Evaluation of ecological criteria for selecting MPAs in Pacific Region: a proposed semi-quantitative approach

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Abstract

In this paper we review some of the semi-quantitative methods for choosing locations for mpas and discuss their potential use for mpa site selection in Pacific region. A number of authorities involved in marine conservation have proposed specific criteria or design principles for mpa selection, often following those set out by the International Union for the Conservation of Nature a number of years ago. Most of the criteria schemes are qualitative, which can make the selection procedure subjective and difficult to track in an open and defensible manner. Because of the complexity of marine ecosystems and the lack of site specific data, development of a quantitative scheme is not possible at this time. A semi-quantitative scoring system (e.g. high, medium, low) for siting criteria may be possible even when data are incomplete. As a template for discussion, we used a slightly modified version of the three natural science objectives (biodiversity, sustainability, and increased opportunities for scientific research) and criteria given in the 1998 Canada/B.C. mpa discussion paper, with full realization that socio-economic and other factors important to Department of Fisheries and Oceans (DFO) partners must be considered in final mpa selection process. Factors to consider when scoring criteria are discussed for the following:

1. Biodiversity (eight factors): representativeness, degree of naturalness, areas of high biodiversity and/or biological productivity, rare and endangered species, unique natural areas, ecological viability, vulnerability, and unique habitats;

2. Sustainability (three factors): areas supporting significant spawning concentrations or densities, areas important for the viability of populations and genetic stocks, areas supporting critical species, life stages, and environmental support systems;

3. Increased opportunities for scientific research (three factors): value as a natural benchmark, value for developing a better understanding of the function and interaction of species, communities and ecosystems, and value of determining the impact and results of marine management activities. We recommend that a working group be established to develop a system for scoring and weighting criteria, with wide representation from the science and layperson communities. To the extent possible, decisions for individual mpas must be considered in the context of a mpa network, with the realization that developing the scientific basis for the configuration of the network is a necessary next step.

Résumé

Nous faisons l'examen de certaines méthodes semi-quantitatives pour le choix des emplacements des zones de protection marines (ZPM) et traitons de leur application au choix d'emplacements dans la région du Pacifique. Diverses autorités du domaine de la conservation marine ont proposé des critères ou élaboré des principes pour effectuer ce choix, souvent en s'inspirant de ceux définis par l'Union mondiale pour la conservation de la nature il y a plusieurs années. La plupart des formules sont qualitatives, ce qui peut rendre le processus de sélection subjectif et difficile à présenter de façon ouverte et défendable. La complexité des écosystèmes marins et l'absence de données particulières aux emplacements rendent impossible, pour le moment, l'élaboration d'une formule quantitative. Un système de cotation semi-quantitatif (élevé, faible, moyen) pour l'évaluation de critères de choix pourrait être faisable même en ne disposant que de données incomplètes. Nous avons utilisé, comme cadre de discussions, une version légèrement modifiée des

trois objectifs des sciences naturelles (biodiversité, durabilité et possibilités accrues de recherche scientifique) et les critères énoncés dans le document de travail Canada/C.-B. sur les ZPM, mais en réalisant pleinement que des facteurs socio-économiques et d'autres facteurs importants pour les partenaires du MPO devaient être considérés lors du processus définitif de sélection. Les facteurs dont il faut tenir compte au moment de l'évaluation des critères sont discutés pour :

1. la biodiversité (huit facteurs) - représentativité, caractère naturel, zones de biodiversité et/ou de productivité biologique élevées, espèces rares et menacées, zones naturelles uniques, viabilité écologique, vulnérabilité et habitats uniques;

2. durabilité (trois facteurs) – zones abritant des concentrations ou des densités de géniteurs appréciables, zones importantes pour la viabilité de populations et de stocks génétiques et zones abritant des espèces ou des stades de développement critiques ainsi que des systèmes écologiques;

3. possibilités accrues de recherche scientifique (trois facteurs) - valeur à titre de repère naturel, valeur pour une meilleure connaissance de la fonction et de l'interaction des espèces, des communautés et des écosystèmes et valeur de la détermination des incidences et des résultats des activités de gestion marines.

Nous recommandons qu'un groupe de travail soit créé pour l'élaboration d'un système de cotation et de pondération des critères bénéficiant d'une large représentation du milieu scientifique et de la population en général. Dans la mesure du possible, les décisions ayant trait à des ZMP particulières devront être analysées dans le contexte du réseau des ZPM et en tenant compte du fait que l'élaboration du fondement scientifique de la configuration du réseau en constitue l'étape suivante et nécessaire.

A. Introduction

The three goals of the DFO Marine Protected Areas (MPA) Program are:

- To conserve and protect the ecological integrity of a MPA site while providing for compatible use
- Further scientific knowledge and understanding of both protected and unprotected marine ecosystems
- Contribute to the social and economic sustainability of coastal communities (DFO, 1998).

DFO Oceans Branch staff requested a review of ecological criteria, linked to the above goals, that could be used to help select MPA sites from the lists of potential locations submitted by various stakeholders. Here, we discuss the current natural sciences criteria used in the Pacific Region to 1) propose a method of developing semi-quantitative criteria to help Ocean managers during their site selection process or when screening potential pilot MPA sites or Areas of Interest (AOIs), and 2), to provide recommendations for needed research that will allow better evaluation of the effectiveness of MPAs in meeting draft objectives, both individually and as part of a MPA network.

The above goals are general and difficult to dissect into measurable criteria to select specific sites. To provide a framework to discuss ecological criteria, we consulted a related MPA strategy discussion document (Canada/B.C., 1998) that implicitly incorporated features of the above goals.

That document listed six objectives, three of which were science related and were accompanied by qualitative criteria. For the purposes of this paper, we focused on those objectives, namely:

- Protection of marine biodiversity, representative ecosystems and special natural features (abbreviated below as the biodiversity objective)
- Protection and conservation of fishery resources and their habitats (abbreviated below as the sustainability objective)
- Providing opportunities for increased scientific research on marine ecosystems, organisms (e.g. long term monitoring of undisturbed populations, special features, and sharing of traditional knowledge (abbreviated below as opportunities for increased scientific research).

This paper should help decision makers better identify and define options for management objectives, which can then be used in a semi-quantitative, rational and transparent process to evaluate potential sites. We fully recognize that other objectives (Canada/B.C. 1998) will be factored into any final decision about a particular site or network. DFO's mandate allows it to establish MPAs in Canada (we use the capitalized abbreviations to indicate a site designated under DFO's *Ocean Act*, which specifically refers to protected areas as Marine Protected Areas). However, DFO partners and stakeholders with ecological expertise (e.g. Environment Canada, Parks Canada, Province of B.C., First Nations, marine industries, academics, and non-governmental organizations) are likely to be involved in the process of MPA creation.

We recognize that site selection is only one of many elements needed to build an MPA system, or network. Also required are identification of site-specific goals, site surveys and data collection, data analyses and data synthesis, and formulation or site-specific management plans. However, development of siting criteria, or predetermined standards used when making a choice of one geographic area over another for establishment of a MPA, is a first and key step in the process. Ecosystem structure and function have numerous components that vary spatially in a complex manner, making it often difficult to weigh one component against another. In addition, stakeholders are typically focused on ecosystem values in their immediate neighbourhood, and so rational science-based criteria helps in the making of regional decisions or recommendations by planning groups considering regional integrated management. We also realize that ecosystem characteristics vary over time, and indeed, depending how they are defined, may even change location, so that on-going monitoring and adaptive management must be adopted as an overriding principle. Finally, we recognise that the ecological definition of a site, and indeed the scientific concept of an ecosystem, are themselves difficult for ecologists to define (Perry 1999). Compared to terrestrial systems, where many ecological concepts have been developed, marine boundaries and connectivity issues are particularly difficult to define and quantify (Jamieson and Levings 1998). The terms "ecosystem, habitats, environments, and communities" are often used interchangeably without recognition of their differences in the strict scientific sense, leading to confusion when objectives are being defined and debated. This is a major problem in Pacific region where there is no consensus among scientists on ecosystem terminology (Levings et al. 1998). Unlike the situation in the north Atlantic (Pauly et al. 2000), no lexicon on marine ecosystem is available.

B. Selected review of semi-quantitative criteria and systems used for rating marine protected areas.

A number of authors have proposed specific criteria or design principles for mpa selection (e.g. Salm and Price 1995), often following criteria set out by the IUCN (Kelleher and Kenchington 1992). MPA criteria given by Canada/B.C. (1998) follow the IUCN criteria fairly closely. Most of the older studies consider criteria that are mostly qualitative, and as far as we could discern, there are only a few papers, reviewed below, that provide semi-quantitative measures for mpa selection. In addition, most published field studies of no-take marine reserves established to sustain ecosystems are in tropical/subtropical locations. Estes and Carr (1999) only found 13 published works on temperate water marine reserves, of which three focused on finfish. Because of important latitudinal differences in ecosystem structure in the world's oceans (e.g. Ekman 1967, Bailey 1998), and corresponding ecological differences, guidelines for tropic or subtropical mpas should be expected to be different than those developed for temperate or subarctic regions. For this reason, we have focused our brief review on mpa establishment criteria on temperate water systems.

As stated by Brody (1998), complex statistical methods for evaluating ecological criteria are cumbersome, expensive and not very effective in eliminating bias from the selection process - "selection criteria are meant to help humans make decisions, not take humans out of the decision-making process". Perhaps because of this point, there has been limited application of semi-quantitative criteria to marine ecosystem management, as described below. It should be noted that to our knowledge, only a few published habitat or ecosystem rating schemes (Kistritz 1985; Hunter et al. 1985) proposed for coastal British Columbia have actually been applied by managers (see also Levings and Thom 1994). We are aware of only one semi-quantitative scheme that has actually been applied by any agency in the Pacific Region of Canada when making a recommendation to a decision-making body. That scheme was the biophysical (habitat) rating procedure for predicting nearshore productivity from coastal habitat features and local biological resources used in the Oil Port Risk Analysis project (OPRA) (Fisheries and Environment Canada 1978). That project evaluated several thousand kilometres of B.C. coast relative to risk of oil spills and to help in decision making about recommended oil tanker routes.

Criteria rating for ecosystems in watersheds with estuaries

We feel it is important to emphasize that the linking of watersheds to estuary and ocean conditions is an important aspect for integrated management. Freshwater flow can affect coastal marine regions, and linking terrestrial and marine protected areas may have a number of advantages. Moyle and Sato (1992) described a proposed rating scheme to protect native freshwater fish species in the western US. Five types of waters are described Class I - completely pristine watershed, Class II - greater degree of modification by human activity, Class III - natural in appearance but have been modified by human activity so that native biotic communities have been severely altered, Class IV - natural area refuges created entirely for the purpose of protecting selected species; Class V - artificial refuges in which no attempt is made to re-create natural conditions (e.g. fish ponds). McPhail and Carveth (1992) provide a somewhat similar perspective for watershed classification in British Columbia, but they only applied it to major drainage basins (e.g. Fraser, Columbia, etc).

Criteria rating based on extrapolations from biophysical features to marine ecosystems

In British Columbia, Zacharias et al. (1998) and Zacharias and Howes (1998) proposed the use of "ecounits" derived from an analysis of five physical features: water currents, depth, wave exposure, relief, and substrate. Sixty-five repetitive classes or unique combinations of these factors were found on the B.C. coast, covering a seafloor area of 453411.8 km^2. The minimum sized ecounit was HDHHS (high wave exposure, moderate depth, high relief, high currents, sand) (15.61 km^2) and the largest was HELLU (high wave exposure, abyssal depths, low relief, low currents, and unknown substrate) (335516.8 km^2). By comparing the number of ecounits in an ecosection (a geographically larger unit under the B.C. Marine Ecosystem Classification (BCMEC), described in Zacharias et al. 1998), the authors gave a comparison of how many ecounits are represented in various ecosections on the coast. As explained below, the basic problem with the ecounit scheme is the reliability of the method to link geophysical variables to the biological communities that need to be considered for biodiversity and/or sustainability objectives.

Although the authors stated the various components of the BCMEC system, and its components such as ecounits, could be used in mpa planning (Zacharias and Howes 1998), we could not find any examples of where this has been done. The BCMEC system was applied in a study by Parks Canada to investigate representative and natural areas within the Queen Charlotte Sound Marine Region in their National Marine Conservation Areas System (Parks Canada, 1999; see below). As far as known, results were not actually used to select Preliminary Representative Marine Areas. A general evaluation of this approach for assessing representativeness for mpas is given below. A more recent paper by Zacharias et al. (1999) proposed the use of biotopes for mpa planning and builds on the Biomar classification approach used in the UK (Connor et al. 1997, cited in Zacharias et al. (1999. However, once again we are not aware of this system having been used to identify mpa sites. Biotopes are defined as "the combination of habitat together with its recurring associated biological community, which operate at specific scales". Zacharias et al. (1999) sampled 1486 km of shoreline on the south coast of Vancouver Island and used complex multivariate methods (Twinspan, regression tree analyses) to generate what they called "biotope complexes" for the area. Five biotopes (2.7 to 597.7 km in shoreline length) were described from the study area, while 201.4 km were not classified by the method. A similar analysis was conducted earlier by Morris (1996) using subtidal data obtained by Foreman (see Levings et al. 1983) from Bath Island, near Gabriola Pass. In Zacharias et al. 1999, the strongest association between biological community and physical environment was found in the "*Egregia/Hedophyllum* 110 biotope", where the regression tree predicted an 86% probability that an average salinity of greater than 30.3 ppt will separate this community from the other six identified in the scheme. Given that the algal species of this biotope are known to change in response to temperature changes with climate shifts such as El Niño (Milligan et al. 1999), it is unlikely that this exact salinity boundary is a functionally usable criterion for community identification.

Criteria rating based on biological benchmarks

Gregory and Brown (1999) proposed a scheme for rating areas for fishery MPAs on the Atlantic coast that used ratios - each candidate MPA would be compared to a common reference area, possibly one of the candidate areas. Various life history features could be factored in. For example, with Atlantic cod, 12 benchmarks were considered: spawning locations, eggs spawned, mean

female size or egg diameter, mean spring surface temperature, larvae produced, mean summer surface temperature, number of juveniles settling, availability of habitat, habitat carrying capacity, number surviving to end of age 0, abundance at age 4, and adult abundance. The potential for improvement could then be used to proportionally weigh one area against the reference area. For example, consider two spawning areas (e.g. for capelin) - Area A (10 ha of spawning beach, 15% utilized) and Area B (2 hectares, fully utilized). Area B would score higher (i.e. if Area A, the reference area, scored 1.0; Area B = (2.0/10.0) x (1.0/0.15)= 1.33) because of the potential productivity of Area B. The authors point out these areal calculations can be weighed by factors such as spawning success in various habitats if needed. Gregory and Brown (1999) provided four examples using Atlantic cod, lumpfish, capelin, and American lobster.

Day and Roff (1998) proposed a modified marine classification system developed by Geomatics International (1996) which utilised enduring and recurrent oceanographic and physiographic features of the marine environment to develop an inclusive heirarchical framework of planning, based on ecological principles. This approach was subsequently applied to the Scotian Shelf by Day and Lavoie (1998) as a "community level" analysis of marine systems. It is unique because it uses physical attributes alone to predict the expected *biocoenosis* (an ecological community, especially when forming a self-regulating unit) on the basis of documented habitat characteristics. It recognises and classifies the two major marine communities (pelagic and benthic) which have entirely different communities and are driven by different processes. Its claimed strengths are to provide a defensible marine classification based on a minimal set of key physiographic and oceanographic factors, and to systematically identify marine communities and delineate their boundaries in a consistent classification way. We find its weaknesses are twofold. First, because nearshore oceanography is very variable and poorly described, it is only really applicable to offshore areas which have larger-scale features, and second, because it ignores biological species per se, it again doesn't differ between biological communities, except at a gross level.

Criteria Ratings based on dimensionless scores

As indicated above, the use of criteria can help decision-makers or panels make judgements as to which candidate mpa site is most deserving of protection. This approach is embodied in the Delphic method of analysis, where a group of experts in the field reach consensus on the priority ranking of potential mpas (Croom and Crosby 1998, cited in Brody, 1998). A subset of the Delphic method is the dimensionless analysis method where scores (low -1, moderate value - 2, high value- 3, unknown value - x) are assigned to criteria for each site. Chosen criteria can then be weighed through a statistical process so that the final score reflects both the relative importance of the qualities a site possesses and the degree to which it possesses them. This is a simple assessment that is both easy to use and understand by individuals with varying levels of expertise. It is similar to the habitat rating scheme used in the OPRA analysis (Fisheries and Environment 1978), mentioned above. The US National Marine Sanctuary Program used this type of process to decide which areas should go on their Site Evaluation List and Brody (1998) described the use of this method for comparing a variety of mpa criteria in the Gulf of Maine. The following are the ecological characteristics that were scored: representativeness, diversity, ecological importance, ecological sensitivity, uniqueness, naturalness, integrity, biological productivity, importance to fisheries, "importance for recruits to a fishery elsewhere", importance to fishery species, and other ecological features.

Hockey and Branch (1997) provided a description of another dimensionless ranking system which uses scores to measure the effectiveness of three types of mpas, namely marine sanctuaries, marine reserves, and fisheries reserves, and in the context of their associated ecological objectives. Each type of mpa was connected with 11 ecological objectives. There were four other non-ecological objectives described. The rating system was "+ +" for "very effective in satisfying a particular objective", "+" for "moderate success", and "-" for "little or no success". Finally the objectives were arrayed against 17 criteria. This system, called COMPARE ("Criteria and Objectives for Marine Protected Area Evaluation), was used in a study of the four major marine biogeographic regions of the country. As noted by the authors, this approach, like other dimensionless rating schemes, has several advantages: it compels an examination of all possible objectives, pinpoints the reasons for decisions, identifies issues that need resolution, and requires the development of management plans.

In British Columbia, Parks Canada (1999), relying on a more detailed study by Booth et al. (1998), used a dimensionless scoring system to evaluate representativeness and naturalness of specific areas to identify Preliminary Representative Marine Areas (PRMAs) within the Queen Charlotte Sound Marine Region (QCSMR). (229286 km^2). The scoring and weighting system in both Parks Canada (1999) and Booth et al. (1998) appears to have been developed by a team of geologists, biologists and planners. Although regional scientists in the region were consulted for information, they did not participate in development of the scoring system and in that sense the scheme may not be a true Delphic approach. Booth et al. (1998) used the BCMEC ecounit scheme to analyse biophysical features - there were 138 ecounits in the QCSMR, implying an average ecounit size of about 1661 km^2. For representivity, four PMRAs were selected from areas that contained a concentration of ecounits with high representivity scores. However, there were arbitrary boundaries drawn because ecounit boundaries were only used "where possible" (Booth et al. 1998, p. 82). The final PMRAs given in Parks Canada (1999) also have different boundaries (judging from the geographic names used) than those identified in Booth et al. (1998), possibly as a result of delineation by field observations mentioned in the former document.

C. Discussion of Objectives Identified for MPAs in the Pacific Region, Canada

I. Biodiversity objectives and criteria

Biodiversity is also referred to as biological diversity and refers not only to the variety or number of species within a prescribed area, but also to the variety of species, communities, and ecosystems. The following definition is from both the UN Convention on Biodiversity and the Canadian Biodiversity Strategy, and is as follows:

Biodiversity or Biological Diversity: "The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems"

The relevant objective in the discussion document (Canada/B.C., 1998) is somewhat more restricted than the above: "to contribute to the protection of marine biodiversity, representative ecosystems, and special natural features (e.g. upwelling environments, eelgrass beds, and soft coral communities)". As a preamble, it should be noted that some scientists believe that maintenance of all components of biodiversity is not essential to protect all the functioning of an ecosystem. There are important generalizations that can be made (e.g. relief provided by structural species) but ecologists remain a long way from being able to predict how many and which species might be expendable for any function in a given ecosystem (Grime 1997, Elliott and Lawrence 1998). Nevertheless, its recognised that society values biodiversity and hence would like it protected. Given that there is then a need to measure biodiversity, there is thus a need for a working or practical definition for biodiversity that is acceptable to all scientists concerning with a particular AOI. However, as Mills (1969) and Vane-Wright et al. (1991) recognized for ecological communities, the way we measure biodiversity is influenced by both the sampling methods used (e.g. quadrat, mesh sizes) and approaches to taxonomy and genetics (e.g. classical morphology identification vs contemporary biochemical techniques).

For the purposes of this paper, we will focus on species diversity, especially of those species that can be sampled or observed by classical or standard methods (SCUBA, nets, etc.) and identified with currently available regional identification manuals. Most marine species diversity is benthic rather than pelagic (Angel 1993, cited in Gray 1997), and hence much emphasis on biodiversity is directed around substrates. We will also include habitat diversity where applicable, recognizing that a habitat lexicon has not been agreed to by a consensus of marine scientists in Pacific region (see Levings et al. 1998).

II Sustainability

The full objective in the Canada/B.C. MPA discussion document is as follows: "to contribute to the protection and conservation of fishery resources and their habitats (e.g. spawning, rearing, and nursery areas)". As a first principle, if the objective of a proposed MPA is primarily to provide a fishery refuge or marine reserve to produce juveniles to be recruited to a fishery, the first datum needed, ideally, is an estimate of the sustainable biomass desired for the harvestable species within a particular site and/or adjacent sites (e.g. if a MPA network is desired). These data are useful in evaluation of how large the individual MPA or MPA network should be to conserve sufficient brood stock to meet this objective. However, because of the complexity of determining biomass estimates, especially for cryptic benthic invertebrates, it is unlikely these data may ever be generally available for all species, and perhaps even for the targeted species. At the minimum, however, stock assessment biologists and fishery managers should provide information on past, present, and potential fishing activity for all relevant species for the proposed site. These data will also help determine any potential conflicts between the desired protection of some species and the potential continued harvest of others. For example, bottom trawling may have to be excluded from a proposed MPA if one of the species planned to be protected is significantly negatively affected by trawling (e.g. Collie et al. 1997).

A second important principle is acceptance of a quantitative relationship between amount of habitat and biological production - in other words, acceptance that density-dependence is in fact operating

in the ecosystem of interest. This notion has not always been accepted by some scientists, although the assumption of a density dependent relationship between adult density and recruitment rate has been used in recent models (e.g. Nowlis and Roberts 1999).

It should be noted that four criteria overlap between the biodiversity and sustainability objectives, and are here discussed within the former category. These are as follows: areas of high biodiversity and/or biological productivity, rare and endangered species, areas supporting unique or rare marine habitats, and vulnerability.

III Opportunities for scientific research

The full objective in the draft discussion document (Canada/B.C., 1998) is: "provide opportunities for increased scientific research on marine ecosystems, organisms, and special features, and sharing of traditional knowledge (e.g. long term monitoring of undisturbed populations)."

The last part of this objective identifies one of the key rationales for creation of mpas - they can provide the basis for adaptive fisheries management by becoming control, i.e. treatment undisturbed, sites to measure change against. Directed and mandated long-term monitoring in control sites is essential for evaluating potential fisheries effects on biodiversity and/or sustainability. Long-term monitoring of variation in ecological processes such as growth and production in undisturbed control sites can also permit evaluation of other specific scientific hypotheses, such as the effects of global climate change on species. At present, other than temperature and salinity monitoring at selected lighthouses, there are few long-term marine data series being collected in Pacific region. Fishery stock assessment data for some species is an exception, but the frequency of sampling and sampling effort is typically driven by management needs, and these can fluctuate with market demand for fishery products.

General research monitoring likely associated with this objective may also be of interest to coastal zone managers, especially since the floral and fauna of the region are poorly described (as mentioned above, Section B, biodiversity). MPAs, or a MPA network, creation might help secure funds to enable researchers from museums to complete a badly needed inventory of coastal plants and animals (Tunnicliffe 1993). Monitoring of special features should include specific vulnerable habitats such as eelgrass, kelp beds, and marshes. At present there is no regular monitoring of these habitats, or indeed any marine habitats, but such monitoring could be built into a network of MPAs so that changes in quantity or quality over time can be tracked.

D. Proposal of criteria for a semi-quantitative rating system

The following are proposed criteria that could be used to rate specific sites proposed for MPAs, categorized by the three natural science objectives given in the discussion paper on MPAs (Canada/B.C., 1998). We feel the criteria could at least be rated using a "high, medium, and low" ranking scheme, with weighting factors decided upon by an evaluation group. Weighting factors are likely to vary among evaluation groups and therefore, may need to be pre-tailored to a specific range of situations.

I. Biodiversity

1. Representativeness:

Criterion: To assess representativeness, the following might be rated: how typical or similar are the species, habitats, and communities in the proposed MPA relative to other locations on the B.C. coast?

A major problem with developing criteria for this factor is that the biodiversity objective does not specify what scale of spatial unit the MPA is to be representative of. In addition, if the MPA is to representative of an ecosystem, a lexicon of marine ecosystems in Pacific region will have to be devised, but there is no consensus among regional scientists on this matter. Parks Canada considers representivity at levels within a hierarchical system. The smallest scale divisions appear to have been decided upon (Canada/B.C., 1998) but more discussion is needed to identify the scale of the larger features – in other words consensus on the hierarchical system has not been achieved. A similar problem has arisen in establishing such criteria for other marine regions, such as the Gulf of Maine (Brody 1998). Unlike the situation on land, it is very difficult to do a gap analysis and quantify what species are represented in a particular area. Inventory data are usually lacking in coastal areas, and habitat-species associations are not well understood, as explained above. Zacharias and Howes (1998) concluded that their ecounit scheme and the BCMEC are a tool for identifying ecological boundaries in order to assess the representativeness of the current system of protected areas. The data on lengths of various types of shoreline in B.C. given in Zacharias and Howes (1998) are useful for estimating the proportion of some kinds of habitats such as rocky shores. However the boundaries of the ecounits are arbitrarily determined, are sometimes counter-intuitive, and are difficult to relate to specific biota. For example, a unique 163 km^2 offshore ecounit in Dixon Entrance near the Canada-US border was characterized by high wave action, moderate depth (200-1000 m), low relief, high currents, and hard substrate. If the ecounit was to represent benthic biota, wave action would be irrelevant. Conversely if the ecounit was to represent plankton biota, hard substrate would not be a major controlling physical factor.

For most areas it will be difficult to rate this factor without a biological survey unless the proposed area is in a very well studied part of the coast. Some possible alternate strategies are as follows:
- Focus on one particular kind of easily identifiable group of organisms, e.g. fish or macroinvertebrates. Nearly 5000 marine species are known to occur on the B.C. coast (Tunnicliffe 1993) and it is unrealistic to expect any one person to be able to identify all, or even most, of them.
- For some sedentary organisms, relationships between habitats and biota may be useful. A recent paper from Australia (Ward et al. 1999) showed this was possible, but it was based on information from a very thoroughly studied bay. Habitat-species relationships were studied within one km^2 grid cells using 13 habitat categories with 977 taxa in a 400 km^2 study area
- It is difficult to extrapolate habitat information into an ecosystem context. However, because most marine organisms have specific temperature and salinity preferences, or tolerances, it might be possible to use water mass structure (Thomson 1998) as a boundary factor to assess some of the above.

The number of non-indigenous species present in the proposed area is an index of representativeness. It should be noted that sites near shellfish aquaculture operations may have a number of non-indigenous species (NIS) of invertebrates and algae that were introduced with Japanese oysters. Sites near harbours used by deepsea ships may also have NIS introduced by ballast water (Levings et al. 1998), and these species may artificially increase quantitative biodiversity estimates unless adjustments are made.

2. Degree of naturalness:

Criterion: To assess the degree of naturalness, the following might be rated: "How much of the proposed site consists of anthropogenic features?"

Areal data on bottom types and intertidal areas, and their characteristics (e.g. sediment type), should be available from GIS analyses from nautical chart databases. For example, the number of hectares devoted to industrial activity such as docks, outfalls, and ocean disposal areas can be found on charts. The shore unit analysis provided by the Province of B.C. (see http://www.gis.luco.gov.bc.ca/mris/coasthm.htm) gives data on shoreline disruption for several coastal areas in southern B.C. Areal data on human use of the marine environment can also be found in the Provincial Crown Lands lease database that is available to the public (Glover and Levings 1998). Unfortunately, leased areas are not properly georeferenced. There may also be some types of human uses that are not documented in the lease database, such as riprap deposition locations. However, data on most common waterfront developments such as floats, docks, log storage areas and aquaculture leases are available. On the other hand, if adjacent terrestrial habitat is already protected and remains pristine, that may lend weight to a proposed MPA. Data on water quality should be available from responsible agencies such as the B.C. Ministry of Environment, Lands and Parks (MELP) and Environment Canada (EC). The extent, or ranges, of some outfall plumes can also be mapped by air photography or other remote sensing techniques. It is possible that EC keeps a data base on oil spills and perhaps the DFO's Habitat Enhancement Branch (HEB) has one on locations of documented wild fish kills.

Quantitative criteria here might be tied in with water quality standards, e.g. those published by Federal/Provincial agencies. Dissolved oxygen (DO) values might be an important criteria, but there may also be some unique low DO habitats in sites such as in Saanich Inlet or Nitinat Lake that might be proposed as MPAs.

Parks Canada (1999) and Booth et al. (1998) considered degree of naturalness in their analysis of proposed NMCAs on the Central Coast of B.C. A variety of factors were considered, including log storage, aquaculture, and presence of human settlements. As mentioned above, dimensionless scoring was used by the authors to rate particular areas according to the amount of industrial and urban disruption.

3. Areas of high biodiversity and/or biological productivity[1]

Criterion for high biodiversity: To assess biodiversity, the following might be rated: "How many species are found in the area and how does this compare to the average number found in similar habitats in other ecosystems?"

Is the proposed area especially unique, or likely to be so, because of the presence of a particularly large number of species or unique species of limited spatial distribution? For example a rocky shoreline on a tidal pass might show higher biodiversity than a rocky shore in a fjord. In most areas these data would have to be obtained but for data from some areas, e.g. the Gulf Islands intertidal fauna (Lewis and Quayle 1972), the information may be published. Regional checklists (e.g. Austin 1985) could also be consulted. Museum specialists and other experts, e.g. those from natural history groups such as the Vancouver Natural History Society (VNHS), should be asked to review species lists that might be prepared by laypersons.

Criterion for high biological productivity: To assess biological productivity, the following might be rated: What are the main energy sources at the site and what is the level of primary production (g C m^{-2} y^{-1}) from plant or algal communities relative to other areas?

Levels of primary production are known for phytoplankton from a variety of pelagic habitats on the B.C. coast, but primarily from the Strait of Georgia (e.g. Harrison et al. 1994). There are also data available on marsh and eelgrass beds, and kelps. Relatively easy methods such as measurement of stem lengths could be used to assess vascular plant production since there are known relationships between lengths, biomass, and annual production. Available regional data on primary production from marshes and macrophytic algae have been summarized (Levings and Nishimura 1996) but need wider distribution.

4. Rare and endangered species[2]

Criterion: To assess rare and endangered species, the following might be rated: "How many species in the proposed MPA are only found on the B.C. coast and how many are on the COSEWIC and/or red list of IUCN?"

The status of the populations of rare and endangered species on the coast of British Columbia can be determined using a variety of published check lists, including those available from COSEWIC [e.g. Jamieson (1999) for abalone], the IUCN red list, and the Conservation Data Centre in Victoria, B.C. A measure for this criterion might simply be the number of red and blue listed species in a proposed area. Unlike those for terrestrial and freshwater invertebrates (e.g. Scudder 1996) these various sources do not give site-specific information but may be useful to help determine if the geographic range of the species is restricted. Quantitative methods for assessing if a species is at risk or endangered, particularly because of harvesting, are poorly developed (Powles et al. 2000) so often the placing a species on the endangered list is a judgement call by experienced taxonomists or museum personnel.

Because of funding problems for maintenance of museum collections, records, and staff, geographic checklists for specific taxa from the B.C. coast are rarely or infrequently updated. However for some taxa such as molluscs and polychaetes, checklists published in the past two decades or so are available and should be consulted. In addition, the Royal B.C. Museum can also be a source of information. Publications of natural history societies (e.g. VNHS's Discovery) can also provide information and frequently alert biologists about new species records.

5. Unique natural phenomena

Criterion: How much of the proposed MPA is characterized by natural phenomena that are unusual features on the B.C. coast?

A wide variety of unique natural phenomena are found on the B.C. coast, some of them not found elsewhere in Canada or perhaps internationally. These include features such as hot springs, intertidal springs, waterfalls, extremely swift tidal rapids, low DO basins, and others. The B.C. Coast Pilot and nautical charts are valuable sources of information as these publications were developed by hydrographers with extensive field experience and high credibility. In addition, topographic maps (NTS) series show features on the adjacent land that may be unique. Maps and charts published by the Geological Survey of Canada are also likely sources of information on unusual landscape features. Local museums and naturalist organizations could also be consulted.

6. Ecological viability

Criterion: To assess ecological viability, the following might be rated: "For long term persistence, how much dependence on distal ecosystems are needed for maintenance of energy flow, recruitment or structural aspects, or is it a "stand alone" ecosystem? If dependence is involved, how many intact adjacent areas are nearby and are they stable?"

Because marine ecosystems are connected by water currents, almost all areas would be expected to have some dependence on adjacent areas to some degree. Depending on the dispersal mechanism of the species within an ecosystem, there may be interchange of juvenile forms, on a variety of scales, which in turn may relate to home ranges. For example, ecosystems tens or hundreds of kilometres apart may easily exchange echinoderm larvae via the plankton. In contrast, ling cod show nesting behaviour and the larval fish do not drift in the plankton. Movement between ecosystems is therefore limited to a few kilometres. There may be some instances where dispersion of larvae along a shore may be interrupted by a causeway or breakwater (Jamieson and Levings 1998) or a source of toxic pollution such as an industrial discharge plume. Advection of deep water over sills into fjords from basins is another instance of dependence, and estuarine marshes may require an annual input of sediment from rivers for much of their production (Levings 1980). Excess or lack of sediment may affect the long-term future of estuaries, or reset community structure. Some ecosystems such as deep sea vents (black smokers) exist independent from adjacent water masses, as their energy sources are immediately beneath them, in the earth's crust (Tunnicliffe and Thomson 1999). Alternatively, sometimes catastrophes such as underwater slumping, internal waves along boundaries of water masses (Jamieson and Pikitch 1988) or turbidity currents can cause significant community disruptions.

7. Vulnerability[1]

Criterion: To assess vulnerability, the following might be rated: "How seriously is the ecological integrity of the area potentially threatened by human activities that could affect the long term persistence of natural ecosystems in the proposed MPA?"

This factor relates to localized changes caused by human intervention, and the spatial scale of the changes here is important. Given the dynamic nature of marine ecosystems, any proposed MPA is vulnerable to natural change, particularly from long term climate trends. Such ecosystem changes owing to natural phenomena should be considered part of the characteristics of the site. Global warming, which may be caused by man, will potentially affect primary productivity controlling factors such as temperature and salinity, but because such global man-induced changes affect all systems, they may not be relevant to choices among particular proposed MPAs.

Proposed MPAs may be vulnerable to direct or indirect effects of nearby industrial activities. Examples are areas of the sea bed that might be mined using direct extraction by dredging. Alternatively, a dredging operation could take place close to the proposed site, and suspended sediment from the operations could drift into the site. There are numerous other kinds of industrial activities that cause acute or chronic effects on marine ecosystems. Some of the more common ones on the B.C. coast are log handling and storage, shoreline armouring and sea walls, dredging for marinas, upland forest harvesting, pulp mill pollution, housing developments, agricultural runoffs, and sewage discharges. The Province of B.C. controls the leases and licenses for these activities. Information on the geographic bounds of the water lots and their leasees and licensees may be found in the public data files of the Crown Lands offices (Glover and Levings 1998), but as described above, there are problems with georeferencing locations in their data base.

Some elements of marine ecosystems are also susceptible to foreign biological factors such as predation or competition arising from NIS. This also includes introduced diseases. Organisms in culture operations may establish themselves in the wild, as observed by Quayle (1971) for oysters and manila clams (*Venerupis philippinarum*). Therefore, proximity to areas leased for aquaculture should be determined from lease data held by B.C., and observations made of the presence of NIS.

Past harvesting for industrial, sport, or traditional reasons is another way in which the proposed MPA may have been vulnerable to human activities. Harvesting may also alter population structure by removal of older individuals with high fecundity and different genetic profiles, as explained below. Mobile fishing gear such as bottom trawls can destroy structured habitat (e.g. hard corals (Breeze et al. 1997). Fixed gear such as traps and longlines may have a similar effect, as often when the gear is hauled, lines are dragged across the bottom that may damage biological communities.

8. Unique habitat[3]

Criterion: To assess unique habitat, the following might be rated: "How many habitats found in the proposed MPA are unusual or represent minor components on the B.C. coast?"

As noted for rare and endangered species, because of the lack of inventory and detailed ecological investigations on the B.C. coast, it will be difficult to address this criterion, except perhaps for intertidal areas. If an intertidal habitat does not feature at all in common lists (e.g. if it is not among the 13 types given in Jamieson et al. 1999), it may be a unique habitat type, at least for the Strait of Georgia. Examples might be tide pools (south Gulf Islands) and sandstone beaches (north end of Gabriola Island).

Whether or not a habitat is considered unique depends on measurement scale. For example, eelgrass beds may be unique habitat in fjords because the shorelines of these water bodies are steep and rocky. Similarly, the brackish marshes on mini-deltas in Howe Sound are unique in this fjord (Levings and McDaniel 1976), if a scale of 1:5000 is used. On the central coast, which is dominated by fjords and rocky shores, entire estuaries might be considered unique at a scale of 1:500,000.

Unique habitat conditions may also be created by specific oceanographic conditions, such as shallow warm water masses from thermal stratification in the summer (e.g. Pendrell Sound), seasonal anoxic conditions at depth in some inlets (Saanich Inlet, Minette Bay at Kitimat, and Hidden Basin on Nelson Island), or cold bottom water masses (e.g. Skidegate Inlet). Other situations can lead to unusually cold situations, such as the cool brackish conditions at the head of Howe Sound caused by cold runoff from the glacier-fed Squamish River, creating a cold water refuge for an amphipod species not known from other parts of the southern Strait of Georgia (Bousefield 1979).

Subtidal and deep water habitats are poorly known on the coast and other than general sedimentary descriptions that can be produced by hydroacoustic methods (e.g. multi-beam sonar), there have been few efforts to map and "groundtruth" underwater habitats and their associated biota. The discovery of black smokers at Endeavour Ridge off the west coast of Vancouver Island (Tunnicliffe and Thomson 1999) and the sponge beds in southwest Hecate Strait (Conway, 1999) are examples of recent discoveries of unique habitats in the region. Some information on unique deep water habitats may also be inferred from basic data on depth and bathymetry. Bowie Seamount, off the west coast of Vancouver Island, is an example, and Halibut Bank in the Strait of Georgia are examples of shallow pinnacles or banks isolated from other shallow habitat by deep water.

Footnotes

[1] - indicates this criterion is also listed in the draft MPA strategy document as relevant to the sustainability objective

[2] - indicates this criterion, with a slight modification (the word "and" is inserted), is also listed in the draft MPA strategy document as relevant to the sustainability objective,

- indicates this criterion, with a slight modification ("areas supporting unique or rare marine habitats" is inserted), is also listed in the draft MPA strategy document as relevant to the sustainability objective,

II Sustainability

The qualitative proposed determining criteria to meet the objective are as follows:

1. **Areas supporting significant spawning concentrations or densities**

Criterion: To assess the significance of spawning habitats in a proposed MPA, the following might be rated: "Within the proposed MPA, are there known spawning grounds for commercially or ecologically significant species? What is its potential productive capacity, based on habitat features, for spawning and reproduction?"

Fishery managers or others concerned with maintenance of historical levels of recruitment from spawning stocks for harvested species should be able to provide site-specific information on spawning areas for the species they manage or study. Generally speaking, this is a species-specific parameter. Habitat features and historical fisheries data may also be used to infer the potential of a proposed MPA. For example, a rocky reef habitat may not be being heavily used by lingcod as a spawning ground at present because of overfishing, but the area may have been used by this species in the past. It could then be proposed as a MPA with the justification that the area could be important for local lingcod re-establishment.

The fact that many species have meroplanktonic larvae, i.e. larvae are produced by relatively sedentary adults and drift from the spawning grounds to colonize other areas, brings up the concept of source and sink populations. Sources are populations at spawning locations where because of current patterns, larvae readily drift to other favourable settlement locations, while sinks are locations from which currents take larvae to other locations where settlement survival is unlikely. Source and sink populations for any species have not been thoroughly determined in British Columbia, but have been suggested in other locations (e.g. Lee and Williams 1999).

2. **Areas important for the viability of populations and genetic stocks**

Criterion: To assess viability of populations and genetic stocks, the following might be rated: "How many populations or habitats connected with unique stocks, e.g. those that have special site characteristics, are found in the proposed area? Have these populations been "protected" from fishing in the past for a substantial period of time?"

Stocks with unique characteristics: The uniqueness of characteristics of specific species' populations can be assessed from scientific publications, local knowledge, and direct observation. Environmental conditions may profoundly affect such parameters as growth rates, maximum sizes and longevity's of fish and invertebrates, e.g. the average size of red urchins on the west coast of the Queen Charlottes is much smaller than in other areas of the coast (Jamieson et al. 1998).

Closure areas: Since the distribution and duration of fishing closures for Pacific region have now been documented (Jamieson and Lessard, in press), proponents can determine if their particular area of interest is within a fishery closure area and how long it has been closed. At some time in the past, fishery managers may have made a decision, based, for example, perhaps on depletion of stocks and/or commercial extirpation, that a particular area was important for maintenance of a local population or stock. The length of time an area has been closed, its spatial extent, the number of species protected from harvesting, and the type of fishing gear that the closure forbids are all factors that might be used to index how much "investment" has gone into a particular closure area, and hence influence whether or not a proposed MPA might be accepted.

3. Areas supporting critical species, life stages, and environmental support systems

Criterion: To assess critical species, life stages, and environmental support systems, the following might be rated: How much of the proposed MPA includes populations or habitat for important forage species, or habitats critical for life history stages?

Important forage species are those thought to be vital in the food chain, such as sand lance. Important habitats or environments are those that are critical for life-history stages, e.g. estuaries are considered as crucial areas (containing a variety of habitats) that are required for smoltification of salmon moving from fresh water to the sea.

The concept of a required environmental support system could include consideration of the combined influence of habitat structure (e.g. relief, substrate, depth) and water environmental properties (e.g. temperature, salinity, nutrients, currents) of the particular locale. These combinations of factors can result in areas critical for a species health (e.g. fishing "banks", such as Goose Island Ground), larval retention areas (e.g. Toquart Bay for oyster larvae), or particular subsurface features such as gullies (e.g. for rockfish). Another example might be shear zone areas between currents around a point of land (e.g. Brooks Peninsula) or a deep trough that conveys nutrients closer to the surface in an upwelling region.

III Increased opportunities for scientific research

1. Value as a natural benchmark

Criterion: How much of the proposed MPA contains species whose life history parameters (e.g. growth, survival) are well established, communities that are well documented, or habitats that have been well mapped? Have the attributes been monitored for a substantial period of time, so that a defensible time series of data are available? Is the database "weak" or strong?

Gregory and Brown (1999) provide a list of some fish life history attributes that are available for some harvested fish and invertebrate species in the Pacific Region. Bond et al. (1999) suggested that density, fidelity, and mean size are attributes of marine fish populations that indicate value among seven habitats in California. Some of these attributes are also available for a few commercial fish species in the Pacific Region. There are some marine communities in the Pacific

Region that have described in detail. For example, demersal fish and benthic infaunal communities have been described thoroughly for the Hecate Strait (Fargo and Tyler 1991; Burd and Brinkhurst 1987). Marine benthic algae and invertebrates communities are well known for a few areas, especially for intertidal and nearshore habitats such as at Bath Island near Gabriola Pass (Levings et al. 1983) and near Bamfield in Barkley Sound (Milligan et al. 1999). As mentioned above, there are few areas in the marine environment of the Pacific Region where ecosystem or habitat attributes have been assessed for long periods of time, i.e. decades. In selected areas such as the Fraser River estuary, some information on changes in marsh distribution might be available. There are of course long time series of catch statistics for marine fish species (particularly for groundfish, crabs, clams, etc.; see PSARC stock status updates) in certain areas and these may be useful. The strengths and weaknesses of any data series should be assessed as survey protocols may have changed over time.

2. Value for developing a better understanding of the function and interaction of species, communities and ecosystems

Criterion: In the view of practicing marine scientists in the region, how important is the proposed area for advancing knowledge?

Scientists often make judgement calls about the importance of a particular area for research based on a combination of representativeness, uniqueness, existence of previous data, input from client groups if they are applied scientists, funding, and personal interest. If the proposed MPA is representative of an area which has already been well studied, the area might not be highly valued. On the other hand, if the area has already been studied extensively and many baseline data are available, it might be an important area to springboard new research from. Examples of previously relatively well studied areas are Hecate Strait (Tyler 1989), Massett Inlet (Hargreaves et al. 1985), Burke Channel (Parker et al. 1965), and the Campbell River estuary-Discovery Passage area (e.g. Brown et al. 1985). Areas near marine biological stations, such as the Bamfield Marine Station or the Howe Sound Marine Station of the Vancouver Aquarium, are also locations where the flora and fauna are relatively well known.

3. Value of determining the impact and results of marine management activities

Criterion: How valuable is the area for application of adaptive management principles?

A proposed MPA or network can be rated for marine management activities relating to fishery and habitat management activities. Experimental management is when management actions are modified relatively rapidly in response to changes in population characteristics, or when different exploitation strategies are practiced, either over time or in different areas simultaneously. For example, if an area was closed for conservation of a particular species, has recovery occurred, and is there enough science to understand why species did or did not recover? Proposed MPAs may be justified to build on management actions that were initiated years earlier. Specific sites where we know earlier relevant fisheries closures have occurred might be Baynes Sound where English sole fisheries have been closed for decades (Jamieson and Lessard, in press) or Porteau Cove where lingcod harvesting was stopped. The closure around William Head penitentiary is a de facto mpa where abalone populations are recovering (Wallace 1999). Another example might a review of

habitat management procedures to see if "no net loss" of marsh fish habitat has been achieved in an estuary (see Kistritz 1996).

E. Discussion of Summary Rating Table

Table 1 is a distillation of the relevant considerations of the various criteria proposed to establish MPAs. While the above narrative is a scientific discussion of the elements that have been proposed for use in a summary rating of prospective marine protected areas, the operational reality is that at the present for most areas of the coast, very little specific data, if indeed any, are available for many of the proposed criteria. For this reason, we realise that the criteria can only be rated semi-quantitatively using terminology such as "high, medium and low (H,M or L)", with appropriate weighting functions. The scoring system need not be complex, and could be worked out with stakeholders during the MPA selection process. However, justification for marine protected area status may be made for a combination of biodiversity, sustainability and research reasons, which may make it difficult to compare the combined relative merits of any one site in any easily quantifiable rationale. For example, different sites will likely have different attributes for different species for sustainability, making any relative comparison difficult, since all species are presumably equally important, and the need for refugia in a fully exploited system can be made for most species. Weighting functions may help in this regard.

A final consideration relates to parameters not mentioned in any of the scientific rationale for the need for MPAs. Since the rationale for any MPA is to protect some habitat or to provide refugia for at least some species, there has to be some way of ensuring that adequate, functional protection can be provided. The reality is that with the extensive, topographically complex coastline that British Columbia has, MPAs will only functionally work if local communities want them to. Agencies with enforcement capabilities are likely to have too few enforcement officers to provide continuous enforcement protection, so support in local communities and their active involvement in the reporting of illegal activities becomes essential. If local peoples are not willing or able to assume responsibility to help ensure that habitats and/or species in nearby waters are protected, then establishment of a MPA nearby may functionally be ineffective without considerable agency expense, even if scientifically desirable.

Given the inadequacies and incompleteness of existing scientific databases for most site-specific areas of the coast, use of perceptually complex scientific data to win community support may be unnecessary and even inappropriate at this time. The relatively simple and easily understood justifications for existing fishery closures [see Table 7 in Jamieson and Lessard (in press) for fishery closure reasons] have largely been accepted by communities, and this may illustrate the level of reason which can be easily explained. Many community-supported MPAs are likely to be proposed for "common-sense" reasons, such as because it is widely recognised that a particular species' abundance is very much reduced and that some immediate, effective remedial action is needed, such as might be created by a MPA refugium for that species. The specific siting of such a refugium and its size and boundaries will often largely again be a common-sense recommendation. The ranked ratings of "H, M or L" which could be made by scientists working with laypeople could help sort out the priority sites, and this along with local habitat consideration will probably play the dominant role in decision making. Also, as Bill Ballantine once said (pers. comm.), when few functional mpas exist, there is not much value in spending a lot of time worrying about where

precisely to place the first ones, since anywhere will have some value. In the future, when concern is being expressed about how many is enough, and are existing ones spaced and sized optimally, then science will perhaps be able to assume a greater role in decision-making. In the initial stages of creating functional mpas, though, socio-economic considerations and the practicalities of enforcement will probably rule the day.

Given the above, we can not propose a scientifically justifiable quantitative scheme for criteria at this time to rationalise MPA siting, size and degree of protection which should be provided which would be appropriate and effective for all the potential MPAs that are likely to be suggested. Instead, we propose below semi-quantitative considerations which could be addressed in the weighting of different factors, but this still won't resolve the relative weights of different factors themselves (see recommendations). Our final suggestion is that a board of representative regional scientific experts be created which would at least be able to identify and evaluate sites that available data suggest are worthy potential MPAs for the reasons proposed by the proponents. Final decisions would presumably be made by a larger board representing a broader cross section of community interests.

Table 1. Relevant key scientific considerations of the various criteria proposed to establish MPAs for objectives relating to biodiversity, sustainability, and increased opportunities for scientific research.

I Biodiversity

Criterion	Relevant Considerations when scoring
1) Representativeness:	How typical or similar are the species, habitats, and communities in the proposed MPA relative to other locations on the B.C. coast?
2) Degree of naturalness:	How much of the proposed site consists of anthropogenic features?
3) Areas of high biodiversity and/or biological productivity:	How many species are found in the area and how does this compare to the average number found in similar habitats in other ecosystems? What are the main energy sources at the site and what is the level of primary production ($g\ C\ m^{-2}\ y^{-1}$) from plant or algal communities relative to other areas?
4) Rare and endangered species	Are there species in the proposed MPA only found on the B.C. coast and how many are on the COSEWIC and/or red list of IUCN?
5) Unique natural phenomena	How much of the proposed MPA is

	characterized by natural phenomena that are unusual features on the B.C. coast?
6) Ecological viability	For long term persistence, how many connections with numerous proximate or distal ecosystems are needed for energy flow, recruitment or structural aspect or is it a "stand alone" ecosystem? If connections are required, how many intact adjacent areas are nearby?
7) Vulnerability	How seriously is the ecological integrity of the area threatened by human activity that could affect the long term persistence of the ecosystems in the proposed MPA?
8) Unique habitat	How many habitats found in the proposed MPA are unusual or represent minor components on the B.C. coast?

II Sustainability

Criterion	Relevant Considerations when scoring
1) Areas supporting significant spawning concentrations or densities	How many populations or habitats connected with unique stocks, for example those that have special size characteristics, are found in the proposed area? What is its potential productive capacity, based on habitat features, for spawning and reproduction?
2) Areas important for the viability of populations and genetic stocks	How many populations or habitats connected with unique stocks, for example those that have special size characteristics, are found in the proposed area? Have the stocks been "protected" from fishing effects for a substantial period of time?
3) Areas supporting critical species, life stages, and environmental support systems	How much of the proposed MPA includes populations or habitat for important forage species or habitats critical for life history transformations?

III Increased opportunities for scientific research

Criterion	Relevant Considerations when scoring
1) Value for developing a better understanding of the function and interaction of species, communities and ecosystems	In the view of practising marine scientists in the region, how important is the proposed area for advancing knowledge?
2) Value of determining the impact and results of marine management activities	How valuable is the area for application of adaptive management principles? A proposed MPA or network could be rated for marine management activities relating to fishery and habitat management activities. For example, if the area was closed for conservation of a particular species, how many data are there to investigate if recovery has occurred and is there enough science to understand why species did or did not recover?
3) Value as a natural benchmark	How much of the proposed MPA contains species whose life history parameters (e.g. growth, survival) are described, communities that are well documented, or habitats that have been well mapped? Have the attributes been monitored for a substantial period of time, so that a defensible time series of data are available? Is the database "weak or strong"?

F. Recommendations

Our two primary recommendations are:

1. Establish a government/non-government organisation/fisher/community based scientific working group (perhaps reporting to the Canada/B.C. MPA Working Group) with the task of refining and evaluating the semi-quantitative scheme proposed in this paper. The process of scoring and weighting criteria should be open and transparent. It is our understanding that a number of sites have been proposed by various groups, e.g. Canadian Parks and Wilderness Society, Living Ocean Society, etc., and this new proposed working group could perhaps use these existing lists as a starting point for their deliberations. Alternatively, the group could test the system against the four DFO pilot MPAs.

2. Decisions about individual MPA sites must be continuously viewed in the context of a network, even if such a network is only just beginning to be established. Establishing criteria for MPA networks will need to be considered in more detail, but this need not be an immediate priority. A systematic selection of individual reserves or MPAs using a semi-quantitative scheme increases the chances of creating effective networks, because these approaches are

repeatable, transparent, and defensible. Nevertheless, the door should always be open for the establishment of individual *ad hoc* MPAs if local circumstances justify it.

Our two secondary recommendations are as follows:

1. Scientists in the Pacific region need to consider working definitions of marine ecosystems at the detailed scale, in order to address questions such as uniqueness and representativeness.

2. Since much fishery and habitat expertise currently resides within DFO, departmental scientists with such expertise should be requested to put forward in a timely manner proposals for potential MPAs, rather than relying primarily on laypeople and interest groups to suggest potential sites. Otherwise, important potential sites may not be recognised in time to have them seriously considered.

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