevertheless, the initial results are clear: **partially protected areas will need to be significantly larger than no-take reserves to achieve the same level of ecological benefit, and this will need to be taken into account when determining the size of the MPA and its impacted habitat patches.** Until such a time when location-specific research is conducted in the NSB, we suggest the above distillation of international studies is a reasonable place to begin.

Additional Recommendations

Shape

7. Generally, design of MPA shape should attempt to reduce the edge-to-area ratio to maximize compactness.

Commentary: Existing good practices often suggest a minimum dimension, reflecting the characteristics of the planning areas. For example, the Great Barrier Reef Marine Park Authority specified a 20 km minimum dimension reflecting the broad scale of the park; whereas the Californian MLPA process specified that sites should have alongshore span of 5-10 km coastline (preferably 10–20 km), thus reflecting the alongshore dominance of that particular process (see Appendix 1). However, the NSB is far more geographically complex and varied than these and other commonly cited examples. For this reason, we find it difficult to suggest a single minimum dimension, particularly given the narrowness of several of the NSB's passages and inlets. Instead, we stress the value of less "leaky" more compact MPA shapes that fit within the geography of the NSB, and the size range specified above.

Size of biogeographic classification classes / habitat patches

8. Fine scale biogeographic classification classes / habitat patches (defined as having a median patch size less than 250 km^2) should not be less than 25 hectares (0.25 km^2), and preferably larger, to count towards representativity targets per Principle 1.
9. Coarse scale biogeographic classification classes / habitat patches (defined as having a median patch size exceeding 250 km^2) should have a minimum patch size of 250 ha. (2.5 km^2) to count towards representativity targets per Principle 1.

Commentary: Habitat patch size is an issue that is often overlooked in MPA network design, but which comes to the fore when analysing an existing network for gaps and ecological coherence (Johnson et al., 2014; Lieberknecht et al., 2014). It is therefore prudent to establish thresholds before designating MPAs, as they could affect the size and shape of individual sites.

The 25 ha habitat patch minimum reflects the lower range of guidance originating from the UK, which ranged widely from 20 ha upwards to 2000 ha depending on the scale of the habitat class. Not knowing what sort of habitat classification will be used in the NSB, we are limited in our ability to set a threshold, and have chosen the lower end of the scale. However, we acknowledge that for broad habitats, this threshold is likely far too low to be ecologically meaningful; hence the subsequent guideline, suggesting 250 ha.

Shape

10. For species with life history stages that move on-offshore, the MPA shape should attempt to capture this. If at too broad a scale, then an ecologically connected cluster should be considered –see Principle 3.

11. For species that have particular local feeding or breeding behaviours, the MPA should reflect this; e.g., seabird foraging grounds around a colony. If at too broad a scale, then an ecologically connected cluster should be considered – see Principle 3.

Commentary: As per Principle 2, protecting key life history stages is an EBSA criterion, and is often discussed in the literature, but in our experience rarely implemented. Even more seldom is a cluster of sites designed for a specific group (sub-population, stock, etc.) such that some of the larvae grow up into juveniles, of which some survive to become adults and breed, thus continuing the cycle. For species with known spatial preferences, such as some demersal rockfish or seabirds, such ecologically connected clusters of MPAs are tenable. For others, more research will likely be required. These recommendations overlap somewhat with Principle 3, above, but for completeness are included here as a determinant of shape, as well.

12. MPA boundaries, while remaining ecologically meaningful, should encourage compliance and ease of enforcement, and therefore should, when possible, follow obvious features (or depths), prefer straight lines, and not be unduly complex in shape.

Commentary: The compliance guidelines should be self-evident, and are reflected in existing text for the Principles. We note that modern electronics offer additional possibilities previously not envisioned, such as remote surveillance, automatic alerts, radar images, and plotter updates, which allow for more flexibility in implementation.

Social, economic, and cultural principles

6. Recognize and consider the full range of uses, activities and values supported by marine environments

Functional networks of MPAs will recognize the fundamental relationship between the environment and human activities, cultures, and values, requiring an understanding of the value of ecosystem goods and services as well as the intensity and pattern of human uses across time and space. Integration of economic and social considerations in MPA network design should also include an evaluation of the costs of inaction or inertia. The costs of sustaining biodiversity and ecosystem services through protected area planning can be significantly lower than the costs of inaction.

Overview

Every economy in the world, in accruing social and economic benefits, also takes natural resources (e.g., fish) from the environment and pumps waste (e.g., effluent, CO_2) into it. This underlines the crucial linkages between the environment, the economy and the well-being of humanity (e.g., Ommer, 2007; Sumaila et al., in press). Through this interconnectedness, the environment (i.e., the BC marine ecosystem) is central to the many things valued by its people. Many communities along BC coasts, especially First Nations, rely heavily on fish for food and employment as well as cultural and ceremonial uses (Berkes et al., 2005; Turner & Berkes, 2006; Ommer, 2007). Provincial, federal, and First Nations governments have a responsibility to manage our oceans sustainably for the benefit of all generations of Canadians (DFO, 2009b). It should be noted that the current generation is able to do this on the credit established by elder societies (i.e., past generations) that relied upon ecological governance approaches that instituted continual re-investment in natural abundance. The current generation therefore has a responsibility to hand over a healthy natural environment to future generations. That said, the sustainable management of marine resources in modern times is challenging, and has led to the development of tools to support sustainable management. MPA networks represent one of these tools. Human dimensions, including social, economic, and institutional considerations, can dramatically affect the outcome of MPA implementation, and are fundamental to the success or failure of MPAs (Charles & Wilson, 2009). Indeed, at broader scales, social and economic concerns have been found to be the primary factor in protected area selection (Cumming et al., 2015). MPAs designed to meet community goals can achieve greater compliance and subsequent conservation success than regimes designed only for biodiversity conservation (McClanahan et al., 2006).

Economically, MPAs have been promoted for reasons that include: (i) protection of a particular location, species, or habitat from certain damaging human impacts; (ii) mitigation of shocks and uncertainty to fisheries (Clark, 1996; Sumaila, 1998); and (ii) helping ensure the long term provision of ecological, social, and economic benefits as a result of ecosystem health and biodiversity (e.g., Roberts et al., 2001; Pereira et al., 2010). Ecological, social, and economic resilience go hand in hand.

More broadly, the oceans provide necessary livelihood support for peoples throughout the world and represent “working landscapes” as much as any terrestrial habitat. The NSB is no exception, with several human activities already documented as part of the PNCIMA process (MacConnachie et al., 2007). However, not all areas are used with the same intensity, nor do they have the same value for biodiversity conservation. Careful documentation and mapping is needed to establish the values of the seascape for human well-being as well as biodiversity conservation. There are many examples worldwide of this process (e.g., Lunn & Dearden, 2006; Ban et al., 2013; Turner et al., 2015). However it is much more challenging when such use and intensity patterns, in the interest of making fair and balanced trade-offs, need to be quantified, compared, and prioritized as different value systems come into play.

As social, ecological, and economic values are not solely in terms of money, market and non-market values are both integral to a thorough analysis. This does not imply that different values will be treated in the same way (i.e., relative weights as a combination of stakeholder inputs and policy constraints), but they should be discussed at the same table. Increased attention has recently been given to developing measurement techniques that are fungible across different values (e.g., financial values; Driml, 1994) and to find ways to derive monetary returns from non-market ecosystem services (e.g., payment for ecosystem services; Redford & Adams, 2009). As yet there is no commonly accepted approach, nor payment mechanism to address this challenge (ibid.). Although there are many different and creative ways in which to attach monetary value to ecosystem services (see commentary on

Recommendation 4) (Daily & Matson, 2008), sometimes it may be best to treat certain values separately. One key pitfall of monetizing ecosystems is that once a value is produced, it can become a benchmark even if we stress that our valuations are almost always incomplete (Toman, 1998).

In addition to spatial and measurement challenges, further challenges arise in terms of assessment of intergenerational value (Heal, 2008; Sumaila, 2004), the opportunity costs of past and current activities, and responsibilities to future generations (Sumaila & Walters, 2005). In the absence of effective approaches and mechanisms to address these challenges, full application of the Precautionary Approach, as discussed under Principle 16 below, must be emphasized.

Human sustenance requires sustainable livelihoods both now and in the future. Highly protected MPA networks have the potential to significantly affect livelihoods, negatively and positively, in the short- and long-term. However, without care being given to those affected, long-term benefits can come at the expense of those that have the least capability to adapt to short-term changes; e.g., low-income small-scale commercial fishers. Attention paid to the planning of sustainable and achievable futures for people negatively impacted should be factored in as part of the establishment of ecologically-effective MPA systems. Livelihoods will need to adapt or change, and the society that sees the need to establish MPAs has some responsibility to ensure that livelihood changes are as positive as possible for those involved. Under certain circumstances, some jurisdictions, including both Australia and the United States, pay compensation to users for their loss of earnings due to fisheries and access restrictions in MPAs (for an overview see Sen, 2010). Canada has not chosen to take this approach but should recognize the socio-economic and cultural implications of MPA establishment and provide support, both financial and otherwise (such as capacity development), to affected communities to adjust to MPA network establishment. Conversely, the historical diminishment and extirpation of culturally valued ecosystem components (e.g., abalone, eulachon) have already led to the loss of livelihoods within communities along the BC coast (for an overview see Ommer, 2007). Thus, the restoration of some aspects of these ecological components presents an opportunity for MPA networks, which may be as important as preventing future losses.

In undertaking economic valuation of the efficacy of MPAs, there are a multitude of questions to consider (Sumaila & Charles, 2002): What are the benefits? What are the costs? Over what time frame are benefits and costs measured? What are the intergenerational flow of these benefits and costs? How do we deal with discounting of future benefits and costs? What about equity issues? Who receives the benefits? Who incurs the costs? Do the benefits of MPAs reach those who suffer the costs? What about the differing levels at which benefits and costs occur: individuals and corporations (e.g., resource users), communities, regions? These questions have been given additional salience by the wording of CBD Target 11 that establishes not just the 10% minimum target for MPA coverage of the oceans by 2020 but that such coverage must be "equitably managed."

Noteworthy is previous work by Parks Canada (2008) that outlined six socio-economic principles which are covered by the current Canada-BC Principles, though some are worded slightly differently (c.f. Parks Canada principle 1: "When selecting fully protected areas, have a consultative process that is balanced, open, inclusive, transparent, and provides opportunities for meaningful involvement" with Canada-BC Principle 10).

BC and NSB context

The social and cultural context of coastal communities worldwide differs widely. What is applicable in one locale may not be so elsewhere, even in relatively close proximity (e.g., Fabinyi et al., 2010; Voyer et al., 2015). This is true of the BC coast where there are some similarities, but also major differences between communities (e.g., Heck et al., 2012a) and these should be taken into account in deciding the most appropriate course of action for a given social, economic and cultural context (i.e., sub-regional setting). LeRoy et al. (2004) for example, discuss a case where there were different perspectives amongst First Nations communities regarding a protective designation on the BC coast resulting in conflict and a failed process. It is realistic to expect that there will be differences both within and amongst various groups (Heck et al., 2011, 2012b).

One of the main challenges to the establishment of functional MPA networks on the BC coast is the extent and intensity of existing uses. Some research has been undertaken on the intensity of use (Ban & Alder, 2008) and the cumulative impacts of such use on various ecosystems (Ban et al., 2010). Clearly it would not be desirable to locate MPAs within the most highly impacted areas without a strong rationale (e.g., the recovery of a vital or irreplaceable ecosystem component). The Ban et al. (2010) analysis suggests that existing protective designations in BC waters were far from effective in mitigating impacts, and surprisingly showed higher impacts than surrounding waters. If the NSB MPA network is to be effective then it must be designed and resourced to achieve meaningful management measures and good compliance.

Some of the human uses have been mapped in the British Columbia Marine Conservation Atlas (BCMCA, 2011) and analyzed using Marxan to identify areas of potentially higher value for various sectors. Of the six sectors considered (recreational fisheries, ocean energy, shipping and transportation, tourism and recreation, tenures, and commercial fishing), only two, commercial fisheries and shipping and transportation, agreed to allow the results to be made public, as concerns were raised by the other sectors about the results' validity and reliability. There was broad concern regarding the lack of *relative* values for each sector, with data focusing more on density (Ban et al., 2013).

The use of relative terminology outlined above for initially setting representativity targets (Principle 1) can also be applied to identify areas of varying value to stakeholders. Non-numeric terms such as "medium", "high", and "very high" can be used to describe places and rank sites. Numerical values can then be applied. Because some individuals will draw or otherwise describe valued areas more carefully than others, additional spatial statistical techniques will be required to combine results from various individuals into a single mapped layer (Ardron, 2005). In the NSB, getting relative values across sectors and communities will require more direct engagement with stakeholders (e.g., O'Regan, 2015). Until such places are mapped, trade-off analyses that can minimize costs will be incomplete, leaving little choice but "horse-trading" style negotiations that can lead to sub-optimal results for all parties (e.g., Klein et al., 2008). However, some stakeholders remain wary of such data-gathering exercises, while others have perhaps grown fatigued or disillusioned with coastal planning processes in general –not an insignificant consideration in the NSB. As is emphasized throughout this report, the NSB process is not a blank slate. In order to succeed it should take into account similar processes that have preceded it, and both their positive and negative effects on stakeholders and local communities.

One of the most distinctive and important aspects of human use values of the BC coast is the intimate relationship between the marine environment and the history, culture, knowledge, livelihoods, and spirituality of the First Nations peoples indigenous to the coast. These values can only be captured through working closely with First Nations to ensure that their views are represented (e.g., Ban et al., 2009; CPAWS, 2009; Gardner & Morales, 2010; Ayers et al., 2012; Augustine & Dearden, 2014). Inclusion of these largely non-market values is a major challenge, given such values are difficult to compare with more easily quantified ones. In meeting this challenge it should not be forgotten that in addition to some of the more intangible values that link First Nations to the marine environment, there are also some very tangible and important local and indigenous subsistence uses that need to be recognized and taken into account in MPA designation, and that these will reflect a mix of traditional and modern values.

Pitfalls to be avoided

The first pitfall is to pay insufficient attention to this principle and ignore the patterns of human use that have evolved over decades, and for First Nations peoples, centuries. Such an approach often generates considerable backlash from local communities – the very communities that need to be relied upon to generate compliance with conservation interventions. There are several examples where MPA economics and social aspects have not been considered, leading to failure of the MPA process (e.g., Christie et al., 2004; Bunce et al., 2010; Bennett & Dearden, 2014).

However, with the establishment of international and national targets for amount of area to be protected (e.g., CBD Aichi Target 11, at least 10% by 2020), there may be increasing temptation to sacrifice quality for quantity in terms of network establishment, though ultimately this will defeat the purpose of establishing the MPAs in the first place. Notwithstanding the first pitfall, existing uses should not exclusively dictate the location, size, spacing and management of the required conservation interventions. Regrettably, there are many examples throughout the world where minimizing conflict with existing uses has in practice ended up as seemingly the dominant design principle for MPA establishment (Devillers et al., 2014). While this approach can result in the rapid expansion of MPA systems, it can also seriously compromise the potential for those systems to protect ongoing losses of marine biodiversity, their main purpose. In some cases, certainly, this strategy could have benefits in the long run because protection may precede the inevitable expansion of human activities into hitherto unexploited areas of the marine ecosystem. However, it remains that protecting areas that few value will not address current pressures on the NSB's marine environment. If the Canada-BC MPA Network Design Principles are to be fully met, with biodiversity better protected than at present, then some conflict with existing human uses will be inevitable. Resolving conflict will require a transparent site-by-site evaluation of the options available, which should neither presuppose nor preclude displacement of human activities.

Minimizing conflict while still reaching the ecological objectives of the MPA network will first require acceptance across sectors of the NSB process's mandate and legitimacy; second, a comprehensive spatial database mapping human valued areas, activities, and uses in the region; and third, a transparent and participative process.

Key Recommendations

This Principle should go hand-in-hand with Principle 10 (*Work with people*) and Principle 11 (*Respect First Nations' treaties, title, rights, aspirations and world-view*), especially around human-use data collection and analysis being characterised by an effective stakeholder engagement process and framed by network objectives. We have not been tasked to address these two Principles; however, the recommendations below assume that they will be implemented. Furthermore, we have not been tasked with discussing management options. While our ecological recommendations (above) presume for the moment that the target species and habitats in an MPA will be highly protected, our recommendations under this Principle 6 presume that there will also be a variety of management measures available to address mitigating impacts to existing human uses, as per Principle 15. This suggests that no-take reserves, while an important part of the NSB MPA network, should not be the only management option.

1. Before collecting data on the range of uses, activities, and valued areas in the NSB, first ensure there is a shared understanding of the planning process, its objectives, and management options.

Commentary: Gaining a shared understanding, and ideally agreement, of a planning process and its objectives helps set a positive tone early in a planning process, and promotes both good research and engagement practices. Knowing the MPA management options ahead of time can more easily lead to agreement on what data will need to be collected, and will let stakeholders know how decisions could affect their activities in the (sub-)region. A shared understanding can help all participants to re-focus later on if discussions become heated. Again, we emphasize that the NSB is not a blank slate, and would encourage a review of visions, goals, and objectives from earlier planning processes, which could save significant time and effort. Working collaboratively on finalising the draft NSB MPA Network Objectives can help achieve this recommendation.

Recommendations 2-7, below, are loosely based on recommendations developed by the BC office of the NGO *Canadian Parks and Wilderness Society,* through expert consultation (Jessen et al., 2011). Recognising these as a good starting point, we have re-ordered them, combined, and modified their wording, in response to comments from internal and external reviewers.

2. Incorporate traditional, local, and stakeholder knowledge concerning usage of the marine and nearshore environment of the NSB to produce fine resolution spatial datasets (location, relative importance, and intensity) of:
   a. human commercial and recreational activities,
   b. culturally and historically significant areas, and

c. spiritual sites.

Commentary: The above recommendation is for nearshore and marine usage only. Terrestrial sites of concern, such as burial sites, are not included. However, adjacent upland activities can at times affect MPA placement.

The type and number of social, economic, and cultural data should be initially constrained by an effective stakeholder involvement process and the network objectives, rather than an exercise to collect everything that may be available. If stakeholders are truly involved in the development (and in some cases, management) of MPAs, they will provide valuation data that are correct and complete, allowing for the process to take into account the rationale under which they make real-world decisions. If this is not the case and projections are made with incomplete or incorrect data, outcomes are unlikely to meet desired policy objectives. **Standardized data collection protocols should be developed and followed to ensure replication of results and trace-back to sources for clarification or corrections**. Trust is key to the gathering of good information.

Confidentiality is often an issue when collecting the above information. There are several technical techniques for addressing confidentiality. The simplest way to avoid the issue is to agree that final MPA options will not show specific (perceived) confidential layers, but rather the integrated results that have emerged with these layers used in the analyses. However this seemingly simple solution precludes external participation and peer review; further, it excludes non-governmental bodies, including industry, from having full access to the information necessary to produce alternative options. It should be acknowledged that not all human marine uses are confidential. In Canada, the marine environment is legally a common property resource for the benefit of all Canadians, administered by the various levels of government, including First Nations. Hence, anonymous information on how this common property resource is used should, as a general policy, remain open and available to the public. Confidentiality concerns of a few come with a loss to the many, and consequentially must be weighed very carefully.

3. Identify community-based conservation initiatives and integrate local knowledge for possible inclusion of these sites in the MPA network.

Commentary: An ecologically effective and socially supported MPA network in the NSB will require integrating both "top-down" and "bottom-up" approaches. Top-down planning has the advantage of seeing bigger picture regional requirements, whereas bottom-up initiatives have the advantage of possessing an intimate knowledge of a local portion of the region's waters. This recommendation should be seen as complementary to, and consistent with, Principle 14 (*Build on existing MPAs, other management tools and marine planning initiatives*).

4. Incorporate non-market values into the MPA planning process, balancing these with conservation and economic concerns.

Commentary: There are many types of values provided by ecosystems, commonly referred to as 'ecosystem services' (De Groot et al., 2002). Direct use values are the most straightforward to appreciate and measure, and include the dollar value of fish purchased, the value of organisms as food, or the number of jobs created by natural resource-based industries. Indirect use values include supporting services, such as the value of lower trophic levels and habitats for species from which we derive direct use, or species that contribute to ecotourism, for example (Costanza et al., 1997). Non-use values are more difficult to measure, but are no less important to consider. Option value refers to our desire to conserve resources for potential future use. Bequest value concerns the benefit of consciousness that resources exist. We can also derive tradition and inspiration values from ecosystems (for example, a fish caught as part of a ceremony is much more valuable that its price at the market) (Winkler, 2006; De Groot et al., 2002; Toman, 1998).

Just as there are many types of ecosystem services, there are many ways of measuring them directly or indirectly, as appropriate (Winkler, 2006). Direct use values are usually straightforward, and are assessed by market price or through models that estimate the number of jobs supported by a resource. Indirect uses and some non-market values can be approximated with formal methodologies (though not without legitimate criticism of the limitations of these methodologies). Travel cost methods value resources by measuring visitor spending to access it. Hedonic pricing models correlate known market values with non-market services to estimate their value (for example, by comparing the price of homes along a coast with varying degrees of environmental quality to better understand the value of a clean coast). Willingness-to-pay (or accept) methods are used when other methods cannot be applied or would be inappropriate, and ask precisely worded questions to understand how much a resource is worth to people. These can be complemented with revealed preference surveys (for example, how much money was donated to conservation efforts in a given place) (Costanza et al., 1997). Cultural and traditional non-market values can be extremely challenging to assess and quantify. Thus, it is often desirable that during discussions, they be kept as separate, non-negotiable values.

5. As that MPA implementation may initially impact some local economic opportunities, identify opportunities for future and alternative uses both within proposed MPA sites and the surrounding region, and develop a displacement policy for those that are impacted by development of MPAs.
6. Use optimization (e.g., Marxan) and decision support tools (e.g., InVEST) to integrate ecological, social and economic considerations into marine spatial planning processes for MPA design.

Commentary: Spatial planning tools, and good practices surrounding their usage, have matured to the point where they can now be seen as best practice when exploring ecological, social, and economic trade-offs, thus helping to maximize benefits and minimize harms (Principles 7 & 8).

Additional Recommendations

7. Incorporate cultural norms and traditional practices into management rules; do not supersede them.
8. Provide visible benefits to those whose behaviour the MPA's success is most contingent upon. These can be non-financial and include infrastructure or access to information, or incentive-based payments such as buy-backs and grants for re-training, as well as monetary compensation.

Commentary: 7 & 8, above are distilled from Hargreaves-Allen et al. (2011) and personal communication with HC & JA. Overlooking or discarding existing traditional practices can come with heavy social penalties. While not all traditional practices are necessarily positive for the environment or local communities, these should nevertheless be considered carefully, and if they can be adapted with the stakeholders to meet network objectives. In any case, the positive benefits of MPAs will have to be apparent to most people affected, if the MPA network is to stand any reasonable chance of acceptance and compliance.

9. For larger MPAs (e.g., > 70 km^2), consider internal zoning to accommodate different objectives.
10. Plan on multi-generational time frames, both for desired socio-economic outcomes and for scientific monitoring.
11. Develop indicators to monitor progress in meeting this Principle (coherent with Principle 13, Adaptive Management).

Commentary: The design of an effective suite of indicators to monitor human uses, ecological and social impacts, is a complex task and falls outside the scope of the current study, but which should be a high priority for future work. Valuable insights can be gained from earlier work on the coast, such as undertaken by the Coasts under Stress project (Ommer et al., 2007). Recent work reported by Biedenweg et al. (2014) suggests one possible approach to measure human well-being –one aspect of a successful MPA network. The development of tractable indicators that inclusively reflect the region's social and ecological values should be seen to support and complement the other recommendations, rather than to duplicate them.

Examples of differentiated roles in MPA network planning

Hargreaves-Allen et al. (in review) in their meta-analysis of successes and failures in what they defined as *marine managed areas* (MMAs), make several insightful recommendations by participant type, summarized here. While not comprehensive (i.e., not including the full range of users), these examples do highlight how a successful planning process hinges on concerted actions by a variety of actors:

<u>Managers</u>

- collect socio-economic data including data on resource use, profitability and violations both before designation and following the implementation of new policies and programs, to inform adaptive management;
- create mechanisms for community participation and influence in decision-making;
- consider the socio-economic and cultural context when choosing management activities undertaken such as choice of enforcement or incentive schemes;
- widely disseminate MMA rules;
- facilitate dialogue between different stakeholders using conflict resolution if necessary;
- demonstrate benefits to local stakeholders;
- capture visitor consumer surpluses through correctly set tourist fees;

- monitor tourism related impacts;
- consider incentives generated for local people by the MMA and modify them as necessary with positive incentives;
- compensation and/or enforcement to increase compliance;
- develop an enforcement strategy including protocols for monitoring, evidence collection, prosecution and boarding; and
- incorporate traditional patterns of resource use and management into MMA design and regulations, and clarify local stakeholder access and use rights.

NGOs
- help facilitate partnerships between stakeholders;
- increase awareness of decision makers of the economic and social benefits of protection;
- increase public and political will for prosecution; and
- develop and help implement sustainable financing mechanisms and fund capacity building for sustainable livelihoods, management and enforcement.

Government agencies
- contribute towards MMA budgets, infrastructure support, staffing and capacity building;
- establish clear and transparent management structures which incorporate or support traditional knowledge and customary practices;
- establish clear and standardized regulatory and legal frameworks;
- help conduct and regulate enforcement efforts;
- co-ordinate disparate research, management and enforcement efforts; and
- integrate MMAs into sustainable development planning and wider coastal zone management.

Local community members
- participate in design, implementation and on-going management;
- communicate their needs and concerns;
- celebrate cultural events linked to marine resources;
- seek out sustainable livelihoods;
- use opportunities provided by MMAs for training and capacity building;
- understand that many benefits will lag behind management activities; and
- participate in learning networks and partnerships with NGOs and universities.

Marine scientists
- use local knowledge;
- develop long term research and monitoring protocols;
- develop decision making tools to aid understanding of trade-offs inherent in regulations and policies;
- promote realistic expectations of MMA outcomes;
- monitor costs generated by MMAs for local stakeholders as well as benefits;
- honestly and transparently disseminate research on MMA outcomes;
- incorporate social impacts and incentives into interdisciplinary management effectiveness research; and
- refine and standardize effectiveness evaluations.

Tourism industry

- allocate a portion of profits to conservation funding;
- educate visitors as to the need and benefit of conservation and the ways to minimize environmental impact; and
- promote marine based eco-tourism activities.

7. Maximize the positive [not an identified priority Principle for this report]

Marine protected area network planning will include identification of opportunities to contribute positively to protection of sustainable socioeconomic activities and cultural and spiritual values. Socioeconomic data are typically incorporated in network design as a cost to be minimized, however, if the inclusion of a social, cultural or economic feature is desired in an MPA network (e.g., a traditional harvesting area, priority areas for fishing, a ship wreck, kayak routes, etc.), then it can be targeted for protection in the same way as biodiversity features. Protection of the feature must also contribute to the primary goal for BC's network of marine protected areas (i.e., to protect and maintain marine biodiversity, ecological representation and special natural features).

Overview

The establishment of MPA networks may be viewed negatively by some local communities, despite the likelihood of positive outcomes for those communities over both the short and long terms. These positive elements are rarely paid as much attention as the mitigation of negative aspects, but can be an important function of MPA establishment. MPAs may strengthen social goals promoting community development, economic diversification and cultural preservation (e.g., Leisher et al., 2007; Torell et al., 2010; McClanahan, 2012). There is therefore a need to work with communities specifically on the identification and enhancement of positive outcomes that are meaningful to those communities, while taking care not to create unrealistic expectations, especially in the short term.

Augustine and Dearden (2014) provide an additional perspective in relationship to First Nations' cultural and subsistence values and their incorporation in marine protective designations on the BC coast. In this case they suggest that re-creation of clam gardens within protected areas would increase the relevance of protective designations for First Nations as well as enhance cultural and livelihood values and provide an example of this Principle in action.

This Principle and the one that follows (#8) are very much two sides of the same coin, whose economic essence can be captured by the term *efficiency*[22]*;* i.e., a situation in which ideally the benefits of MPAs are enlarged while the costs associated with them are minimized. That is, until the point is reached when it is not possible to increase the benefits to members of society without more greatly decreasing the benefits to others, which cannot (theoretically) be compensated. However, in most real situations, any move from the status quo will be opposed by those stakeholders who fear short-term costs or lost opportunities, regardless of whether the overall long-term situation may be improved. These stakeholders can become vociferous opponents of MPAs, as has been experienced in MPA designation processes worldwide (Appendix 1). There can be a variety of theoretically ideal solutions in which long-term improvements could be achieved, each with their own trade-offs, which would need to be discussed with affected stakeholders, beneficiaries and opponents alike. A classic example is a depleted fish stock, in which a rebuilding effort could result in the benefits of all fishers increasing relative to what they obtained previously; however, to get to that optimal situation would require making decisions that in the short-term will likely negatively affect many of them. Nonetheless, as the official text of the previous Principle points out, “The costs of sustaining biodiversity and ecosystem services through protected area planning can be significantly lower than the costs of inaction.”

The Treasury Board of Canada Secretariat (2007) puts forward a five-step approach to guide cost-benefit impact analysis:

1. Identifying issues, risks, and the baseline scenario;
2. Setting objectives;
3. Developing alternative regulatory and non-regulatory options;
4. Assessing benefits and costs; and
5. Preparing an accounting statement.

Balancing several objectives (step 2) and costs (step 4) can quickly become complicated, and falls into the realm of multi-objective problem solving. Addressing such problems requires spatial information for both. Decision-support and optimization tools (commented upon below), when combined with multi-stakeholder discussions, can help arrive at more efficient and socially acceptable solutions.

BC and NSB context

Using the multi-objective optimization tool Marxan, several attempts to maximize positive benefits with a particular focus on ecological values have already taken place in BC and the NSB, and should inform future NSB planning. These include (sequentially):

- A Central Coast analysis by the NGO Living Oceans Society (Ardron et al., 2000);
- Two subsequent analyses by the Coast Information Team (CIT, 2004) assisted by NGOs as part of the North and Central Coast LRMP process (shoreline (The Nature Conservancy) and marine (Living Oceans Society; Ardron, 2008);
- Separate analyses by Parks Canada for Haida Gwaii and the Southern Gulf Islands;

[22] Specifically, *Kaldor-Hicks efficiency.*

- Various analyses by BC marine conservation scientists (e.g., Ban et al., 2009; Ban & Vincent, 2009);
- The independent multi-stakeholder BC Marine Conservation Analysis (BCMCA, 2102); and
- Analyses underway as part of the Marine Planning Partnership for the North Pacific Coast (MaPP) including the Haida Gwaii Draft Marine Plan (Haida & BC, 2014).

Additionally, in work done for the West Coast Aquatic Management Board (outside of the NSB planning area), InVEST, a software tool to assess marine ecosystem services, was used to estimate changes in a suite of services under different management scenarios and to investigate trade-offs among the scenarios (Guerry et al., 2012).

8. Minimize the negative [not an identified priority Principle for this report]

MPA network design should strive to minimize user conflict and balance conservation objectives with social and economic opportunities. Where there is a choice of several sites which if protected would add a similar ecosystem or habitat to the MPA network, the site(s) chosen should minimize adverse impacts on existing users.

Economic analyses can identify design measures that maximize conservation success while minimizing costs. For example, network design should take advantage of best available knowledge (e.g., traditional, local and scientific), bio-economic models and decision support tools (e.g., Marxan) to support MPA site selection in order to reduce potential conflicts and ensure more equitable distribution of the costs and benefits of conservation between communities and users. The availability of various designation options provides additional opportunity to customize the level of protection to achieve goals and objectives for an area while minimizing impact on human activities. The result should be a network that maximizes benefits and minimizes detrimental impacts, providing fair and equitable consideration of the effects on livelihoods while still achieving conservation goals.

Overview

The discussion above on the previous Principle also applies here.

Costs and benefits can take on many forms, which can be difficult to disentangle (Ban & Klein, 2009); for example, they can be measured in dollars earned (Lam et al., 2011), jobs (Teh & Sumaila, 2011), GDP (Dyck & Sumaila, 2010), triple-bottom line, etc., each of which will lead towards different conclusions. Costs can include potential revenues lost from extractive activities, costs of monitoring and enforcement, costs of maintaining a site for tourism activities (anchorages, kayaker camp grounds, etc.), and could also include non-fungible costs such as impacts on spiritual values, or political opportunities. Inter-generational costs and benefits add another dimension to this already complicated picture.

BC and NSB context

As noted in the previous Principle, a number of Marxan analyses have already taken place in BC (and one InVEST analysis). None of them, however, considered a full range of costs or benefits. The data for many costs are not available in a spatial format, necessitating in-depth stakeholder consultations of the sort we have already seen in BC, from the LRMPs, to the BCMCA, to MaPP, to the current NSB process. **Collecting spatial information on human uses and their associated values and costs should continue to be a priority for the NSB process**. The analytical process used in designing the California network plan is instructive in this regard (White et al., 2013), as well as other studies illustrating approaches to minimize reserve establishment costs to fisheries (e.g., Stewart & Possingham, 2005; Watts et al., 2009).

Principles 9 - 11 are not considered here. Please see Appendix 2 for some issues identified in the peer-reviewed literature.

General operating principles

12. <u>Foster ecosystem-based management</u> [not an identified priority Principle for this report]

Marine protected area network planning will take into account the broader movement towards ecosystem-based management (EBM) of marine areas. EBM is an adaptive approach to managing human activities in a manner that ensures the coexistence of healthy, fully functioning ecosystems and human communities. The intent of EBM has been described as "to maintain those spatial and temporal characteristics of ecosystems such that component species and ecological processes can be sustained and human well-being supported and improved".

Overview

Ecosystem-based management (EBM) offers an integrated, collaborative approach to balancing the diverse services that humans obtain from ecosystems. However, the complexity of social and ecological systems and the diverse values held by different social groups makes implementing EBM very difficult. Attaining the necessary social license to apply EBM in the management of shared natural resources has proven challenging, especially given the broad nature of the concept, which is difficult for the public to appreciate and for practitioners to bound and apply in a consistent manner. Additionally, it is so broad a concept that it can be difficult to determine when its implementation is complete.

EBM is widely recommended in the literature. The CBD has identified 12 principles related to EBM, which range from taking the ecosystem as a whole into account to engaging with society. The communications consultancy, COMPASS (2005), formulated a widely-quoted definition of EBM with scientists and policy experts for U.S. policy-makers, *inter alia*:

[EBM] is an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors (p.1).

BC and NSB context

Notwithstanding the challenges in implementing EBM, both BC and the federal governments have committed to integrating it into land and marine planning and management processes. Although EBM is not specifically mentioned in federal legislation, it is in the Oceans program[23] of Fisheries and Oceans Canada, established to implement the *Oceans Act*. Also, Canada's Oceans Action Plan states, "integrated management is a comprehensive way of planning and managing human activities so that they do not conflict with one another and so that all factors are considered for the conservation and sustainable use of marine resources and shared use of oceans spaces. It is an open, collaborative and transparent process that is premised on an ecosystem approach" (DFO, 2005, p.13).

Subsequently participants (stakeholders, governments and First Nations) in the PNCIMA process have extensively discussed and by consensus agreed upon the following working definition of EBM (PNCIMA, 2013):

Ecosystem-based management is an adaptive approach to managing human activities that seeks to ensure the coexistence of healthy, fully functioning ecosystems and human communities. The intent is to maintain those spatial and temporal characteristics of ecosystems such that component species and ecological processes can be sustained and human well-being supported and improved.

The following EBM principles have been defined for the PNCIMA process:

1. The EBM approach seeks to ensure ecological integrity. It seeks to sustain biological richness and services provided by natural ecosystems, at all scales through time. Within an EBM approach, human activities respect biological thresholds, historical levels of native biodiversity are met, and ecosystems are more resilient to stresses and change over the long term.
2. The EBM approach includes human well-being. It accounts for social and economic values and drivers, assesses risks and opportunities for communities, and enables and facilitates local involvement in sustainable community economic development. An EBM approach aims to stimulate the social and economic health of the communities that depend on and are part of marine ecosystems, and it aims to sustain cultures, communities and economies over the long term within the context of healthy ecosystems.
3. The EBM approach is precautionary. It errs on the side of caution in its approach to management of human activity and places the burden of proof on the activity to confirm that management is

[23] The Role of the Canadian Government in the Oceans Sector. Oceans Directorate, 2009.

meeting designated objectives and targets. Uncertainty is recognized and accounted for in the EBM approach.

4. The EBM approach is adaptive and responsive in its approach to the management of human activities. It includes mechanisms for assessing the effectiveness of management measures and changing such measures as necessary to fit local conditions.
5. The EBM approach includes the assessment of cumulative effects of human activities on an entire ecosystem, not just components of the ecosystem or single sector activity.
6. The EBM approach is equitable, collaborative, inclusive and participatory. It seeks to be fair, flexible and transparent, and strives for meaningful inclusion of all groups in an integrated and participatory process. EBM is respectful of federal, provincial, First Nations and local government governance and authorities, and recognizes the value of shared responsibility and shared accountability. It acknowledges cultural and economic connections of local communities to marine ecosystems.
7. The EBM approach respects Aboriginal rights, Aboriginal titles and treaty rights, and supports working with First Nations to achieve mutually acceptable resource planning, stewardship and management.
8. The EBM approach is area-based. Management measures are amenable to the area in which they are applied; they are implemented at the temporal or spatial scales required to address the issue and according to ecological rather than political boundaries.
9. The EBM approach is integrated. Management decisions are informed by consideration of interrelationships, information, trends, plans, policies and programs, as well as local, regional, national or global objectives and drivers. The EBM approach recognizes that human activities occur within the context of nested and interconnected social and ecological systems. As such, EBM concurrently manages human activities based on their interactions with social-ecological systems. The approach helps to direct implementation of measures across sectors to integrate with existing and, where agreed, new management and regulatory processes.
10. The EBM approach is based on science and on wise counsel. It aims to integrate the best available scientific knowledge and information with traditional, intergenerational and local knowledge of ecological and social systems and adapt it as required.

With regard to the application of EBM, terrestrial management in BC should be studied for lessons learnt. Both the Clayoquot Biosphere Reserve and Gwaii Haanas models of co-management provide instructive examples. In February 2008, the Province introduced the new legal framework for the Central and North Coast of BC that began the process of establishing EBM, covering an area of 6.4 million hectares of land. In 2009, Biodiversity Areas were established, Land Use Objectives amended to recognize Aboriginal Rights and Title, and Strategic Land Use Planning Agreements renegotiated. Similarly, "Coastal First Nations have focused their efforts in several areas to ensure our ability to implement EBM on our territories: developing and negotiating land use plans and agreements for each territory; envisioning new roles and responsibilities and developing new governance institutions; securing economic investments and funds for local community economic development initiatives; and, developing guidelines for applying the EBM approach to forestry on the ground" (Turning Point First Nations, nd, p.1).

PacMARA, over the course of two workshops in 2010, and through inter-sessional correspondence, led a BC-based working group from academia, federal government, First Nations, industry, provincial government, and NGOs to develop Marine Ecosystem-based Management (EBM) Principles. The goal of creating this document was to provide a more applied elaboration of marine EBM than existing high-level lists of aspirations. The group developed a brief, clear, and understandable set of principles describing the step-wise context, purpose, and process of effective EBM implementation, with supporting elaborations (*Sidney Consensus*, Appendix 3). Follow-up work developed a visual representation or roadmap (*Charting a Course for Sustainable Prosperity*[24]) with which specific projects can be elaborated in more depth, and checklists for each step of the EBM process can be developed.

We encourage the NSB process to make use of the EBM work to date in BC, with particular attention being paid to the PNCIMA EBM definition, assumptions and principles, as well as the *Sidney Consensus (Appendix 3, below)*.

Principles 13- 15 are not considered here. Please see Appendix 2 for some issues that have arisen in the peer-reviewed literature.

16. Take a precautionary approach

> ***A lack of scientific certainty will not be used as a reason for postponing establishment of MPA networks as a tool to help mitigate or prevent serious damage to the marine environment.***

Overview

The precautionary approach (also known as the precautionary principle in some jurisdictions[25]) entered the conservation policy realm as a series of proscribed practices (though not at that time identified as "precautionary") in 1982 when the World Charter for Nature was adopted by the United Nations General Assembly (UNGA, 1982). Its first international implementation with regard to environmental practices was arguably in 1987 through the Montreal Protocol. However, it is most famously known as Principle 15 in the Rio Declaration of 1992. The concept has since permeated the text of national and

[24]http://pacmara.org/chart.

[25] There is an ongoing debate about what differences, if any, distinguish the Precautionary Approach from the Precautionary Principle. Many view the word *principle* as being inherently more stringent than *approach*, though there is little empirical evidence to suggest this is operationally so. For the purposes for this report, they shall be treated as being operationally the same.

international agreements and treaties. The Seabed Disputes Chamber of the International Tribunal for the Law of the Sea in its 2011 advisory opinion stated, *inter alia*:

> 135. The Chamber observes that the precautionary approach has been incorporated into a growing number of international treaties and other instruments, many of which reflect the formulation of Principle 15 of the Rio Declaration. In the view of the Chamber, this has initiated a trend towards making this approach part of customary international law […] (ITLOS, 2011; emphasis added).

Precaution is also included in Canada's Species at Risk Act. From the perspective of the NSB, Canada-BC Principle 16 can be seen as further evidence of a global trend in this direction, and while its implementation remains open to some interpretation, it is nevertheless well grounded in three key points (IPCC, 2007): First, precaution relates to decision-making under deep uncertainty. This is characterized by an insufficient description of the risks, the possibility of irreversible change, or simply large knowledge gaps (i.e., unknowns). In addition to the uncertainty associated with this risk dimension, it also recognizes the temporal dimension – that policy action should not wait for scientific certainty. Finally, it must be recognized that precaution can cut both ways because choices are about choosing one risk over another. This makes the application of the precautionary principle fundamentally about trade-offs. The application of precaution recognizes that the absence of full scientific certainty shall not be used as a reason for postponing decisions where there is a risk of serious or irreversible harm. It is distinctive within science-based risk management and is characterized by a risk of serious or irreversible harm, the need for a decision, and a lack of full scientific certainty.

BC and NSB context

The groundwork for implementing the precautionary approach in science-based decision making was established by the Government of Canada (2003) with *A Framework for the Application of Precaution in Science-Based Decision Making About Risk*. This document outlines guiding principles for the application of precaution to science-based decision making in areas of federal regulatory activity for the protection of health and safety, and the environment and natural resources. These principles include, *inter alia*:

- Sound scientific information and its evaluation must be the basis for applying precaution; the scientific information base and responsibility for producing it may shift as knowledge evolves;
- Mechanisms should exist for re-evaluating the basis for decisions and for providing a transparent process for further consideration;
- A high degree of transparency, clear accountability and meaningful public involvement are appropriate; and
- Precautionary measures should be non-discriminatory and consistent with measures taken in similar circumstances.

Beneath this modern, somewhat academic view of precaution lies a much more pragmatic one, based in the reality that people and communities have been making trade-offs based on various levels of precaution every day for millennia. Culturally, in the NSB, this is well articulated by six Haida Nation ethical principles for marine planning (Jones et al., 2010). Such ethics are mirrored by the First Nations on the Central Coast (Cripps et al., 2008), and include values such as respect, balance, interconnectivity, and responsibility to future generations. The modernized concepts of precaution, and its key objective sustainability, are deeply embedded in this cultural view. From this perspective, sustainable resource use is paramount. Thus, Jones et al. (2010) noted that this may be at odds with the dominant paradigm focused on objectives related to economic development. For the NSB MPA process, the emerging guidance is related to the trade-off aspect of the precautionary principle, and implies a shift away from the human value of goods and services towards ensuring ecological integrity and sustainability.

With reference to the description of this Canada-BC Principle, we note that while it does reference scientific uncertainty, it does not discuss addressing this uncertainty. Rather, it only says that scientific uncertainty shall not be used as a reason for postponing establishment of MPA networks. This opens two avenues of investigation: (i) how to implement MPA networks in the face of scientific uncertainty, and (ii) how to reduce this uncertainty. In terms of moving forward, the first should be seen as having primacy over the second.

Relevant to addressing uncertainty, DFO has begun to develop a modified form of an *ecological risk assessment framework* to support the identification of risks and threats to VECs in the PNCIMA region (DFO, 2012c, 2014; O et al., 2012). Although this work is limited to identifying and quantifying (when possible) risks associated with human activities and their potential effects on critical ecosystem components, it nevertheless provides an indication of the level of risk to which various ecosystem features may be exposed. Clearly, this and other approaches to filling knowledge gaps and reducing uncertainty are desirable. However, this Principle requires action in the face of uncertainty, and in that regard there is little quantitative guidance.

Unsurprisingly, existing guidance on applying precaution in the presence of uncertainty includes building in redundancies and buffers to serve as insurance against uncertainties, and requiring enhanced monitoring to support adaptive management (Foley et al., 2010). More broadly, the problem of making decisions under uncertainty has generated considerable literature spanning risk analysis, decision making and management science. Much of this literature is devoted to the application of robust (i.e., precautionary) strategies (e.g., *satisficing*, and maintaining options) which are considered preferable to optimum strategies when uncertainty is deep and a wide range of alternatives are available (Lempert & Collins, 2007). Scenario construction is the main approach to ensuring the range of possible outcomes are considered, including things we don't know we don't know (e.g., Schoemaker, 1995).

Pitfalls to be avoided

An ecologically robust and resilient MPA network will require difficult trade-offs to be made in the absence of a fully quantified benefit-cost analysis. Thus, the most likely pitfall concerns striking a balance between using best available evidence and precaution. In practice, under pressure from various interests, it is tempting to decide that the best available evidence is insufficient to make a decision. This is contrary to the precautionary approach, under which the default option should be to protect a place if there is reasonable cause to believe that harm could ensue. Therefore, decision-making rules and guidance concerning how such a balance can be struck should be established at the outset of a process, including any minimum standards for establishing unacceptable risk. This requires a clear statement of values and objectives.

The precautionary approach should not be watered down to only "be careful", which suggests that human activities can proceed, if done carefully. In some cases, such as container shipping traffic, this may be so but in others (e.g., oil tanker traffic), the consequences of possible environmental harm could preclude such activities, no matter how "carefully" executed. This emphasizes the consequence component of any risk analysis, and particular values may, in fact, negate the need for more detailed study. Regarding the establishment of MPAs, the precautionary approach should not be misconstrued to mean that they cannot be designated without ample evidence of their utility.

The *evidence-based approach* and the calculation of cumulative effects are seen as risk-based responses to the precautionary approach. Epistemologically, however, this is the obverse of the PA; that is, two sides of the same coin, and both are required in good decision-making. Risk-based approaches can be used when information is available, and the precautionary approach will structure management responses when some information is missing. A lack of information about the likelihood or magnitude of consequences does not mean there are none; rather, under the precautionary approach a potential for significant consequences should trigger particularly restrictive management measures for the causal activities to safeguard against the possibility of irreversible harm. Thus, the precautionary approach should be seen as an incentive to gather more and better information so that better risk-based decisions can be made. Fundamentally, the precautionary approach suggests that decisions concerning MPA networks err on the side of minimizing significant harm to the environment, even though it comes with economic costs.

> *"While managing what we do not know may at first glance appear to be a contradiction in terms, it is actually the normal state of affairs for many human enterprises. For example, economists and financial planners would rarely claim full understanding of how financial markets operate or predict with complete certainty how they will perform in the future. Nonetheless, even with an imperfect understanding of the behaviours of these markets, a good financial planner can provide clients with suggestions that will likely produce a solid financial portfolio. Similarly, good integrated oceans governance should be able to use a variety of techniques that, while not guaranteeing success, would certainly improve its likelihood."*(IUCN, 2006, p.8)

Key Recommendations

1. Avoid making irreversible decisions that could lead to substantive or irreversible harm to the environment (species and habitats).

Commentary: Precaution relates to decision-making under deep uncertainty. The application of the precautionary principle is fundamentally about trade-offs. It is distinctive within science-based risk management and is characterized by a risk of serious or irreversible harm, the need for a decision, and a lack of full scientific certainty. Ultimately, the degree of precaution is a reflection of societal values.

2. Identify critical knowledge gaps so the appropriate decision-making strategies can be applied, and research can be applied in filling these gaps.

Commentary: The Achilles heel of all planning is the quality of data, and nowhere is this more so than in the hard-to-access marine environment. However, data gaps should not be used as a reason to delay critical decisions. Data gaps can lead to unforeseen problems, and should be filled as soon as possible. In situations of high variability (such as climate change) combined with dated or very general data sets, care must be taken to not read too much into the information available, but instead to craft resilient options that follow the available data in a general fashion, while accounting for the possibility of unanticipated changes.

3. More precaution will be required in the face of more significant knowledge gaps. Build in safety factors (e.g., buffer zones) in calculations of MPA network design and the management of human activities within, and outside of, the network.
4. While some MPAs should be seen to improve human well-being, not all of them need have this objective. Some should be established solely for reasons of ecological precaution.

Commentary: The NSB MPA Network can be seen as natural capital growing "in the bank" and also as an insurance policy in case of undesired and unanticipated events, allowing for broader ecosystem recovery. In this latter sense, not all MPAs in the network need demonstrate that they are improving human well-being, through fisheries etc.; rather, they need only demonstrate that they are successfully maintaining ecological "seed stock" should events go wrong.

5. Given that a key pitfall involves achieving an acceptable balance between using best available evidence and precaution, an attempt should be made to develop agreed minimum standards for acceptable risk at the start of the MPA process.
6. Treat the MPA Network Design Principles as a package, which as a whole contain several elements of the precautionary approach. Do not restrict implementation to a subset of Principles.

Commentary: The Canada-BC Principles capture most of the salient aspects of the precautionary approach. However, their effectiveness would be greatly reduced if some were not implemented, leading to increased risk of potentially irreversible consequences.

Additional Recommendations

7. Incentivize data collection to clarify the likelihood and magnitude of poorly documented impacts and activities.
8. Recognizing that scientific budgets are greatly curtailed, other funding sources (including all levels of government, non-governmental organizations, and industry) for scientific research to fill knowledge gaps should be considered.

Commentary: All levels of government, including First Nations, as well as industry and non-governmental bodies should be encouraged to support research to fill in gaps that would better allow for a full and proper assessment of industrial proposals. Industry-funded research would be most credible if management, including the awarding of contracts, were through an arms-length independent body, and data made fully available.

9. Avoid 'over-fitting' data and instead 'keep it simple' in calculations of MPA network design and the management of human activities within, and outside of, the network.

Commentary: Unless data span the range of temporal (e.g., seasonal, inter-annual) and spatial variability, over-fitting can lead to over-generalizing the results, putting unique or rare places at risk. Ensure that the inherent, natural variability in the NSB is accommodated.

10. Continue to develop and use the methods underway by DFO regarding an ecological risk assessment framework (O et al., 2012) and the guidance provided in *A Framework for the Application of Precaution in Science-Based Decision Making About Risk,* by the Government of Canada (2003).

IUCN's analogy of managing natural capital like financial capital

In a paper submitted to a United Nations working group, the IUCN (2006) compares MPA network planning in the face of incomplete knowledge to that of planning a robust financial portfolio in the face of market uncertainties, and suggests seven practical steps, several of which overlap with the Canada-BC Principles discussed above, to build ecological resilience. They are abridged here with more space given to the novel concepts:

1. **Protect good examples of representative habitats:** In financial planning, a portfolio should be spread out across various sectors, with good (or outstanding) examples from each.
2. **Ensure that duplicate examples of all major habitat types are protected:** Just as in a financial portfolio, where one should ideally invest in more than one representative company from each major sector.
3. **Apply varying degrees of protection, from fully protected reserves through to limited openings for high-risk activities:** In financial planning, a strong portfolio is made of investments with varied degrees of risk, usually with more low risk investments and fewer high risk investments.
4. **Use adaptive management:** In financial management, this means monitoring how well your investments are doing, comparing these to certain overall market indices, and buying and/or selling as appropriate. In ecosystem-based management, this is about monitoring MPAs, setting up indicators of various aspects of ecosystem health, both within and outside of the network, and making adjustments to the MPAs as necessary.
5. **Recognize intangible values:** In modern economics, many intangible values are being recognized and incorporated into overall economic assessments; for example, standards for Emotional Leadership and Intellectual Capital. For MPA networks, this could include spiritual, cultural, recreational, and scientific values. The reasoning is that while it may not be clear exactly how these support a healthy economy (or ecosystem), it is recognized that they play their role.
6. **Maintain capital**: In financial planning, this translates to not spending all your profits, even during bull markets, and instead re-investing a portion for a "rainy day" just in case something unexpected happens. In ecosystem-based management, this means moving away from narrow maximum yield

management approaches (e.g., fishing heavily in years of abundance), and setting aside a proportion of your capital. This reserved capital (e.g., in the form of well-protected MPAs) is then available to rebuild losses in the event of a mishap.

7. **Take out adequate insurance:** The previous six principles have generally compared MPAs to investments. However, MPAs should also be viewed as insurance. This duality of roles has caused confusion in the past, with users expecting to see "profits" when the MPAs were in fact set up as safety nets. In financial planning, there are a variety of insurance policies, covering accidents, illnesses, and even "Acts of God", recognizing that uncertainties exist in the world. In an uncertain world, the user pays this price, not expecting a profit, knowing that the additional security is a worthwhile investment in the long run.

V. Summary of Key Recommendations

Table 2: Summary of Key Recommendations. This table draws on the main body of this report, as well as Appendix 1 and Appendix 2 to summarize key recommendations and their rationale. Further explanation and additional recommendations are provided above in the body of the report. For brevity, references have been omitted unless necessary for clarity. Full references are provided in the reference section, at the end of this report, and in Appendix 2.

Canada-BC MPA Network Design Principle	Guideline(s) for applying design principle (from literature)	Specific recommendations for applying design principle in the Northern Shelf Bioregion	Rationale
1. Include the full range of biodiversity present in Pacific Canada (representation and replication)	BC has already developed a broad classification of "eco-regions" and "eco-sections" sub-dividing the NSB. Both the federal and provincial governments have developed methods for sub-dividing large regions into sub-regions.	1. Sub-regions: Divide the Northern Shelf Bioregion into sub-regions that reflect the network's ecological objectives, while taking into account management and logistical realities.	As recommended by DFO (2009a), sub-divisions of Canadian Bioregions, including the NSB, should be based on both physical and biological considerations, and should be of approximately similar scale. Previous classification systems, analyses, and planning processes have generally treated Haida Gwaii (Queen Charlotte Islands), the North Coast, and Central Coast separately. First Nation delineations also highlight these different sub-regions (apropos Principle 11) which should be considered to further characterize and guide planning within the NSB. Historical differences in data collection and analysis also suggest it may be analytically expedient to separate the three sub-regions to avoid issues related to different survey methods, different contractors, and sample bias. Regardless of how sub-regions are defined, the recommendations in this report would clearly still apply to all sub-regions.
	Because it is logistically difficult and expensive to	2. In order to track progress in the protection of the full range of	It is outside of this contract to suggest representative species and habitats for the NSB. However, there has

	survey diverse marine habitats and biota at high resolution (e.g., 1:5000) over large spatial extents (e.g., a bioregion), bio-physical classifications are commonly used. Bio-physical classifications use environmental variables to approximate known habitats or species distributions, calibrated using biological observations when available. Unique or unusual features can be captured separately, often through the use of local and expert knowledge, and can be located within an otherwise representative habitat (see EBSAs, below). Three or more examples are commonly recommended (e.g., in the UK and California; Appendix 1). Determining representativity targets	biodiversity, lists of "representative" (indicative) species and habitats for the NSB will need to be developed.	already been a lot of good work done on this topic in the region. We recommend reviewing the species and habitats used by the LRMP, CIT, PNCIMA, BCMCA, and MaPP processes and compiling this previous work for consideration in the NSB. We note that these processes have listed few fully marine species (fishes and invertebrates), focussing instead on the available data for anadromous species (e.g., salmon, eulachon), and seabirds. Therefore, additional fully marine species may need to be added to existing lists, where data permit.
		3. Classifications: Use credible species-habitat classification systems where they exist. More than one can be applied in the same (sub-) region to highlight different aspects of biodiversity, but those that have been verified with biological data or local knowledge should be prioritized.	Each classification will bring strengths as well as "blind spots"; hence using a variety of classifications can provide for a more comprehensive view of representativity than using any single system alone. However, much hinges on data quality, and those systems that use field validated data should be prioritized.
		4. Replication: Replicate feature types and classification classes 3-5 times in each sub-region where they occur.	Replication assumes a minimum of two examples (of ecologically sufficient size) of each representative feature in a given bio-geographic region (where the features exist). Ensuring more than two examples is a self-evidently better practice, all other things being equal, and consistent with the precautionary approach (Principle 16). Because the characteristic habitats of the NSB vary much more widely in size than those in many other regions, we have added some further considerations in Additional Recommendations 7-11 (above).

	for individual habitat types is addressed in a wide variety of ways in practice. In the UK, for example, species-area curves were approximated, which led to targets of 11-42% per habitat type. Often expert opinion is used. Earlier studies often set across-the-board targets (e.g., 20% or 30%), which we argue against in the main body of the report. As pointed out in the OSPAR Commission's background report on MPA network design (2007), a variety of network sizes generally ranging from 10% to 50% have been suggested as being effective as a conservation and fisheries management tool. Recommendations falling in the range of 20%-40% overall protection are typical. In practice, this is not often achieved, but there are some notable exceptions,	5. Targets: Targets for features should vary according to the commonness / rarity of the feature and the threats it faces, and could range widely from < 5% to 100%.	Some features will need more, or less, percentage protection than others. This is particularly relevant when considering representation of species at risk, where targets may have to include 100% (or nearly so) of the species' habitat. Appropriate protection of representative features will require considering distribution, rarity versus commonness, and the pressures it faces.
		6. The minimum recommended footprint of the NSB MPA network is 20% of the planning region. Footprints across sub-regions should be approximately the same.	We view 20% as an ecologically meaningful minimum, chosen for the NSB due to the relatively healthy ecosystems compared to other places globally. On the other hand, Burt et al. (2014) in their recent study of BC's Central Coast suggest 30% overall coverage, a value echoed by the recent World Parks Congress declaration. Therefore, this recommendation may be too low. It is worth recalling that discussions for the CBD's Aichi Target 11 began with scientifically suggested values exceeding 20%. Subsequent political negotiations reduced this value to (at least) 10%, mainly because less than 2% of the global marine environment had been protected at that time. The lower marine target of 10% versus 17% for land cannot be said to be scientifically based. Rather, it reflects the weaker state of marine conservation at the time it was negotiated. Meeting this CBD target does not preclude using a variety of targets for individual species and habitats, nor does it preclude aiming higher in the NSB, using a target that better reflects the scientific literature.

	such as Great Barrier Reef, which set a minimum threshold of 20% no-take for each representative habitat, and of which overall about 33% is now fully protected.		
2. ***Ensure ecologically or biologically significant areas (EBSAs) are incorporated***	Identifying important areas complements the representativity approach, above. The DFO EBSA process in Pacific Canada was initiated in 2006 when Clarke and Jamieson (2006a, 2006b) surveyed regional experts for the identification of important areas for 40 species in the PNCIMA region, from which a total of 15 EBSAs (one of them multi-part) were recommended. The Canadian Scientific Advisory process while recommending these sites be recognized, highlighted several issues, and recommended future revisions based on more	1. The existing NSB EBSAs identified by DFO should each be reviewed by scientific and local experts for inclusion in the MPA network based on the network objectives. Decisions (for or against) and rationale thereof should be documented and attributed.	While selecting existing EBSAs for their possible inclusion in the NSB MPA network is beyond the scope of this report, we do suggest there be a transparent and accountable process by which they can be assessed.
		2. Other designations, such as *Valued Ecosystem Components* (DFO) and *Valued Marine Environments and Features* (Province of BC) should also be used to inform the selection of MPA sites. 3. Identification (or estimation) of species and habitats not covered by existing designations is recommended, with particular consideration given to: a) spawning, breeding, nursery, rearing, foraging migration, and seasonal refugia; b) intertidal, shallow nearshore,	Because the Pacific EBSA identification was one of the first in Canada, it has many features of learning by doing (note the caveats discussed in DFO, 2013b). In this light, the NSB represents an opportunity to review and refine these EBSAs for possible inclusion in the MPA network, perhaps in a modified fashion. Very large EBSAs, while unlikely to become MPAs in their entirety, may have portions which are appropriate for that purpose. Further, with the benefit of hindsight, other areas previously not considered could also be included in the NSB process.

	quantitative methods. In later work, Jamieson and Levesque (2014) modified three of the previously identified EBSAs in the PNCIMA region, as well as adding two more, with a general focus on the nearshore not considered in the first exercise. Clark et al. (2014) illustrate how thousands of features can be sorted through to identify possible EBSAs. Systematic approaches taken to protect *vulnerable marine ecosystems* (VMEs) are also largely applicable to EBSAs (c.f. Ardron et al., 2014).	and deep offshore habitats and processes. These newly identified areas should also be reviewed for possible inclusion (or parts thereof) in the MPA network, based on the network objectives. 4. To facilitate management considerations, sub-divide large identified areas into smaller sub-units based on the network objectives.	
		5. Identified areas not included in the final MPA network should not be forgotten, but instead be listed as part of the description of the NSB's recognized ecologically valuable places.	Places not selected as MPAs can nonetheless be held as 'understudies' should there arise issues with selected sites. In any case, these ecologically important places will likely require enhanced management measures.
		6. Use of local and traditional knowledge in the identification of EBSAS and EBSA-like areas is recommended.	As EBSAs are meant to capture exceptional biological or ecological areas, local knowledge can go far in identifying such places that are often well-known by those who live and work on the sea. Previous EBSA assessments in BC have relied exclusively on scientific expert knowledge, however we believe that local and traditional expertise could bring to light additional places.

3. Ensure ecological linkages (connectivity and spacing)	Connectivity is perhaps the least addressed Principle in practice. When addressed, it is through rules for site spacing, which are broad and variable. In the case studies in Appendix 1, 50–100 km (x2); 40–80 km, and < 200 km were used. In the Baltic, that has smaller MPAs, 25 km spacing was recommended. Commonly, 25–100 km is suggested, with closer spacing generally reflecting smaller more confined planning areas. Groups of extremely large MPAs, such as Pacific Remote Islands Marine National Monument, have no spacing requirements. Spacing calculations in previous processes internationally were sometimes associated	1. The spacing and configuration of an MPA network should reflect the ecological objectives of that network, such that sites for species' life history stages and habitats of particular interest are close enough to conceivably be ecologically connected.	While this first recommendation may appear self-evident, there are currently very few representative MPA networks that take target species and habitats into account when considering the spacing of sites. A network designed to protect only particular species or habitats will be narrowly focussed with sites chosen to specifically meet those objectives. However, a representative network, in capturing a range of habitat types, can lose sight of the ecological coherence of species of particular concern. For the recommendations that follow, it is suggested that the NSB MPA network should be designed to capture a wide range of the NSB's biodiversity (per Principle 1), while still containing ecologically connected "clusters" relevant for species and habitats of particular concern in the NSB.
		2. In general, a representative MPA network should be visibly well distributed, alongshore and offshore.	This is adapted from the first (of 3) initial tests for ecological coherence in the northeast Atlantic used by the OSPAR Commission (2008). When looking on a map, there should be no (or few) visual gaps.
		3. MPA size and spacing should reflect the predominant geography, oceanography, and scale of the local ecosystem into which sites are placed.	In practice, large MPAs will tend to be offshore and further apart (e.g., Great Barrier Reef), whereas smaller MPAs are more likely to be inshore and more closely spaced (e.g., in the Baltic Sea –the whole of which is about the same size as the GBR). To date, however, no single rule of thumb captured this variability.[26] The simple formula (next Recommendation) is our attempt to do so.

[26] However, OSPAR (2008) set up different guidelines for inshore, offshore, and high seas areas.

	with alongshore connectivity; e.g., the Californian 50–100 km rule was implicitly alongshore, since the planning area extended only 5.6 km (3 NM) offshore.	4. Generic MPA spacing should not exceed nine times the square-root of the average size of the neighbouring MPAs; i.e., **MPA Spacing ≤ 9·((Area$_1$ + Area$_2$)/2)$^{0.5}$** a. This formula can also be used in reverse.[27] That is, if site locations were already decided upon, then their minimum sizes could be calculated based on their separation. However, other considerations apart from spacing should also go into size calculations, as discussed under the next Principle. [Additional sub-sections to this recommendation are in the main body of the report.]	The NSB is a much more complicated than most planning regions, where scales of features and processes vary considerably and in-offshore ecological connectivity can be significant. Therefore, a more sophisticated approach is required. Large MPAs will produce more adults, juveniles, and larvae than smaller ones, and therefore can be spaced further apart, assuming some intermediate survival between sites. The generic formula captures both the range of spacing commonly identified in the literature and the range of MPA sizes, and links the two together in a simple way that generally captures values recommended in practice. The constant (9) can be seen as an indicator of precaution, whereby a lower value would indicate greater precaution. It should be re-visited as more data specific to the characteristics of connectivity within the NSB become available. Results from this rule of thumb should be treated as a minimum requirement, not a target.
		5. Same or similar habitats in close proximity to one another (e.g., rocky reefs and islets < 5 km apart) are likely to be a single ecological system, and if protected, should be treated either as a single larger MPA or as a cluster of ecologically connected MPAs.	In cases when specific habitats and species are under consideration, generic spacing per #3, above, should be of secondary concern, with known ecological linkages taking precedence when determining site locations. In some cases (e.g., bird nesting and feeding areas for some long ranging species) the spacing between ecologically connected sites could be much further apart than the generic formula would indicate. (In other cases, it might be closer together.)

[27] That is, the square-root of the average area of the two neighbouring MPAs should be greater or equal to the spacing divided by 9.

		6. When known, the spatial distribution of species' life history stages, including the movement of adults (foraging and feeding, breeding, migratory behaviours) should be considered, to be protected as an ecologically connected MPA cluster.	
5. Ensure maximum contribution of individual MPAs (size, shape)	Size of MPAs is generally recommended to err on the side of bigger (> 100 km^2) rather than smaller (Edgar et al., 2014). In Great Barrier Reef, for example, MPAs in their shortest dimension could not be less than 20 km, which for a hypothetical circular MPA would mean an absolute minimum of 314 km^2. In CA, they should cover 5-10 km coastline (preferably 10–20 km), and should extend from intertidal to deeper waters (which could be about 5 km or so, offshore), meaning the overall minimum area	1. MPA shape should attempt to capture the locally dominant ecological processes and features, in accordance with the MPA network objectives.	Protecting one feature in its entirety is ecologically more parsimonious than protecting two (or more) features partially, wherein 'leakage' will be greater and ecological effectiveness reduced. Notwithstanding the value of compact sites (#7, below), there are instances when sites may break that guidance when capturing a feature in its entirety; for example, rocky reefs or a cluster of reefs, rocks, and small islets; or, estuaries, shoreline features, ridges, troughs and canyons. Pelagic processes such as upwellings or fronts should be reflected in the orientation of the MPA; e.g., along a front, or around an upwelling / gyre.
		2. An uncertainty factor should be included as part of an MPA's overall shape and size calculation.	"Uncertainty factor" in this recommendation should be interpreted to be part of an MPA, rather than a separate spatial designation. Including spatial uncertainty is considered good practice here because it can address several issues in a straight-forward way, including *inter alia*: data uncertainty, variability of species distributions, protecting species that "wander over the line", protecting species and habitats from extractive users who wander over the line, simplification of boundary for enforcement

	could range generally from 50-100 km^2. In their guidance, 23-47 km^2 was considered the bare minimum, with 47-93 km^2 being preferable. In New Zealand, the alongshore minimums are the same as CA, but the length from shore can extend out to 12 NM (~22 km) or more, thereby pushing the distribution of MPA sizes upwards considerably. For the UK, the minimum dimension is 5 km, suggesting a circular minimum of about 20 km^2. They also specified minimum patch sizes for special habitats of $1/100^{th}$ that value; i.e., about 20 hectares. In all cases, authors have emphasized that these minimum sizes are not targets, but rather minimum thresholds, and that the MPA network should include mostly		reasons, and ecological edge effects more generally.
		3. The NSB network should contain MPAs across a broad range of sizes.	The NSB region is more geographically complex than most other regions studied in the literature; therefore some added complexity in the guidance of placing sites within this physically complex region is warranted. The 5-150 km^2 MPA minimum size guideline is necessarily broad to capture the diversity of the NSB, and should be considered alongside the subsequent guidelines that clarify appropriate usage. The 5 km^2 end of the spectrum is much smaller than is commonly proposed in the literature, but we believe is appropriate for a small minority of places in the NSB. However, we stress that the majority of MPAs should be at least 50 km^2, which reflects existing good practices. When circumstances allow, sites should preferably be larger in the range of 100 km^2 or more to increase their prospects of success (Edgar et al., 2014). As noted in the foreword, correct implementation of these broad ranges of minimum values will hinge upon a conscientious and responsible interpretation of the guidance by the planning process participants.
		4. MPAs, at a minimum, should be 5 km^2 to 150 km^2 in size, depending on their location and conservation objectives, as follows: a) For the protection of waters surrounding small "point" features such as singular haul-outs, rubbing beaches, singular seabird colonies, seamounts or estuaries, or "skinny" features such as herring spawn beaches, or tightly constrained features such as parts of narrow inlets or small lagoons, minimum sizes at the lower end of the range (e.g., 5-50 km^2) may be appropriate. b) For the protection of moderately sized features such as most representative habitats as well as complexes of species use areas (e.g., waters surrounding clusters of bird colonies, haul-outs and foraging grounds, and areas of increased biodiversity), minimum sizes in the middle of the range (e.g., 50–100 km^2) are more appropriate than smaller sizes.	

	larger MPAs and habitat patches than these minimums might first suggest.	c) For the protection of larger features, especially offshore features, minimum sizes at the top end of range (e.g., 100–150 km^2) are most appropriate, and in some cases (e.g., for offshore pelagic features) could be significantly larger.	
		5. The majority (more than half) of MPAs should be at least 50 km^2.	
		6. MPA and protected habitat patch size should take into account anticipated management measures, such that ecological function is preserved: a) Under management that will allow some limited extractive activities (IUCN category IV), or otherwise negatively affect species or habitats, affected areas should generally be at least two times as large as outlined above; and b) Under management that will allow sustainable use (IUCN category VI), affected areas should generally be at least four times as large as outlined above.	This recommendation is based on the results of Ban et al. (2014). Recommendations 1−5 assume highly protected areas. To achieve the same conservation result, no-take areas can be considerably smaller than partially protected areas. Ban et al., recently quantified the differences through an extensive literature review. IUCN Category VI “protected areas with sustainable use of natural resources” had a predicted effectiveness score of 24% compared to 100% no-take reserves in the findings; i.e., about one quarter as effective. Category IV parks, which have greater protection (“habitat / species management areas”) had a predicted effectiveness score in the study of 60; i.e., just over half as effective. Until such a time when location-specific research is conducted in the NSB, we suggest the above distillation of international studies is a reasonable base from which to begin.

6. Recognize and consider the full range of uses, activities and values supported by marine environments (human activities, cultures and values, ecosystem goods and services, spatio-temporal intensity of human uses, costs of inaction)	All cases considered in the literature review recommended comprehensive and inclusive stakeholder engagement. However, in the five real-life processes considered in greater detail (summarized in Appendix 1), none had outcomes that pleased all stakeholders, with some processes facing considerable, and at times acrimonious, opposition. There are several examples where MPA economics and social aspects have not been considered, leading to failure of the MPA process (e.g., Christie et al., 2004; Bunce et al., 2010; Bennett & Dearden, 2014). The social and cultural context of coastal communities worldwide differs widely. What is applicable in one locale	*This Principle should go hand-in-hand with Principle 10 (Work with people) and Principle 11 (Respect First Nations' treaties, title, rights, aspirations and world-view).*	
		1. Before collecting data on the range of uses, activities and values in the NSB, first ensure there is a shared understanding of the planning process, its objectives, and management options.	Gaining agreement on a shared understanding helps set a positive tone early on in a planning process. It allows participants to express their perspectives in a constructive environment. A shared understanding (and ideally agreement) can help all participants to re-focus later on if discussions become heated. Again, we emphasize that the NSB is not a blank slate, and would encourage a review of visions, goals, and objectives from earlier planning processes, which could save significant time and effort. If stakeholders know how their information will be used, and what management options are under consideration, they will be more inclined to participate in a data-gathering exercise. Working collaboratively on finalising the draft NSB MPA Network Objectives can help achieve this recommendation.
		2. Incorporate traditional, local, and stakeholder knowledge concerning usage of the marine and nearshore environment of the NSB to produce fine resolution spatial datasets (location, relative importance, and intensity) of: a. human commercial and recreational activities, b. culturally and historically significant areas, and c. spiritual sites.	This recommendation is for nearshore and marine usage only. Terrestrial sites of concern, such as burial sites, are not included. However, adjacent upland activities can at times affect MPA placement.
		3. Identify community-based	An ecologically effective and socially supported MPA

	may not be so elsewhere, even in relatively close proximity (e.g., Fabinyi et al., 2010; Voyer et al., 2015). This is true of the BC coast where there are some similarities, but also major differences between communities (e.g., Heck et al., 2012a) and these should be taken into account in deciding the most appropriate course of action for a given social, economic and cultural context (i.e., sub-regional setting). LeRoy et al. (2004) for example, discuss a case where there were different perspectives amongst First Nations communities regarding a protective designation on the BC coast resulting in conflict and a failed process.	conservation initiatives and integrate local knowledge for possible inclusion of these sites in the MPA network.	network in the NSB will require integrating both "top-down" and "bottom-up" approaches. Top-down planning has the advantage of seeing bigger picture regional requirements, whereas bottom-up initiatives have the advantage of possessing an intimate knowledge of a local portion of the region's waters. This recommendation should be seen as complementary to, and consistent with, Principle 14 (*Build on existing MPAs, other management tools and marine planning initiatives*).
		4. Incorporate non-market values into the MPA process, balancing these with conservation and economic concerns.	One of the most distinctive and important aspects of human use values of the BC coast is the intimate relationship between the marine environment and the First Nations peoples. These and other non-market community values can only be captured through working closely with First Nations, and other local communities. Such values are difficult to compare with more easily quantified ones; however, this should not preclude their consideration.
		5. As that MPA implementation may initially impact some local economic opportunities, identify opportunities for future and alternative uses both within proposed MPA sites and the surrounding region, and develop a displacement policy for those that are impacted by development of MPAs.	The society that sees the need to establish MPAs has some responsibility to ensure that livelihood changes are as positive as possible for those involved. Under certain circumstances, some jurisdictions, including both Australia and the United States, pay compensation to users for their loss of earnings due to fisheries and access restrictions in MPAs. Canada has not chosen to take this approach but should recognize the socio-economic and cultural implications of MPA establishment and provide support, financial or otherwise (such as capacity development) to affected communities to adjust to MPA network establishment.

		6. Use optimization (e.g., Marxan) and decision support tools (e.g., InVEST) to integrate ecological, social and economic considerations into marine spatial planning processes for MPA design.	Spatial planning tools, and good practices surrounding their usage, have matured to the point where they can now be seen as best practice when exploring ecological, social, and economic trade-offs, thus helping to maximize benefits and minimize harms (Principles 7 & 8).
16. Take a precautionary approach	Some guidance on implementing the precautionary approach in science-based decision making about risk has been established by the Government of Canada (2003), which should be used as a starting point in the implementation of this Principle. (See main body of report for more.) Currently, operationalization of the precautionary approach is often in the form of risk-management, such as environmental impact assessments, and strategic environmental assessments. As part of taking a precautionary and ecosystem-based	1. Avoid making irreversible decisions that could lead to substantive or irreversible harm to the environment (species and habitats).	Precaution relates to decision-making under deep uncertainty. The application of the precautionary principle is fundamentally about trade-offs. It is distinctive within science-based risk management and is characterized by a risk of serious or irreversible harm, the need for a decision, and a lack of full scientific certainty. Ultimately, the degree of precaution is a reflection of societal values.
		2. Identify critical knowledge gaps so the appropriate decision-making strategies can be applied, and research can be applied in filling these gaps.	The Achilles heel of all planning is the quality of data, and nowhere is this more so than in the hard-to-access marine environment. Data gaps can lead to unforeseen problems, and should be filled as soon as possible. However, data gaps should not be used as a reason to delay critical decisions. In situations of high variability (such as climate change) combined with dated or very general data sets, care must be taken to not read too much into the information available, but instead to craft resilient options that follow the available data in a general fashion, while accounting for the possibility of unanticipated changes.
		3. More precaution will be required in the face of more significant knowledge gaps. Build in safety factors (e.g.,	Part of applying the precautionary approach is to build in safety factors such that if certain critical assumptions turn out to be incorrect, there is sufficient robustness and redundancy in the managed

	approach, DFO has begun to apply a modified form of an *ecological risk assessment framework* to support the identification of risks and threats to valued ecosystem components (VECs) in the PNCIMA region (DFO, 2012c, 2014; O et al., in press). Initial results look promising.	buffer zones) in calculations of MPA network design and the management of human activities within, and outside of, the network.	system to cope. Replication, buffer zones, and set-aside areas are manifestations of this approach.
		4. While some MPAs should be seen to improve human well-being, not all of them need have this objective. Some should be established solely for reasons of ecological precaution.	The NSB MPA Network can be seen as natural capital growing "in the bank" and also as an insurance policy in case of undesired and unanticipated events, allowing for broader ecosystem recovery. In this latter sense, not all MPAs in the network need demonstrate that they are improving human well-being, through fisheries etc. Rather, they need only demonstrate that they are successfully maintaining ecological "seed stock" should events go wrong.
		5. Given that a key pitfall involves achieving an acceptable balance between using best available evidence and precaution, an attempt should be made to develop agreed minimum standards for acceptable risk at the start of the MPA process.	An ecologically robust and resilient MPA network will require that difficult precautionary decisions are made, despite a lack of full information. Perhaps the most common pitfall concerns striking a balance between using best available evidence and precaution. In practice, under pressure from various interests, it is tempting to decide that the best available evidence is insufficient to make a decision, which is contrary to the PA. Therefore, decision-making rules / guidance concerning how such a balance can be struck should be established at the outset of a process, including any minimum standards for scientific certainty.
		6. Treat the MPA Network Design Principles as a package, which as a whole contain several elements of the precautionary approach. Do not restrict implementation to a subset of Principles.	The Canada-BC Principles capture most of the salient aspects of the PA. However, their effectiveness would be greatly reduced if some were not implemented, leading to greater risks.

VI. Appendix 1: MPA design criteria compared across five planning processes

References and text distilled from Appendix 2 (literature review). Acronyms: CA = California; EEZ = exclusive economic zone; GBRMP = Great Barrier Reef Marine Park; GBRMPA = Great Barrier Reef Marine Park Authority; km = kilometres; MCZ = Marine Conservation Zone; MLPA = Marine Life Protection Act; NM = nautical miles.

	Australia GRBMP	**California Channel Islands**	**California MLPA**	**UK Marine Conservation Zones**	**New Zealand** (from case studies)
Scale & setting	The GBRMP is 60-250 km wide, 344,400 km^2 total area. Average depth is 35 m inshore, continental slopes extend to > 2 km. Original GBRMP zoning was established in 1975; a second assessment occurred from 1999 – 2004, resulting in significantly increased protection.	The Channel Islands National Marine Sanctuary is 4294 km^2 in area. The process was highly divisive and consensus was not reached. Eleven federal, state, and local agencies have some jurisdiction in the planning region. Planning: 1999 – 2003, establishment: 2003 – 2007.	Statewide system of MPAs within 14,374 km^2 of state waters along 1770 km coastline. The MLPA was enacted in 1999. Statewide processes in 2000 and 2002 were unsuccessful. The third attempt staged from 2004 – 2012 resulted in final MPA designation in all four regions.	English waters from Mean High Water to 200 NM (or neighbouring EEZ), and offshore waters around Wales. MPAs already existed, but MCZs aim to protect nationally important habitats and rare / threatened species / habitats, and to integrate various designations into an ecologically coherent network. 2009 – present.	Entire marine environment including estuaries, the Territorial Sea (within 12 NM of the coast and islands), and the EEZ (12-200 NM). MPAs Policy and Implementation Plan released in 2005 and work is underway.
Features	The world's largest coral reef ecosystem, protecting some 3000 coral reefs, 600 continental islands, 300 coral cays and about 150 inshore mangrove islands.	Temperate rocky reefs, intertidal zones, sandy or soft ocean bottoms, underwater pinnacles and topographic complexity, kelp forests, amongst offshore islands.	Five depth zones: intertidal, intertidal to 30 m, 30-100 m, 100-200 m, and > 200 m. Ten key habitat types: sand beach, rocky intertidal, estuary, shallow sand, deep sand, shallow rock, deep rock, kelp, shallow canyon, and deep canyon. (The science team unsuccessfully recommended mandatory	Features of Conservation Importance were identified for habitats, low or limited mobility species, and highly mobile species based on existing lists of rare, threatened and declining features. 23 Broad scale habitats were identified from the European classification system,	Hierarchical coastal classification system: biogeographic region (13) / Environment type (estuarine / marine) / depth (intertidal, 0-30 m, 30-200 m) / exposure (low, med, high) / physical habitat type (mud, sand, rock, etc.).

			habitat definitions to include ocean circulation features, principally upwelling centers, freshwater plumes from rivers, and larval retention areas.)	describing biogenic reefs and intertidal, littoral and subtidal rock and mixed sediment habitats characterized by high, medium, low energy. Also included geological and geomorphological features of interest which should be considered for protection.	
Representation	Whole features should be incorporated, without transecting or dissecting a feature. A minimum of 30% of each bioregion should be incorporated into an MPA network.	A simple multidimensional habitat classification was developed using depth, exposure, substrate type, dominant plant assemblages, and a variety of additional features as they occurred.	MPA networks should include "key" marine habitats (above), and each of these habitats should be represented in multiple MPAs across biogeographical regions, upwelling cells, and environmental and geographical gradients. MPAs should extend from the intertidal zone to deep waters offshore.	Examples for each of the 23 broad-scale habitats and each of the 22 habitats of conservation importance should be protected in each planning region, where they occur. Examples of each of the 29 low or limited mobility species of conservation importance, and the 3 highly mobile species for which MCZs are an appropriate tool, should be protected in each planning region where they occur.	All habitats are represented in the network. The appropriate habitat classification should match the spatial scale of the conservation planning efforts and ecosystem processes should be represented.

Targets	Represent at least 3 reefs and 20% of reef area and 20% of reef perimeter in each reef bioregion in no-take areas. Feature targets should be 10-50%. Targets less than 10% or higher than 50% will require strong justification. Some threatened or unique features may be as high as 100%.	Reserving 30% of all unique and representative habitat types to conserve populations of approximately 80% of species of concern. For analytical purposes, targets of 30%, 40%, and 50% of each of the ecological criteria (e.g., habitats and features) were trialled.	Guidelines for the state-wide MLPA planning effort did not specify a percentage of available habitat or area that should be included in MPAs.	Targets for overall amount of habitat included within a network of all MPA types were set between 10-40% coverage depending upon habitat. Protect a range of percentages specific to each habitat type and ecological function (minimum: 11%, maximum: 42%).	While 10% (based on CBD criteria) is recognized as the target set out in the Biodiversity Strategy, there is no explicit MPA Policy guideline providing a recommendation on the amount or proportion of area to be protected.
Replication	All features should be replicated across their unique geographic and biological range, with a minimum of 3 repetitions. For most bioregions, 3-4 no-take areas were recommended.	It was recommended that 1–4 reserves be designated within each of the 3 biogeographic regions, comprising 30–50% of the Sanctuary, multiplied by an insurance factor of 1.2-1.8 to require minimum protection of 36-54% of the planning region.	At least 3-5 replicates within a bioregion. MPAs that were of at least the minimum size and contained sufficient extent of a habitat to encompass 90% of associated biodiversity were considered a 'replicate'. Species-area relationships were derived for each habitat type through analysis of available monitoring data and areal percentages of minimum habitat coverage to be a replicate.	At least 2 examples of each broad-scale habitat type should be protected and spatially separated across each of the regional MPA planning areas. At least 3-5 examples of each feature of conservation importance should be protected where their distribution allows in each planning area.	There will usually be 2 replicate MPAs included in the network. However, where a habitat or ecosystem is particularly vulnerable to irreversible change, more replicates may be established. Several examples of each habitat should be included within separated MPAs. A precautionary number of replicates would be 3, with two replicates being the minimum.

Individual MPA size	MPAs should not be smaller than 20 km at their smallest dimension. Features should not be transected or dissected in any way, but include the full feature (per representativity, above).	Designate 2-3 reserves, each of 200-550 km^2, in the Oregonian Province. In other regions reserves may be larger or smaller, and more or less numerous.	MPAs should have alongshore span of 5-10 km coastline (preferably 10-20 km), and should extend from intertidal to deeper waters offshore (constrained by state jurisdiction). “Larger MPAs would be required to fully protect marine birds, mammals, and migratory fish.” (CDFG, 2008) Minimum MPA size range: 23-47 km^2. Preferred: 47-93 km^2.	For broad-scale habitats a 5 km minimum distance across and an average of 10-20 km. Individual habitat types are given minimum patch sizes ranging from 0.5 to > 10 km diameter, and in some cases recommending protection of the entire patch (e.g., those patches smaller than 5 km across).	MPAs should be large enough to cover the majority of species adult movement distances. MPAs should have a minimum coastline length of 5-10 km, preferably 10-20 km, and should extend along the depth gradient from intertidal to deeper offshore waters, preferably to the 12 NM limit.
Spacing	Reserve sites should be placed not more than the average larval dispersal distance for targeted species. If dispersal distance is unknown, reserves should be placed less than 200 km apart.	Broadly distribute the network of reserves throughout the planning region and vary reserve spacing.	MPAs should be placed within 50-100 km of each other.	Known species-specific dispersal distances or critical areas for life-cycles of listed species should be used to determine the spacing. MPAs of similar habitats should be separated, where possible, by no more than 40-80 km. MPAs should overall be spatially well distributed.	The spacing between MPAs should allow larval dispersal. MPAs, with similar habitats where possible, should be placed within 50-100 km of each other.

Public / stakeholder participation	GBRMPA enlisted extensive direct public and stakeholder consultation. Local Marine Advisory Committees, Reef Advisory Committees, and the Tourism and Recreation Reef Advisory Committee (TRRAC) also participated. A structural adjustment package provided $213.7 (Aus) million to 1,782 fishers, seafood processors and upstream providers.	An inclusive decision-making process was attempted, but failed to reach consensus. In the end, amid protests, CA Fish and Game Commission made a decision without full stakeholder support.	Two previous MLPA processes failed to reach their objectives. The third attempt sub-divided the coast into separate regional processes. Stakeholders were encouraged to work together to submit proposals. Final decisions based on these proposals were made by a seven person 'Blue Ribbon Task Force' made up of public leaders selected by the secretary of the California Natural Resources Agency.	The four regional MCZ processes in England & Wales each had broad stakeholder participation. Reaching consensus was achieved, but was hindered in part because the government was unwilling to commit to management measures before sites had been selected. A subsequent scientific review was critical that many sites lacked adequate evidence that an MPA was needed. However that review did not take into account the give-and-take nature of the stakeholder discussions that arrived at the agreed-upon sites.	The current MPA selection process appears to be government-led and science-driven, followed by public consultation, which is ongoing. (However, the outcome of an earlier process to establish offshore Benthic Protected Areas closed to fishing was largely based on fishing industry proposals.)

Management designations / restrictions	Preservation zones (No entry), Marine National Park Zones (No take, some traditional use), Scientific Research Zones (No take, some traditional use), Buffer Zones (Trolling only), Conservation Park Zones (restricted fishing), Habitat Protection Zones (no trawling), General Use Zones, Commonwealth Island Zones (no take, some low impact activities).	State Marine Conservation Area, State Marine Reserve, Federal Marine Conservation Area, Federal State Marine Reserve.	State Marine Conservation Area, State Marine Park, State Marine Reserve, State Marine Recreational Management Area, Special Closure.	MCZs can have any combination of restrictions. 'Reference Area MCZs' are highly protected areas with no extraction, deposition or disturbance. Each of the 22 habitats of conservation importance and each species of conservation importance and broad-scale habitat should have at least one viable reference area, within each planning region. However, none have been designated to date.	Type I MPAs are no-take zones and Type II MPAs are other management tools that meet the protection standard (e.g., prohibit bottom trawling, Danish seining, dredging).

Outcome	In 2004, the proportion of the GBRMP protected by 'no-take' zones was increased from < 5% to > 33%, and now protects representative and replicated examples of each of the broad habitat types. The average size of a no-take area increased 5 times to 700 km^2 and the overall network now contains a minimum amount of each bioregion: reef bioregion percentages range from 20-47% and non-reef bioregion percentages range from 20% to > 90%. A majority of the fishing-related stakeholders felt strongly that the compensation package failed to adequately address impacts of the Zoning Plan, and thus failed to meet their needs.	Process ran from 1999–2003. Ten no-take marine reserves and two partially protected MPAs covering a total of 12% of state waters in the planning region were established in law. These reserves were augmented in federal waters and contributed to the MLPA Initiative that immediately followed. There was at the time considerable acrimony with some fishermen.	The network includes 124 MPAs protecting 16% of state waters. Of these MPAs, 61 are designated as no-take, covering 9.4% of state waters. A further 17 (2.7%) allow extraction of some marine resources, but still offer a high level of ecosystem protection sufficient to contribute toward the ecological goals of the MLPA. The remaining 46 MPAs in the statewide network (~4%) offer less protection to ecosystems and are unlikely to contribute substantially to the ecological goals of the MLPA. However, these contribute to the other goals (e.g., recreation). All sub-regions in CA experienced some level of stakeholder (generally fishermen) dissatisfaction. In some, fishermen lodged legal appeals.	The UK MCZ process is not yet complete. After designation, the levels of protection associated with each MCZ will be determined. Final stakeholder recommendations for 127 MCZs and 65 Reference Areas (some RAs occurred entirely within MCZs) were submitted in 2011. The UK Government declared that it would designate MCZs in a series of 'tranches', with the first 28 MCZs now designated, although none of these are highly protected Reference Areas. A second tranche will be consulted on in early 2015. There has been disillusionment of process participants because, in part, most of their 127 recommended sites were not taken up after the ambitious £8 M consultation process.	Ongoing. In the South Island West Coast –four NTZs (protecting 1.3% of the Territorial Sea) and two MPAs (0.7% of the Territorial Sea) are recommended. In the Sub-Antarctic Islands – 3 NTZs were recommended protecting 39% of the Territorial Sea around Campbell Island, 58 % of the Territorial Sea around the Bounty Islands and all of the Territorial Sea around the Antipodes Islands. (The earlier Benthic Protected Area process was criticized by environmental groups and some scientists for protecting areas that were mostly deeper than current bottom fishing activities.)

Key references	Beaver & Llewellyn, 2009; Fernandes et al., 2009; UQ, 2009; Kirkman, 2013; Thomas & Shears, 2013; Gunn et al., 2010.	Airame, 2003; Thomas & Shears, 2013.	CDFG, 2008; Saarman et al., 2013; Thomas & Shears, 2013. Example legal appeal: http://www.savecafishing.org/mlpa-news/.	Hiscock & Breckels, 2007; Natural England & JNCC, 2010; Thomas & Shears, 2013. Lieberknecht et al., 2013; JNCC web site: http://jncc.defra.gov.uk/mczmap.	Thomas & Shears, 2013; Penney & Guinotte, 2013.

VII. **Appendix 2: Literature review** (separate document).

Due to its large size, Appendix 2 is a separate document.

VIII. Appendix 3: The Sidney Consensus.

Marine Ecosystem-Based Management Principles

The principles governing effective implementation of marine ecosystem-based management (EBM) in British Columbia, Canada, are listed below and followed by supporting elaborations of concepts. *The Sidney Consensus* was developed collaboratively by Marine EBM Gaps workshop participants representing academia, federal government, First Nations, industry, non-governmental organizations, and the provincial government.[*]

Principles: EBM[1] recognizes that human activities occur in the **context** of nested and interconnected social and ecological systems[2] (including those in/on air, land, and water) that are:

- complex,[3]
- evolving,[4] and
- dynamic.[5]

The **purpose** of marine EBM is to ensure that the individual, interactive, and cumulative effects of human activities on ecological systems do not preclude multi-generational sustainable use of ecosystem products and services.[6] This is accomplished by:

- directing and regulating human activities and actions (including consumptive, restorative, mitigative, enhancing, destructive, disruptive, etc.) towards long-term goals of maintaining/enhancing ecosystem
  - resilience,[7] and
  - structural and functional integrity;[8] and
- supporting human activities that lead to
  - sustainable human communities and economies,[9]
  - sustainable ecosystem service provision,[10] and
  - fairness in the distribution of benefits and costs within and across generations, locally and globally.[11]

It therefore follows that the **process** of marine EBM:

- is integrative and place-based in concurrently managing a broad set of human activities, based on their interactions within social-ecological systems[12] (rather than separately managing activities by economic sector);
- incorporates the best available science and traditional/inter-generational knowledge,[13] and monitors against stated objectives that are
  - precautionary,[14]
  - systematic,[15]
  - adaptive,[16] and
  - proactive and pragmatic;[17] and
- is fair, striving for meaningful inclusion of all groups in a process that is
  - collaborative and participatory, and
  - recognises and respects aboriginal rights and title.[18]

*Draft principles (http://pacmara.org/ebm_dialogue) were refined by: Jon Chamberlain, BC Ministry of Agriculture and Lands; Kai Chan, University of British Columbia; Heather Coleman, PacMARA; Steve Diggon, Coastal First Nations; Dan Edwards, Area A Crab Association; Kim Houston, Fisheries and Oceans Canada; Michelle Molnar and Bill Wareham, David Suzuki Foundation. Please cite as: Chamberlain, et al. 2010. The Sidney Consensus: Marine EBM Principles. PacMARA Working Group. http://pacmara.org

Supporting Elaborations

1. EBM is an ecosystem approach to management that considers connections between people and ecosystems, as well as connections among ecosystem components. EBM is place-based (see #12), but must recognize that it may have an impact on a much broader spatial and temporal scale.
2. Most resources cannot be effectively or reliably managed individually because they are connected to other resources within the same ecosystem, and to other ecosystems and social systems (such as economic, legal, and political, systems).
3. Understanding ecosystem and human interactions in the context of coupled social-ecological systems implies recognizing that there will be frequent cases of multiple causality and indirect effects that cross spatial and temporal scales in complex ways: one phenomenon may have multiple causes (both social and ecological), and it may result in numerous unintended side-effects (again, both social and ecological).
4. Cause and effect relationships do not follow simple or straightforward pathways. Interactions among and between species and social-ecological subsystems are often non-linear (outputs are not directly proportional to inputs) and operate at and across multiple scales, such that patterns at any scale are a product of processes operating at multiple scales.
5. Species, ecosystems, and societies evolve concurrently, and each component can change independently, with, or because of others. These changes are therefore difficult to predict.
6. Many natural and human processes that affect ecosystems and societies are subject to change over time at diverse temporal scales.
7. Cumulative effects alter the environment through a combination of diverse past, present and future activities. EBM must consider the effects of multiple human activities and actions, and their potential interactions. These effects may be additive, synergistic, or antagonistic.
8. Resilience traditionally refers to an ecosystem's overall ability to maintain continued functioning in the face of change, and to recover from impacts to species and habitats, including cumulative effects and catastrophic events.
9. Ecological resilience has more recently been defined as the finite capacity of a system to adapt and maintain core structures and functions despite disturbance. While this can be considered negative when systems are in an undesirable state, here "resilience" applies to maintaining desirable structures and functions, such that adaptive capacity is a key element of resilience.
10. The structure of an ecosystem includes many pieces both biological (e.g., the species in an area and the size of individuals) and physical/chemical (e.g., habitat quality and oceanic conditions). Ecosystem functions are the processes such as nutrient cycling and energy transfer that result from interactions between organisms and also their physical environments. Integrity is inherently a value-based and therefore subjectively defined term, but it generally implies that ecosystems have not been fundamentally compromised.
11. Maintaining/enhancing sustainable human communities and economies means that communities are planned, built, or modified to meet the diverse needs of the present generation, without compromising the ability of future generations to meet their needs. Sustainable development relies on healthy and productive ecosystems that continue to maintain their integrity and serve their function if altered.
12. Service provision describes the ecosystem processes that yield benefits for people, directly or indirectly. These include provisioning services (e.g., food), regulating services (e.g., flood control), cultural services (e.g., spiritual benefits), and supporting services (e.g., nutrient cycling).

13. EBM should promote responsible and respectful resource management that leads to sustainable opportunities for coastal communities. Benefits include opportunities and indirect benefits provided by ecosystem services. Costs broadly range from that of management itself to a variety of consequences, including foregone opportunities. Here, fairness means that all stakeholders and constituents have equal moral standing, and that the process should involve deliberation rather than dictation. Fairness recognizes that humans are not the only entities dependent on ecosystems, but cannot be measured objectively. Global considerations are important because BC's resources are globally unique and significant.
14. The connection between social and ecological systems is important, and exists on many levels in time and space. Human societies and globally interconnected economies depend upon functioning ecosystems and the services they provide. The systemic interdependencies among natural and social processes occur at different temporal and spatial scales.
15. EBM starts from a perspective that is inherently "place-based" rather than the traditional "population-based" or "sector-based" approaches to management. This shift means that spatial patterns within the ecosystem that may be relevant to its functioning or to the potential impacts of various uses of the ecosystem are considered and accounted for in management. It also places attention on challenges posed when the spatial boundaries for management decisions differ from the spatial scale on which the population, community, or ecosystem processes are functioning. The hierarchical nesting of ecosystem processes means that there is no single spatial scale that is "right" for all policies and management measures. Rather, "place-based" means that policies and management must function coherently in each "place" they are applied, taking into account the particular social and ecological context of a place, as well as the spatial scales of key ecosystem processes and pressures associated with the human activities being managed.
16. EBM must be informed by science (but not science alone), including both natural and social science e.g., socioeconomic analysis, social and environmental impact assessment, risk assessment, stakeholder preference analysis, and statistical studies. Traditional, intergenerational and local knowledge should also inform the EBM process; such information could include social, economic and ecological components. These diverse sources of information can inform managers of potential risks and rewards of alternate approaches to EBM, and help reduce the risk associated with uncertainty. All information is most useful when it is accepted by participants and interested parties.
17. The precautionary approach to resource management means being cautious of potential risks, including when understanding and information are limited. This approach does not treat a gap in information as a reason to stall or avoid taking action to prevent harm to a resource. Lack of full scientific certainty is not a reason for postponing effective measures. Thus, policy-makers can take discretionary action to protect ecosystems and societies from exposure to harm when data are uncertain, or inadequate.
18. A systematic process is characterized as an organized, co-ordinated, orderly, and explicit set of procedures.
19. Most loosely, adaptive management is a process in which management decisions are changed as more information about the action or resource becomes available through monitoring and evaluation efforts. Our use of 'adaptive management' refers to a *purposeful* approach that entails (1) recognizing the limitations that current uncertainties place on decision-making, (2) establishing a decision framework to clearly outline how and when management decisions will change to reduce those uncertainties, (3) monitoring (ideally through a scientific approach of testing hypotheses) for effectiveness, (4) providing pre-determined approaches to adapt management measures based on the monitoring results, and (5) structuring policy decisions in order to learn from monitored outcomes.
20. EBM should allow new ideas and be forward-thinking to improve future management and assist decision-making in a timely manner, given the current state of information.
21. First Nations are historically tied to their ancestral territories and have played integral roles in these ecosystems.

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