Marine protected areas in Canada—implications for both conservation and fisheries management[1]

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Abstract: Legislated marine "protected" areas are now widely distributed throughout tropical and temperate waters, but the nature of human activities actually restricted in any area varies. This ambiguity about what "protected" means has resulted in contradictory claims as to both the benefits and costs of marine protected areas. Here, we give our perspective on the current status of marine resource protection in Canada in general and British Columbia in particular. We first describe and discuss the history of Canadian marine protected areas established to date. Many areas are claimed to be protected, with little understanding by either the general public or even most marine resource experts as to what human activities are actually regulated by legislative designations. Second, we present an overview of biological reasons and objectives for marine protected areas, followed by a review of both the conservation and fisheries management effects and implications resulting from effective renewable resource protection. Finally, we propose a unique qualitative scheme for classifying and describing marine protected areas of different types to determine relative measures of protection.

Résumé : Bien qu'il existe dans les eaux tropicales et tempérées de nombreux pays des zones de « protection » marine établies par voie législative, les activités humaines qui y sont réglementées varient considérablement d'une région à une autre. Cette ambiguïté entourant la notion même de « protection » engendre des affirmations contradictoires sur les avantages et les coûts des zones de protection marine. Nous présentons ici notre point de vue sur la situation actuelle de la protection des ressources marines au Canada en général et en Colombie-Britannique en particulier. Nous décrivons d'abord et commentons l'histoire des zones de protection marine établies jusqu'à maintenant au Canada. Plusieurs zones sont dites protégées, sans que la population en général, et même les spécialistes des ressources marines, ne comprennent bien quelles activités sont de fait contrôlées par les dispositions législatives. Nous faisons ensuite une synthèse des principes biologiques et des objectifs qui sous-tendent l'établissement des zones de protection marine, une revue de leurs effets sur la conservation et l'aménagement des pêches, ainsi qu'un résumé des conséquences d'une protection efficace des ressources renouvelables. Nous proposons enfin une méthode qualitative pour la classification et la description des divers types de zones de protection marine dans le but de pouvoir établir des mesures relatives de protection.

[Traduit par la Rédaction]

Introduction

Marine protected areas are the legislative designation for the protection of specific coastal and marine areas from otherwise unrestricted human activities. The International Union for Conservation of Nature and Natural Resources (IUCN) defines them as "any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which have been reserved by law or other effective means to protect part or all of the enclosed environment" (Kelleher and Kenchington 1992). Rationales for marine protected areas can vary widely, ranging from extensive preservation of relatively pristine environments for their own sake to endangered species protection, continued recreational opportunities, fisheries enhancement, etc., and are largely determined by the legislative Acts that can be used to designate them. The recent considerable interest in marine protected areas in the 1990s in Canada (Shackell and Willison 1995; Canada – British Columbia 1998) and worldwide (Agardy 1995; McArdle 1997*b*) has arisen because of increased recognition that the world's marine and aquatic environments and ecosystems are considerably less healthy and are providing fewer ecosystem services (Costanza et al. 1998) than before humans began impacting these systems on a global scale. Impacts include fishing down the food web (Pauly et al. 1998), overfishing, sometimes to local species extirpation (Jamieson 1993; Powles et al. 2000), pollution (Waldichuk 1990), disturbance and habitat destruction (e.g., through ocean dumping, dredging, and land reclamation through dyking (LOICZ 1999), etc. There is general concern by many that ocean health will continue to decline to increasingly unacceptable levels unless human activities, or their effects, are limited or mitigated in some manner.

Studies of the consequences of marine area protection have been mostly associated with, or at least identified with, tropical waters. They have typically been associated with

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Table 1. Provincial (P) and federal (F) marine protected areas established in Canada by DFO regions over time.

	Pacific		Arctic		Laurentian		Maritimes		Newfoundland		
Decade	P	F	P	F	P	F	P	F	P	F	Total
1910–1919	2	0	0	0	0	2	0	3	0	0	7
1920–1929	0	1	0	0	0	8	0	0	0	0	9
1930–1939	0	2	0	1	0	1	0	3	0	0	7
1940–1949	0	0	0	2	0	0	0	0	0	0	2
1950–1959	4	0	0	4	0	0	0	0	0	1	9
1960–1969	14	2	0	8	0	0	0	0	5	0	29
1970–1979	19	2	0	2	0	1	0	5	0	0	29
1980–1989	21	1	3	3	1	5	0	5	0	0	39
1990–1999	56	1	0	4	0	2	1	0	1	3	68
Total	116	9	3	24	1	18	1	16	6	4	198

Note: Pacific data from Jamieson and Lessard (2000); remaining data from T. Kurvits (DFO, Ottawa, Ont., personal communication).

preservation of long-lived species and particularly vulnerable ecosystems, such as coral reefs (e.g., Kriwoken 1996). While many marine protected areas have been designated in temperate waters (e.g., 124 in British Columbia (B.C.) alone; Jamieson and Lessard 2000), these have often been relatively small (in B.C., 66 (52%) are <1 km^2 in area) and mostly associated with human recreation values rather than ecosystem or species conservation values per se. Recent significant declines in fished species, such as abalone (*Haliotis kamtschatkana*) (Jamieson 1999) in B.C. and northern cod (*Gadus morhua*) (Myers et al. 1997) in Atlantic Canada, have facilitated both the need for a precautionary fisheries management approach (Agardy 1994) and the implementation of marine protected areas as an important fisheries management tool in Canada. These were important considerations in the development and design of the Canadian Oceans Act, passed in January 1997. This Act gave authority to the Minister of Fisheries and Oceans Canada (DFO) to designate specific marine areas, termed Marine Protected Areas (capitalised (MPAs), since this is the specific name designated for marine protected areas under this Act; other federal legislation can establish different marine protected areas, such as national parks (Parks Act), national wildlife areas (Canada Wildlife Act), etc.), for special protection, with specific human activity exclusions defined on a site-by-site basis. Other Canadian provincial government departments and ministries with the appropriate mandate have also established marine protected areas, and these have been termed marine parks, sanctuaries, reserves, wilderness areas, wildlife areas, ecological reserves, "protected areas," and so on.

The purpose of this paper is to give our perspective on the current status of marine resource protection in Canada in general and B.C. in particular and to propose a qualitative scheme for the classification and description of different marine protected areas. We first describe and discuss the history of Canadian marine protected areas established to date and their types. Many areas are claimed to be protected, with little understanding by either the general public or even most marine resource experts as to what human activities are actually regulated by legislation. There are, for example, 10 different types of legislated marine protected areas (including Parks Canada's national marine conservation areas (NMCAs), which are expected to soon be established) in B.C. alone, each with its own characteristics. Second, we present an overview of realistic biological reasons and objectives for marine protected areas, followed by a review of the results of conservation. We specifically discuss the implications of restricting human activities on themes for conservation such as community dynamics, intraspecies genetic and (or) behavioural diversity, and habitat, sensitive species, and biodiversity conservation. Third, we discuss the implications of marine protected areas for fisheries management, specifically topics such as reference, or "control," sites, experimental management, the optimal proportion of the coast in reserves, and marine protected area networks. Finally, we propose a new qualitative scheme for classifying and describing marine protected areas of different types so that a relative measure of level of protection (i.e., restrictions on human activities) can be determined by the type of designation.

History of marine ecosystem protection in Canada

In this section, we discuss the historical pattern for establishment of marine protected areas in Canada, the relative geographical areas protected by region, and what the term "protected" actually means in terms of both habitat and species protection. We also summarise what federal and provincial Acts are available to establish protected areas, how governments have used them to define protected areas, and associated enforcement challenges.

Areas, primarily terrestrial, have been protected in Canada since at least 1885 when the first national park was established in Banff, Alberta. However, as will be discussed below, calling an area protected in Canada may not actually restrict many human activities. Protected areas established by provinces have been set aside to protect a province's diverse natural, cultural heritage, and recreational values (e.g., British Columbia 1993). In B.C., protected areas are defined as inalienable: the land and resources may not be sold, and they are areas where no industrial extraction of nonrenewable resources or development is permitted. The first provincial protected area in B.C. with a marine component, and the first provincial terrestrial park established there, was Strathcona Provincial Park. This park was established in B.C. in 1911. There are currently many other primarily terrestrial parks that also have a relatively minor marine portion (Jamieson and Lessard 2000). The first marine protected area established in B.C. based only on marine aesthetic values was Maquinna Marine Park, established in 1955. Most marine

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Table 2. Legislated areas with a marine component by general type (provincial designations may not all be exactly similar) by DFO region.

	Pacific[a]	Central and Arctic[b]	Laurentian[b]	Maritimes[b]	Newfoundland[b]	Total
Provincial total	**116**	**3**	**1**	**1**	**6**	**127**
Ecological reserves	15	0	0	0	6[c]	21
Provincial parks	81	3[d]	1	1	0	86
Wildlife management areas	4	0	0	0	0	4
Wildlife reserves	15	0	0	0	0	15
"Protected areas"	1	0	0	0	0	1
Federal total	**9**	**24**	**18**	**16**	**4**	**71**
National park (reserves)	1	5	0	2	1	9
National marine parks (= national marine conservation areas)	0	0	1	0	0	1
Migratory bird sanctuaries	5	17	15	7	3	48
National wildlife areas	2	2	2	7	0	13
Marine protected areas	1(3)[e]	0	0	(1[e])	0	1[e]
Grand total	**125**	**27**	**22**	**17**	**10**	**198**

Note: Great Lakes protected areas are not included here, as they are freshwater.
[a]Jamieson and Lessard (2000).
[b]DFO (1999) and T. Kurvits (DFO, Ottawa, Ont., personal communication).
[c]Anderson et al. (2000).
[d]Ontario = 2, Yukon = 1.
[e]Candidate MPAs; the first MPA in Canada was gazetted on October 28, 2000.

protected areas have been established in B.C. in the last few decades (Table 1).

In eastern Canada, the first provincial marine protected areas to be established were four wildlife reserves (now called ecological reserves: Cape St. Mary's, Witless Bay, Hare Bay, and the Funk Islands) in Newfoundland (Table 1) by the Provincial Department of Tourism, Culture and Recreation in 1964 (Table 2) to protect seabirds (Anderson et al. 2000). There has only been one marine protected area based only on marine aesthetic values established in eastern Canada to date, the Saguenay – St. Lawrence Marine Park, established in 1998 as a joint initiative of the federal Department of Canadian Heritage and the Province of Quebec.

The first marine protected areas established solely by the federal government were migratory bird sanctuaries (MBSs) established through the Canadian Wildlife Service, Environment Canada. The first in B.C., Victoria Harbour, was established in 1923, and the first in Atlantic Canada, Port Joli Basin in Nova Scotia, was established in 1915. The role of an MBS is to protect migratory birds — shorebirds, waterfowl, and seabirds — from hunting and other sources of disturbance at their breeding grounds and on migratory stopovers. Environment Canada has another marine protected area designation, national wildlife areas, that focuses more on protecting bird habitat (see Jamieson and Lessard 2000).

Relative to the rest of Canada (Atlas of Canada: total Canadian coastline is 243 792 km; the total provincial coastline, i.e., excluding the Yukon, Nunavut, and Northwest Territories, is 81 689 km; values include mainland coast and perimeters of both major and minor islands), B.C. has a relatively small coastline (25 725 km, 11 %), yet it has 63% of the 198 legislated marine protected areas in all of Canada (Table 2). B.C. has a total marine protected area of 2252 km^2 (55 and 22% of this area in provincial parks and ecological reserves, respectively). An additional 3458 km^2 is in the proposed Gwaii Haanas National Marine Park Reserve, which while its boundaries are established has officially yet to be gazetted (Jamieson and Lessard 2000). DFO divides the coast in the rest of Canada into four management regions (DFO 1999). The total marine area currently protected by statutes other than the Oceans Act in each of these regions is as follows: Laurentian (southern Quebec), 1514 km^2 (98% federal, with 75% of this area in national parks); Maritimes, 80 km^2 (99% federal, with 54% national parks, 26% MBSs, and 20% national wildlife areas); Newfoundland (including Labrador), 1084 km^2 (47% national parks and 52% provincial ecological reserves); Arctic, 21 152 km^2 (98% federal, with 63% MBSs, 30% parks, and 7% national wildlife areas) (T. Kurvits, DFO, Ottawa, Ont., personal communication).

Parks Canada approved a National Marine Parks Policy in 1986, with a revised NMCA Policy in 1994. An agreement to establish the first NMCA — Fathom Five in Georgian Bay in Lake Huron (note: the above Parks Canada policy statements do not differentiate between the Great Lakes and oceans) — occurred in 1987. In 1988, the signing of a federal–provincial agreement committed the governments of Canada and B.C. to work towards the creation of the Gwaii Haanas NMCA in the Queen Charlotte Islands. Parks Canada has divided Canada's three oceanic coasts and the Great Lakes system into 29 marine regions, each with a distinct combination of geological features, coastal landforms, oceanographic processes, and marine-associated wildlife (http://parkscanada.pch.gc.ca/nmca/nmca/index.html). Its long-term goal is to represent each region within a system of NMCAs.

The federal department with a strong marine resource management mandate, DFO, has only had the authority to establish marine protected areas since January 1997, when the Oceans Act was approved. This Act gave authority to the Minister of DFO to designate MPAs for special protection for one or more of the following reasons: (*i*) the conservation and protection of commercial and noncommercial fishery resources, including marine mammals and their habitats, (*ii*) the conservation and protection of endangered or threatened marine species and their habitats, (*iii*) the conservation

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and protection of unique habitats, (*iv*) the conservation and protection of marine areas of high biodiversity or biological productivity, and (*v*) the conservation and protection of any other marine resource or habitat as is necessary to fulfill the mandate of the Minister.

In contrast with the proposed Marine Conservation Areas Act, the Oceans Act does not apply to the Great Lakes. As of September 2000, five candidate MPAs had been established in the Pacific (four) and Atlantic (one). Numerous additional Areas of Interest are also being proposed through various planning processes. The other conservation tool available to fisheries resource managers is fisheries closure under the Fisheries Act. However, since such closures are by regulation rather than legislation, like Ramsar sites (Anonymous 1971) and biosphere reserves (UNESCO 2000), they are not considered MPAs (see "Types of marine protected areas" section).

What does "protected" mean?

There are two general categories for marine protected areas: those that were primarily established to preserve habitats and ecosystems (parks, etc.) and those that are focused on the protection of individual species or species groups such as shorebirds, waterfowl, and seabirds (MBSs, etc.). In the latter case, restrictions on human activity typically only apply when the protected species are present (often only in the spring or fall with migratory birds) and may provide little protection of habitat per se. Forty-eight of the 71 existing federal marine protected areas nationwide are of this latter type (Table 2).

The remaining 150 marine protected areas nationwide — 127 are provincially legislated, with 116 in B.C. — primarily protect habitat identified on a biophysical basis but not necessarily the water column, which is also fish habitat (Table 2). Fishing occurs in most existing designated marine protected areas in Canadian coastal waters, often over the objections of the province that established the marine protected areas (e.g., B.C. (K. Morrison, Ministry of Environment, Lands and Parks, Victoria, B.C., personal communication). This occurs because the federal government of Canada is the senior level of government and has the mandate to manage renewable marine resources, and so its fisheries regulations supersede provincial regulations. The consequence is that at present, fishing can and does occur in virtually all areas that might be desired to be fully protected by the provinces.

The level of habitat protection provided to any marine protected area is somewhat determined by the legislative Act that was used to establish it but sometimes is primarily determined on a site-by-site basis, typically in consultation with local communities and interest groups. Restrictions on human activities can be grouped into three basic categories. (*i*) Prevention of habitat destruction or modification (nonrenewable resource extraction (water diversion, mining, etc), ocean dumping, dredging, etc.). The habitat provisions of the federal Fisheries Act provide penalties under the criminal code for the unauthorised alteration or disruption of fish habitat and the deposition of deleterious substances. However, to our knowledge, this Act has never been used in the context of prosecution for habitat changes in a protected area. Environment Canada regulates ocean dumping under the Canadian Environmental Assessment Act. (*ii*) Prevention of species harvest or exploitation (i.e., logging, fishing, or hunting, with restrictions often species specific). (*iii*) Prevention of species' disturbance (e.g., feeding wildlife or interfering with their natural behaviour, reproduction, and rearing of young).

From a habitat protection perspective, provisions of the Fisheries Act are reactive rather than proactive. The Oceans Act and the proposed National Marine Conservation Act provide no minimum level of protection for any species or habitat, with protection of habitat and species to be determined on a site-by-site basis. Protected areas established under either Act can be homogenous, i.e., a common level of protection applies over the entire protected area, or the marine protected area can be zoned internally, with different levels of protection applied to each zone. Zoning is particularly useful for separating incompatible activities, protecting resources, and reducing conflict (Bohnsack 1996). For example, a specific MPA might have a core area where no species may be harvested ("no-take" area), harvest of only migratory or pelagic species, such as salmon or herring, over the remaining area, and no ocean dumping, dredging, or nonrenewable resource extraction (mining, etc.) over the entire area. Similarly, a specific NMCA, which tend to be large areas, may have a number of internally zoned no-take areas, with variable levels of harvest of particular species permitted in other specific zones.

The option of having a very large marine protected area, such as the entire Strait of Georgia in B.C., with internally zoned areas thus compares relatively equally to the idea of a network of smaller marine protected areas. The main difference between them is in the method and perhaps ease with which monitoring and adaptive management (Walters 1986) can be effected. Future change in the spatial pattern and relative sizes of areas of higher protection may be easiest to effect within a single protected area. Australia's Great Barrier Reef, the largest existing legislated marine protected area in the world, is an example of the former case. As presently proposed (Canada – British Columbia 1998), a network of MPAs, i.e., many relatively small Areas, is the management approach anticipated to be effected through the Oceans Act (C. Masson, DFO, Nanaimo, B.C., personal communication). NMCAs, although intrinsically like the Great Barrier Reef in concept, will probably be larger than MPAs but not large enough to include whole identified ecoregions (http://parkscanada.pch.gc.ca/nmca/nmca/index.html). In B.C., for example, the proposed Gwaii Haanas NMCA, which will be the largest marine protected area in Pacific Canada at 3457.5 km^2, is considerably smaller than each of the two ecoregions that it straddles (see http://parkscanada.pch.gc.ca/nmca/nmca/pacific/index.htm).

It should also be pointed out that different marine protected areas may overlap each other. Thus, the XwaYeN (Race Rocks) MPA, gazetted on October 28, 2000, will overlap B.C.'s existing Race Rocks Ecological Reserve. Similarly, the potential Gulf Islands NMCA, if established, will overlap many existing provincial marine protected areas (provincial parks, ecological reserves, designated areas, etc.; Jamieson and Lessard 2000) and possibly some future MPAs, such as the candidate MPA at Gabriola Pass.

The issue of federal and provincial ownership of the seabed and overlying water has some relevance, as it can deter-

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mine what Act is used to protect an area and the types of marine protected areas that can thus be established. In Canada, the federal government alone has the mandate to protect and conserve (*i*) migratory bird species, all marine species (except in B.C., where oysters have been delegated to B.C. to manage), and most anadromous species, (*ii*) habitat below high tide that falls under federal legislation, such as recognized fish habitat or habitat in national parks, NMCAs, and national wildlife areas, and (*iii*) habitat in "offshore" areas, i.e., within the Extended Economic Zone (EEZ) seaward of recognised provincial land. The provinces' conservation mandate includes all other species and habitats. There is some disagreement between Canada and B.C., at least as to how the "offshore" is determined. Provincial land in B.C. is all land between "headland to headland," and while this is accepted by the federal government, there is a difference of legal opinion as to what constitutes a "headland." There is agreement that most of the bottom of the Strait of Georgia is provincial land, but B.C., for example, also claims that this definition defines a line from the northern tip of Vancouver Island and the southern tip of the Queen Charlotte Islands. Such a boundary would make Hecate Strait and Queen Charlotte Sound provincial land, but this boundary has not been accepted by the federal government and has not yet been resolved by a court.

In Pacific Canada, most existing marine protected areas (Table 2) are provincial (116, 94%), nearshore, and relatively small (Jamieson and Lessard 2000). In eastern and arctic Canada, most marine protected areas are federal (62, 82%), and most are MBSs (Table 2). MBSs in eastern Canada are relatively small in area (average marine area = 14 km^2, SD = 24 km^2) and focus on migratory staging areas, but those in the Arctic tend to be larger and focus on breeding grounds, with marine portions averaging 841 km^2 (SD = 1 650 km^2) (T. Kurvits, DFO, Ottawa, Ont., personal communication).

Most provincial marine protected areas protect habitats or ecosystems, and only incidentally those marine species that are not of interest for commercial or recreational harvest. Many habitats that are of commercial or recreational fisheries interest are only protected under the Fisheries Act. The DFO Minister can authorise habitat disruption or alteration, but only after specific compensation or mitigation procedures are agreed to. Charges can only be laid after damage has occurred if authorisation to cause damage was not obtained. Most federal marine protected areas are MBSs, and so primarily protect only a few species and little habitat per se. The federal exceptions are with the nine national parks with a marine component, which protect habitat and most marine species but often still permit fisheries for those species that were being exploited at the time a national park was established ("grandfathered" fisheries). Thus, for example, fisheries for Dungeness crab (*Cancer magister*) and Pacific salmon (*Oncorhynchus* spp.) are still permitted in Pacific Rim National Park Reserve in B.C. What this means from an operational perspective is that in the marine environment, there are virtually no areas at this time where all marine species and habitats are simultaneously protected through legislation, i.e., as an marine protected area. In B.C., only five areas are totally protected, all of which are small. Those that have a complete ban on fishing through fisheries regulations and are also protected from habitat alteration are Porteau Cove Marine Provincial Park and XwaYeN (Race Rocks) MPA (42 and 251 ha, respectively, the only legislated marine protected area of the five), a 0.85-ha research study site off Point Atkinson in West Vancouver, and Whytecliffe Municipal Park in West Vancouver (19 ha). The fifth area is the immediate area (<1 km^2) around Williams Head Penitentiary near Esquimalt where a ban on all fishing is enforced by guards to prevent inmate escape. Other areas in B.C., as mapped by Jamieson and Lessard (2000), may have some fishing closures superimposed on marine protected areas, but these are either not for all species or not for the entire area. Fishing closures relative to marine protected areas have also been mapped in Newfoundland and Labrador (Anderson et al. 2000), and there, no areas are fully protected.

In addition, the above does not mean that effective protection is provided through enforcement at marine protected areas all the time (Jamieson 2000). If a species' value is high enough, as it is with abalone, illegal harvest, or poaching, may occur and particular populations may be relatively depleted (Wallace 1999*a*, 1999*b*). The only continuous and totally effective enforcement in Canada appears to be around Williams Head Penitentiary. Legislating protection and actually enforcing it are two quite different issues, with the former easiest to effect.

Types of marine protected areas

Gubbay (1995) and Agardy (1997) provided brief global perspectives of MPAs and summarised the six categories of protected areas now recognised by the IUCN (1994), based on what the protected areas are managed for. However, while some marine protected areas have existed for many years and are described in each respective country through their legislative designations, descriptions of protected areas in the published literature are limited, with the last effort being that of the IUCN (1994). In recent years, however, there have been some documents produced that give these data, particularly in the northeast Pacific. There are now summary documents for California (McArdle 1997*a*), Washington (Murray 1998*a*, 1998*b*), and B.C. (Jamieson and Lessard 2000). Documentation for eastern Canada is less detailed, but marine protected areas have been listed by Nicholls (1998), DFO (1999), and Anderson et al. (2000). In addition, the Gulf of Maine Council has an marine protected area project that is still ongoing, with one of the outputs a database currently under revision of Canada–U.S. protected areas (http://www.gulfofmaine.org/library/mpas/mpa.htm). Some of these documents include designations for areas that are not legislated protected areas, which we consider pseudo marine protected areas because they have no management or regulatory authority associated with them. This includes United Nation's designated biosphere reserves (UNESCO 2000), which are established around locally legislated protected areas; Ramsar sites (Anonymous 1971), which focus on the conservation and wise use of wetlands by national action and international cooperation; national whale sanctuaries, which provide voluntary guidelines for vessel traffic in the presence of specific whale species (DFO 1999); and municipal parks (see Jamieson and Lessard 2000), which are established through local council designation. However, in at least some of the marine protected areas included in the above

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summary documents, agencies with management authority have established closures that complement the boundaries of the above pseudo marine protected areas. Thus, functionally, their establishment may have resulted in the protection of marine areas from some potential human impacts.

To understand the actual level of protection that is actually enforced at any particular legislated marine protected area, it is necessary to know the overlapping regulations that restrict human impacts at each site. This information has been compiled for B.C. by Jamieson and Lessard (2000) and for Newfoundland and Labrador by Anderson et al. (2000). The problem with databases on fishery closures is that protection established through regulation is relatively dynamic, with regulations relatively easily created, modified, or deleted on an annual basis. Databases describing them need to be updated frequently to be accurate, but documents like those referenced above at the least provide a snapshot picture in time to compare future situations against.

The legislative tools, designations, and mandates for marine protected areas that have been established in B.C. are listed in Table 3. There are five provincial types of marine protected areas and potentially five federal types (no NMCAs have currently been designated in Canada; the first MPA in Canada, XwaYeN (Race Rocks) MPA, was recently announced). The federal types of marine protected areas described in Table 3 include all the types of federal marine protected areas that can presently be established anywhere in Canada. In arctic and eastern Canada, two types of marine protected areas (provincial, or territorial, parks and ecological reserves) have been established with regional legislation (Table 2).

With many new marine protected areas being established worldwide each year, it is difficult to maintain an up-to-date inventory of their numbers and characteristics. There is no accurate current collective summary of the types of marine protected areas that occur worldwide that we are aware of, although past summaries exist for some countries (e.g., Australia, McNeill 1994). This may be in part because there is no universally accepted method for categorising areas on the basis of mandate or level of protection provided. Also, the establishment of marine protected areas is currently an area of particular interest in many countries, with legislation allowing the establishment of such areas being developed or only recently just developed. Worldwide, many new marine protected areas are being proposed or considered, and many have been established over the past decade (e.g., see Table 1 for Canada). Increased interest in marine protected areas has resulted for a number of reasons, including (*i*) that the world's exploited fish stocks are now almost fully exploited and yields are declining from many fished populations, (*ii*) increased public awareness of the need for increased marine resource protection, and (*iii*) increased recreational and ecotourism use of the marine environment.

Marine protected area objectives and effects

Biologically, some of the major objectives of marine protected areas are to protect and conserve renewable marine resources (including marine birds and mammals), unique habitats and ecosystems, and (or) representative examples of the marine environment (Canada – British Columbia 1998). Environmental managers are attempting to conserve or reestablish natural resources in important and representative areas, and having the authority to restrict human activities that impact natural resources is essential in this regard. Defensible methods to determine specific sites or networks from the myriad of MPAs are also important (Levings and Jamieson 1999). Resource managers try to establish procedures for sustaining stable exploitation, but because of social and economic pressures and periodic unanticipated natural fluctuations in abundances of targeted species or changes in habitat conditions, they are frequently tasked with the need to rebuild depleted populations. In both instances, marine protected areas are increasingly recognised as an important resource management tool. Having specific areas clearly defined as protected areas where identified actions cannot occur eliminates the pressure for managers to continually restrict developers or exploiters of natural resources. For managers of exploited renewable resources, having refugia where species can reproduce at their maximum rates can provide insurance against possible overexploitation of harvested resources and improved opportunities for resource recoveries. Exploitation of one or more species may be restricted to ensure that reproductive refugia exist for these species. The goal is to provide reproductive refugia that will help better sustain harvesting in adjacent exploited areas.

Where harvesting is not permitted within protected areas, there are three main biological effects that marine protected areas are likely to influence: the demographic characteristics of species' populations, community dynamics and ecological functions within ecosystems, and the maintenance of genetic and (or) behavioural diversity within species. Each of these factors is important, as collectively, these effects maintain ecological integrity. The nature and extent of effects will be determined by the level of protection offered, and in the following, it is assumed that no harvests or habitat disruptions are permitted in at least the no-take portions of marine protected areas. These no-take areas will be generically referred to below as reserves, as used by Ballantine (1991). This is similar to Allison et al.'s (1998) definition of reserves as areas of high, spatially explicit protection.

Demographic characteristics

Marine reserves have been proposed as "reproductive refugia" (e.g., Carr and Reed 1993; Tegner 1993) where adults of spatially persistent, or resident, species would be permitted to increase in abundance and fecundity, the latter because older individuals are often larger. Increased population fecundity could compensate, via the export of larvae, for possible overfishing in areas outside the reserve (Quinn et al. 1993; Hastings and Botsford 1999). It is intuitively logical, and supported by all studies to date, that in the absence of fishing, the number of resident animals approaching the asymptotic size of the species will increase (e.g., Roberts 1995; Russ and Acala 1996). The reproductive characteristics of a population in a reserve will gradually revert to what might have been expected before significant fishing occurred. Given larger population sizes with older and more fecund individuals (Brooks et al. 1997), reproductive output for the protected portion of the population would then tend to be maximised. Factors influencing reproductive contributions from

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Table 3. Federal and B.C. statutory powers for protecting marine areas.

Agency	Legislative tools	Designations	Mandates
Fisheries and Oceans Canada (federal)	Oceans Act	Marine Protected Areas	To protect and conserve: •fisheries resources, including marine mammals and their habitats •endangered or threatened species and their habitats •unique habitats •areas of high biodiversity or biological productivity •areas for scientific and research purposes
	Fisheries Act	Fisheries closures	Conservation mandate to manage and regulate fisheries, conserve and protect fish, protect fish habitat, and prevent pollution of waters frequented by fish
Environment Canada (federal)	Canada Wildlife Act	National wildlife areas	To protect and conserve marine areas that are nationally or internationally significant for all wildlife but focusing on migratory marine birds
	Migratory Birds Convention Act	Migratory bird sanctuaries	To protect coastal and marine habitats that are heavily used by birds for breeding, feeding, migration, and overwintering
Parks Canada (federal)	National Parks Act Proposed National Marine Conservation Areas Act	National parks Proposed marine conservation areas	To protect and conserve for all time marine conservation areas of Canadian significance that are representative of the five natural marine regions identified on the Pacific coast of Canada and to encourage public understanding, appreciation, and enjoyment
Ministry of Environment, Lands and Parks (provincial)	Ecological Reserve Act	Ecological reserves	To protect: •representative examples of B.C.'s marine environment •rare, endangered, or sensitive species or habitats •unique, outstanding, or special features •areas for scientific research and marine awareness
	Park Act	Provincial parks	To protect: •representative examples of marine diversity and recreational and cultural heritage •special natural, cultural heritage, and recreational features To serve a variety of outdoor recreation functions including: •enhancing major tourism travel routes •providing attractions for outdoor holiday destinations
	Wildlife Act	Wildlife management areas	To conserve and manage areas of importance to fish and wildlife and to protect endangered or threatened species and their habitats, whether resident or migratory, of regional, nationa,l or global significance
	Land Act	Designated wildlife reserves	To reserve Crown land for specified periods for a variety of reasons, including the protection of sensitive habitat or habitat important for the conservation or well-being of species
	Environment and Land Use Act	"Protected areas"	To protect: •representative examples of marine diversity and recreational and cultural heritage •special natural, cultural heritage, and recreational features

Note: Modified from Jamieson and Lessard (2000).

refugia are species fecundity, parameters influencing larval survival (e.g., density dependence) and dispersal (i.e., the larval transfer function), and the relative proportion of the species' population that occurs in the reserve area. Modelling (e.g., Man et al. 1995) suggests that increased overall population reproductive output from protected areas

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has the potential to significantly support adjacent fisheries. Conversely, managers may have a false sense of security if inappropriate placing of reserves makes them functionally inadequate (Carr and Reed 1993; Tegner 1993). Inappropriate siting of reserves could involve situations where relevant spawning habitat was not protected or where larvae were exported to unsuitable habitat. Depending on home ranges in a harvested stock and the distances that larvae drift, benefits from reserves may be adjacent to and (or) remote from a reserve.

Another manner in which reserves may be important is through the emigration of exploitable-sized individuals across the border of the reserve into exploited areas (Guénette et al. 1998; Lauck et al. 1998). Opportunity for "spillover" of harvestable sizes is greatly influenced by reserve location, size, and shape. Documentation of spillover is relatively limited (e.g., Attwood and Bennett 1994), both because it is often difficult to determine the origin, i.e., from closed or exploited areas, of untagged harvested individuals and because the strongest evidence would occur with study of relatively heavily exploited, large, old individuals with limited mobility. Few temperate water species meeting these criteria have been studied in this manner, but in Canada, species such as Pacific rockfish (*Sebastes* spp.), lingcod (*Ophiodon elongatus*), Dungeness crab, and American lobster (*Homarus americanus*) seem particularly appropriate for study. Alcala and Russ (1990) showed that with the opening of a reserve to fishing, regional catch-per-unit-effort declined by 57% for hook-and-line, 58% for gillnet, and 33% for trap fishing, even though the fished area was larger afterwards because it then included the previous reserve area. However, this was in a tropical location (the Philippines), and results may have been influenced by site-specific factors because tropical species tend to have smaller home ranges with reduced potential for spillover. Rowley's (1992) literature review concluded that what data do exist support spillovers occurring but that data are limited overall.

The opposite perspective is that reserves would inherently reduce yields in existing fisheries, if for no other reason than that they would reduce the area currently accessible to a fishery. This concern has often tended to impede the establishment of reserves because of initial opposition by fishers. Many theoretical studies (e.g., Sladeck Nowlis and Yoklavich 1998; Hastings and Botsford 1999) have now addressed this point. Typical assumptions are that adults are relatively stationary and will not move outside the protected area, that larval settlement distribution along the coastline is independent of location, and that all density dependence occurs at the time of settling and only depends on the density of settling juveniles. Under these conditions, these theoretical studies concluded that management of fisheries for relatively mobile species using either protected areas or management through effort controls produces similar fishery yields. The greatest potential increases in yield as a result of protected areas are achieved with spatially persistent, i.e., relatively sedentary, species. Some studies have been less conclusive: DeMartini (1993) suggested that catches might be increased or at least maintained for some species, while they would decline for others, Holland and Brazee (1996) suggested that catches might increase, but only if effort was excessive prior to creation of the protected area and if further expansion was controlled after the reserve was created, and Hannesson (1998) suggested that area closures will generally reduce overall catches and increase costs. In summary, results may be species and site specific, and there is a strong need for field studies to test hypotheses.

There has been only one evaluation (Wallace 1999*b*) of the biological consequences of no-take areas in Canada. Increases in average individual size and abundance of abalone were observed, but population fecundities and fishery spillover effects were not investigated per se.

Community dynamics

The direct consequences of harvesting species are a reduction of individuals because of removals and the potential loss of future individuals because of decreased fecundity, reproduction, and growth at the population level. The indirect effects of exploitation include (*i*) the potential loss of food items for other species that may at least partially depend on the exploited species, (*ii*) a removal of predators that may represent a significant population control component for many species, (*iii*) the incidental or intentional, depending on which species are being harvested, destruction of important habitat structuring species (e.g., corals) upon which many species depend, and (*iv*) the modification or destruction of other habitat characteristics such as sediment type. The presence of reserves would prevent any of this from occurring from fishing.

One of the problems of documenting community effects in the present, typically many years after full exploitation of many local species has occurred, is that contemporary community dynamics may not be representative of what existed in the preexploitation period. Important species may have been extirpated from a local environment (Koslow et al. 1988; Roberts and Polunin 1993), and both the resulting community structure and the dominance of species may now be significantly different from those that used to occur. An example from the Pacific is the consequence of sea otter (*Enhydra lutris*) extirpation. Estes (see Estes (1996) for a review) and his students have documented the influence of sea otters on the relative abundances of a wide range of different species through their predation of subtidal benthic invertebrate grazers, such as sea urchins and abalone. In the absence of sea otters, grazers abound, consuming sufficient macroalgae to create what is locally known as sea urchin "barrens." Kelp beds are largely prevented from establishing, and since these beds provide important cover and habitat for many other species, relative abundances of these latter species in the nearshore environment have been substantially modified.

Species do not have to be extirpated to have their structural roles in the community impacted by fishing. When intertidal grazers such as keyhole limpets (*Fissurella* spp.) are the targeted species, as occurs in Chile, their harvest resulted in the luxuriant growth of algae, which reduced the space available for numerous other species in the intertidal and thereby altered the diversity and species assemblages in the community (Moreno et al. 1984; Durán et al. 1987). Algae were only abundant in midintertidal areas where limpets were continuously harvested.

Thus, present fishers and today's general public, who may not have been present when a pristine environment existed,

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often assume that the current species biodiversity, community structure, and relative mix of species observed now are relatively normal. The immense impact that humans have had on many marine communities is often largely unrecognised until studies document the effects, as in Chile (e.g., Castilla and Bustamente 1989) and Australia (e.g., Underwood 1993). On the west coast of Canada, there is substantial documentation about how abundant nearshore species such as salmon, lingcod, rockfish, Dungeness crab, and others used to be. However, in the absence of major reserves where these large populations can be demonstrated today, most people simply do not realise just how much humans have modified and decreased the relative abundances of virtually all exploited species. Serial depletion of one species after another has too often occurred (e.g., Orensanz et al. 1998; Pauly et al. 1998). Too often, our response following collapse of a fishery is to look for another species to exploit rather than to ask the difficult questions as to how to rebuild and sustain overexploited populations and then implement the answers. Short-term economic needs and political benefits regularly tend to override the much larger, potential long-term benefits that would be obtained from sustainable exploitation of our ecosystems.

Intraspecies genetic and (or) behavioural diversity

Although most marine species are managed as if the exploited population was a single homogeneous "stock unit," it is now widely accepted that many populations of spatially persistent species may consist of a number of discrete adult stocks, or metapopulations. Often, these are populations where the adults do not intermingle but that are connected through meroplanktonic larval dispersal. Specific habitats or ecosystems may favour either the survival of specific genotypes that differ from other populations of the same species or the expression of unique behaviours. However, while studies may have reported that different populations have different behaviours and that observed behaviours are uniquely adapted to local conditions (e.g., Dungeness crab; Jamieson and Phillips 1993), whether they are manifested because of genetic differences or environmental features has invariably not been studied. An exception is with some Australian abalone, where it has been shown that more distantly separated populations are genetically more different from each other (Shepherd and Brown 1993).

The more diverse age structure and genetic base associated with reserves may also reduce the risk of fishery collapse (Roberts et al. 1995; Holland and Braze 1996). Trippel (1995) suggested that reproductive capability and resiliency to environmental fluctuations in heavily fished populations may be reduced as the average age and average age of maturity are reduced. Jamieson et al. (1989) expressed concern that virtually complete harvest in the whole population of the fastest growing portions of crustacean cohorts before they have the opportunity to reproduce may be inadvertently selecting for either slower growing individuals or a lower probability of moulting to the legal size. Although the genetic basis behind growth rates for many species has not yet been studied, a precautionary management approach would ensure that all members of a year-class would have the opportunity to breed. Since this is difficult to achieve in many existing exploited areas, the benefits of having reserves would be that at least a portion of every entire year-class would have a breeding opportunity largely unmodified by fishing activity.

Implications of marine protected areas for conservation

The implications of marine protected areas for marine conservation or fisheries are both complementary and contradictory. Renewable resource conservation through protected areas may imply some probable restriction of human fishing activity but is likely to enhance achievable yields in adjacent exploited areas. In both cases, the relative geographic scales of reserves in comparison with exploited areas and the nature of the protection provided become important and should be related to the objectives that are defined with the establishment of each marine protected area. Here, we separately consider habitat, individual species, and ecosystem, or biodiversity, protection.

Habitat

Apart from the effects of ocean dumping, mineral, oil, and gas extraction, and fishing activity, most marine habitat is unlikely to be negatively physically impacted by humans except in very nearshore areas, where dredging and shoreline modifications, such as dyking, infilling, and pier construction, may occur. Effects of water pollution and sediment runoff are also more acute in the shallower areas. In Canada, habitat and renewable marine resource management are to a large extent the responsibilities of separate departments and ministries within the federal and provincial governments. In the past, DFO has vetted all perturbations that might affect renewable resources but typically has only restricted habitat alterations or deposition of deleterious substances (pollution) if sensitive habitats in potential impacted areas were likely to be directly or indirectly affected. Examples are the high level of protection given to separate habitats, such as seagrass beds, estuarine marshes, or kelp beds, and the concern about dioxins in shellfish. In some instances, DFO is a key stakeholder for the management of large geographic areas, such as the Fraser River estuary, but even here, only productive salmonid habitat is afforded the most protection (see http://www.bieapfremp.org/fvision.htm). Passage of the Oceans Act has broadened this department's mandate, and it is now beginning to proactively identify areas worthy of protection even if exploited species are not obviously at risk. For example, identification of extensive sponge reefs in Queen Charlotte Sound and southern Hecate Strait in B.C. by Conway (1999) has led to internal DFO recommendations that they be protected through MPA designation (Stocker and Pringle 2000). However, as discussed above, the level of protection applied in each MPA is individually considered, so it will not be known what "protection" will actually be applied until each specific designation is finalised.

B.C. has historically been more proactive than the other Canadian coastal provinces in establishing habitat protection through marine protected areas. However, with provincial parks representing most of the areas protected in B.C., protection has primarily been for terrestrial and water surface recreation values (sheltered coves and harbours are well represented) rather than for the intrinsic value per se of the in-

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digenous marine life's habitat. Because most nearshore habitats, being within headlands, are provincially managed, from a conservation perspective, the most complete protection for reserves would result from a collaborative designation of marine protected area status by both provincial and federal levels of government. The participation of DFO is essential, since it alone regulates marine fish habitat and fishing activity and thus the indirect habitat effects arising from fishing.

Sensitive species

Some sedentary species that are relatively fragile to physical impact (e.g., corals, gorgonids, and sponges) are particularly sensitive to human impacts. Other species may be particularly vulnerable to human impacts: (*i*) at different times in their life cycles to fishing (e.g., gillnetting in estuaries for returning salmon) or to particular gear types as bycatch (e.g., rockfish to salmon trolling), (*ii*) if they are relatively rare and localised, even if only for a short time period (e.g., marine bird and pinniped rookeries, spawning abalone, and killer whales at rubbing beaches), or (*iii*) if they are long-lived with relatively low fecundity, such as some whales, sharks, and sturgeon, making them more vulnerable to risk of extinction (Powles et al. 2000). For fragile species that are sedentary, immobile, and long-lived (e.g., corals and reef sponges), ideally, species concentrations would be located and significant areas protected before the population could be seriously impacted. For mobile species that either have to pass through spatial "bottlenecks" in their movements or are frequently caught as bycatch in the targeted fishing of other species, marine protected areas that include areas of particular species vulnerability might provide critical protection to help sustain specific stocks or cohorts. Examples of marine protected areas in Canada established primarily to protect species using specific habitats (protection may be seasonal, i.e., only when the species are present) are MBSs, B.C. ecological reserves (e.g., Robson Bight (Michael Bigg)) for killer whales, B.C. wildlife management areas, and some provincial parks for seabird breeding colonies (e.g., in B.C., Scott Islands and Mitlenatch Island Nature provincial parks).

Biodiversity

With the current move towards an ecosystem-based management approach by DFO, the challenge now is to understand what this actually will mean in an operational sense. Most marine biological communities are poorly described, and while species lists of larger harvested species may be available, their full roles in and contributions to the ecosystems that they occur in are largely speculative. In addition, historically fishers targeted higher trophic level species, which has now disrupted relative species abundances and therefore local ecosystem dynamics. What ecosystems were historically like is now mostly speculation. Marine reserves provide the opportunity for natural ecosystems to become reestablished by permitting exploited populations to achieve their natural size frequency distributions and, if monitored, the research opportunity to determine how exploitation of some species affects the relative abundances and ecosystem roles of other species. This allows evaluation as to whether or not there are keystone species and, if so, what their specific ecological roles are (Power et al. 1996; Miller et al. 1998).

An example is the B.C. gooseneck barnacle (*Pollicipes polymerus*) fishery and its potential impacts on exposed rocky intertidal ecosystem dynamics. Recent reports by Lauzier (1999) and Jamieson et al. (1999) described both fishery and ecosystem concerns, respectively. They discussed the need for reserves and experimental management areas to determine the ecosystem role of this species and that of the sea mussel *Mytilus califorianus*, which together are the dominant structural species in this ecosystem. Up to 300 other species are associated with the microhabitat that these two species create, so their harvests, if substantial, may have widespread ecosystem implications. The conservation value of reserves in this ecosystem is now being investigated. With single-species management, population reference points have been accepted for many species. A fishery, for example, might be shut down if the population size decreases to below a specified percentage of an historical average abundance estimate. Studies are now needed to establish comparable ecosystem reference points. If harvest of a species affects the numbers of other species in an ecosystem, or the relative abundances of other species in the ecosystem, then criteria are needed to determine what levels of impacts are acceptable and how impacts should be measured. This is an area of fishery science that has not been intensively studied, yet is one that is now perceived as important, since it is related to the overall sustainability of both ecosystems and fisheries.

As an example, ICES (2000) recently considered the ecosystem effects of fishing activities (beam and otter trawling) in the Northeast Atlantic and proposed a number of priority management measures, including the creation of closed areas. ICES (2000) also considered species abundance thresholds in ecosystems that might inadvertently be crossed. The result might be new, relatively stable, ecosystem equilibria being established, with different species dominating in abundance in each. The slowness in the recovery of Atlantic cod may in part be because of a change in ecosystem dynamics, and it has been postulated (Guénette et al. 2000) that the presence of substantial reserves could have helped sustain cod abundance if they had been in place. These are theoretical analyses, but modelling suggests that with precautionary management, the presence of reserves can be advantageous and reduce the risks of potential ecosystem change. Where broad reviews have been conducted (e.g., Anonymous 1997), effective reserves are felt to increase resource harvest sustainability.

Implications of marine protected areas for fisheries management

The beneficial results of having marine protected areas can best be evaluated by considering the primary species involved and site-specific aspects (Murray et al. 1999), as ecosystems and species are too complex to permit any quantitative generalisations that would be meaningful everywhere. However, there are some general benefits that merit discussion regarding the utility of marine protected areas as a tool in fisheries management. Specifically, we discuss the science need for baseline reference sites, the use of protected areas in experimental management, optimal proportions of coastal areas that might ultimately be protected and still sus-

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tain acceptable fish harvests, and the implications of an marine protected area network.

Baseline, or control, sites

One of the challenges in evaluating the potential of reserves is in a priori determination of what the biological community would be like with minimal human impact. Most marine systems have already been extensively impacted (e.g., Lindeboom 1995; Dayton 1998). However, even if fishing in an area was totally eliminated, some human impacts might still continue to exert effects. These include fishing of mobile species elsewhere, possible upland impacts and discharges into the ocean, the possible movement of pollutants and toxins into the area via currents, and climate change if shown to be an effect of human activity. However, in many areas, the effects of fishing are likely to be the present dominant factor affecting the abundances and size frequency structures of most exploited, relatively sedentary species. Reserves would allow natural trophic levels in the community to reestablish themselves. Some of the larger, typically more mobile species that may have been extirpated from the region, such as some whales, basking sharks (*Cetorhinus maximus*), and sea otters in B.C., may take a relatively long time to reestablish, if they ever do. Thus, the biological system that will reestablish now over the long term may not be quite that of the pristine system, but it would be the most natural system possible at this time.

From a research perspective, having such representative systems available for study has a number of advantages. First, comparative monitoring would allow natural mortality and growth rates of exploited species unbiased by fishing to be estimated. While there may be some site-specific differences for these parameters between reserves and exploited areas, in many cases the consequences from fishing are likely to be most significant. Having unbiased parameter estimates could allow improved evaluation of estimates obtained from exploited areas. The basis behind maximising yields in existing fisheries is that by modifying population size frequency structures, the effects of density dependence can be used to maximise production, i.e., growth and survival of recruiting individuals, so that the harvestable yield is optimised. It is thus important to know how parameters estimated in fished environments have actually been modified by fishing. Second, estimates of potential population fecundity are difficult to predict from a significantly modified population size, or age, structure, and while such a natural structure can be postulated, having actual data from unharvested populations would again be desirable to evaluate predictions against.

Experimental management

Theoretical analyses (e.g., Hastings and Botsford 1999; Sladeck Nowlis 2000) and a few field studies (e.g., Alcala and Russ 1990; Bennett and Attwood 1991) suggest that reserves can increase yield with spatially persistent species. Additional field evidence within Canada would be desirable to show fishers that this is indeed the case. However, a problem is that as reserves begin to be established, the full potential of reserves as a stock management tool may not become evident until fishing is terminated over a significantly large amount of the total exploitable area, i.e., until the collective benefits of a reserve network have been established. There is thus the danger that evaluations of field data may be made either too soon or on the basis of inadequate reserve area to allow their full benefits to be evaluated. In the absence of functional reserves that restrict fishing in Canada, the benefits of having a variety of sizes of marine reserves protected may only be assessable theoretically. Only through actually protecting areas can actual benefits and costs be accurately determined and the concerns of cynics as to the merits of reserves be best addressed. Adaptive management (Walters 1986) needs to be accepted as the desirable way of managing a resource. A monitored experimental manipulation of the benefits of having different-sized areas closed to all fishing for specific species has not been attempted to date, so trials that would do this would be “experimental management.” Ongoing monitoring of population responses for relevant species is required at an appropriate time scale, since restrictions on fishing that might be imposed should be adjustable over time so that closures with optimal characteristics can ultimately be identified.

Optimal proportion of the coast in reserves

Politics are to a large extent the balancing of different human interests against each other, and as the marine environment becomes more extensively utilised by humans, the politics of how the marine environment will be used become more complex. In balancing options, there is often the assumption by managers that if areal allocations are approximately equal within an arbitrary accepted harvest level, then they are probably fair. However, while this assumption may generally apply to opportunities for accumulation of monetary wealth, its application to biological systems is not based on science and is not likely to ensure sustainability over the long term. Fairness has nothing to do with the realities of habitat availability, relative species abundances, and so on. “Protection” in reserves of a relatively low (e.g., 10–20%) arbitrary overall percentage of an area with many diverse habitats is likely to be ecologically unsound if the sustainability of a diversity of renewable resources is a primary objective. Some species may benefit, but since protection of the most productive areas is likely to be most resisted by existing users of these areas, the result may tend to be excessive protection of the least productive areas and minimal protection of the most productive areas. Protection is thus not likely to be truly representative of the actual diversity of habitats that exists unless particular efforts are made to achieve comparable protection of all habitats.

Strong science arguments as to the benefits of an optimal level of protection in reserves for significant amounts of all habitats are required. The effectiveness of reserves is some function of reserve size (Edgar and Barrett 1999), and reserve size needs to be judged against the objectives identified. Theoretical studies are needed to evaluate how the productivity of habitat is related to the benefits that might be achieved through reserves. The protection of highly productive areas may suggest that less overall area would need protection while still achieving the benefits associated with reserves. However, minimising the area protected may not be commensurate with maximising benefits and should not necessarily be substituted as a surrogate goal.

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The benefit arising for many species from having a relatively large proportion (e.g., ≥40%) of the marine environment in reserves is a hedge against overexploitation by fisheries (Clark 1996; Sladeck Nowlis and Roberts 1999). Results are related to assumptions around larval transfer functions between reserves and exploited areas. However, it must be recognised that connectivity in the marine environment differs significantly from that in the terrestrial environment (Jamieson and Levings 1998). Connectivity between populations may also largely be a function of habitat type, with species from reef habitats likely to be more sedentary than those inhabiting flatter bottom habitats. The latter habitats are more homogenous, and so, individuals in them are likely to be more wide ranging. The dispersal of most species through meroplanktonic larvae and the open nature of most water bodies means that high harvest rates may be sustained in exploited areas if sufficient reproductive refugia are maintained to provide the exploited area with sufficient larvae for the habitat's carrying capacity for that species.

As a consequence, some marine conservationists have proposed protecting in reserves a specific percentage (e.g., 20% of the area for Atlantic reef fish (Bohnsack 1990) and 10% of all marine habitats in New Zealand (Ballantine 1991)) of the marine environment. This concept is controversial in the terrestrial environment (e.g., 12% is the government's protected area goal for terrestrial B.C.), where it is being questioned by conservationists, and we suggest that it is an even less appropriate concept for the marine environment. The recent petition by many scientists to the world's leaders to set aside in reserves the minimal value of 20% (e.g., U.S. Coral Reef Task Force 2000) is admirable but runs the risk of having insufficient productive or important areas protected to achieve the results expected. However, many environmentalists felt that having something significant protected, at least initially, was better than possibly having relatively little protected and that the time was right to make this argument. However, the devil is often in the details. Without any clear assurance as to what areas might comprise the protected 20%, there is a substantial risk that while that goal may be met, the twin objectives of having all habitats adequately conserved and all existing fisheries sustained may not be. If an appropriate conservation percentage were applied to all a region's major consensually defined marine habitats, then the merits of using a percentage value as a good starting point may be more justifiable. However, the logistics of doing this may be relatively difficult to effect.

Marine protected area networks

Having an adequate prior understanding of at least some of the factors affecting dispersal of the targeted species would seem to be a requirement to develop an optimal network of reserves for species enhancement and the sustenance of fisheries. If metapopulations are known, or are assumed, to exist, it is ideally important to know whether the area where a reserve is being proposed has source or sink populations (Pulliam 1988; Roberts 1998). Sources are areas that contribute disproportionately large quantities of recruits, i.e., larvae and juveniles that survive to reproduce, to future generations, whereas sinks are areas that receive recruits but contribute little to future generations. However, such knowledge is known for only a few species worldwide, and the point has been made (Roberts 1998) that attempting to identify sources and sinks a priori will needlessly delay the establishment of reserves and so oppose rational resource management. Also, different species may have different source and sink areas, so no one reserve is ever likely to be ideal for all species. B. Ballantine (in Pitcher 1997) stated that when little is protected in the early stages of the development of a network of reserves, it does not make too much difference in the long run which area is first protected. Roberts (1998) agreed and stated that the surest way to achieve fishery and conservation goals is to establish a dense network of reserves that incorporate a wide variety of habitats and locations, since then at least some source areas are likely protected by reserves.

Networks also require consideration of the areal scales of the individual reserves involved — should there be a few large or many small reserves? This issue has been discussed under the SLOSS (single large or several small) debate mostly for terrestrial situations. With connectivity issues so different in the marine environment (Jamieson and Levings 1998), its applicability in the marine environment is less certain and has been less studied. McNeill and Fairweather (1993) described an experimental evaluation of this issue, and while they obtained inconclusive results, they did emphasise that processes affecting species' recruitment and the suggested importance of a fragmented habitat on recruitment need particular consideration. Study of how pattern and variability change with the scale of description becomes an important factor (Levin 1992; Dutton and Saenger 1994), as does the mobility of species. The species most likely to disappear from small reserves are those that range most widely, irrespective of population size (Woodroffe and Ginsberg 1998).

Qualitative scheme for classifying and categorising marine protected areas by "level of protection"

Given the variety of marine protected area designations and the different restrictions of human activity associated with each designation type, we believe that there is value in having a relatively objective method of comparing different marine protected area designations by the relative levels of protection that each designation type implies. We therefore propose a process by which this may be done.

We categorise protection with regards to both habitat and (or) species and consider the nature of protection offered by legislation rather than the broad types of impacts that might actually be occurring. Because the nature of impacts can be quite variable, we have considered impact effects in three ways: their severity, duration, and extent. Severity was the relative degree of harm or destruction, without consideration of duration or geographical extent, and was low, medium, or high. An example of a low impact would be disturbance arising from anchoring. Weight is put on the sea floor and the substrate may even be slowly disturbed if the anchor drags, but since anchoring in most coastal areas is by vessels <20 m in length in waters with no significant biological structure (macrophytes or corals), little species mortality typically arises. An example of a high impact would be complete

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Table 4. Impacts and their proposed relative weightings for different human activities on habitat and species.

General activity	Specific activity	Extent of impact (0 = least, 10 = greatest)	
		Direct	Indirect
Habitat impacts			
Resource extraction	Mineral extraction	5	7
	Oil and gas	3	7 (accidents)
	Gravel and sand	5	7 (sediment plume)
Effluent discharge	Industrial or domestic outfall	3 (if diluted adequately)	7 (sublethal effects may promote toxic blooms)
Ocean dumping	Dredged material (may include wood)	5	4 (possible toxics)
	Garbage	5	4 (possible toxics)
	Rock and soil	5	4 (sediment plume)
Dredging	Channels	5	4 (sediment plume)
	Loading areas and terminals	2	4 (sediment plume)
Construction	Piers and docks (piling)	2	2
	Piers and docks (infill)	2	2
Land reclamation	Dyking	10	8
	Groins and breakwaters	2	5 (accretion and erosion)
	Sea walls	2	5 (erosion)
Anchoring		2	2
Fishing	Trawling	8	7
	Longlines	8	5
	Intertidal clam digging or algae harvest	2	2
Aquaculture	Suspended	1	2
	Fish net pens	5	4 (possible toxics)
Ballast water dumping	Introduction of structural species (e.g., mussels and algae)	1	2
Upland disturbances	Increased sedimentation discharge	2	1
	Reduced freshwater discharge	3	2
	Disturbance of natural vegetation	2	1
Logbooming		4	2
Species impacts			
Fishing (managed)	Trawling	8	0
	Longlining	4	0
	Single-pot trapping, diving, gillnetting, pole fishing, etc.	4	0
	Marine plant harvest	2	0
Fishing (unmanaged)		10	0
Aquaculture	Benthic shellfish	3	0
	Intertidal poles	1	0
	Suspended (bivalves, plants)	1	0
	Fish net pens	3	3 (waste and chemical dispersion)
Hunting		3	2 (disturbance)
Behaviour disturbance	Any human activity, including tourism	4	3

Note: Relative "level of protection" would be the sum for those habitat and species impacting activities that are specifically excluded by legislation. *w*,

habitat destruction by dredging or ocean dumping. Duration was the estimated time from the initial stress to recovery and was short term (<2 years), medium term (2–15 years), or long term (>15 years). Extent was the geographical extent of the impact and was site specific, local, or regional. We then considered both the direct and the indirect effects of each activity, with the total score for the impact of each activity the sum of the direct impacts plus a variable proportion (0.1–0.5) of the indirect impacts. We have tried to include all the potential impacting activities that may occur at any site, but additional ones can be added as needed. The scoring that we propose was developed by us and then modified by comments from a number of recognised regional experts (Delphic approach; Crosby et al. 1997 (see Acknowledgements)).

Relative "level of protection," which we term the "protection coefficient" (PC), for each designation type is the sum for those habitat and species impacting activities that are specifically excluded by legislation. The higher the cumulative value of the total excluded impacts, i.e., the PC, the

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Severity and duration of impact (0 = least; 10 = greatest)		Impact (Σ direct) + (*w* × Σ indirect)		
Direct	Indirect	*w* = 0.1	*w* = 0.3	*w* = 0.5
10	8	16.5	19.5	22.5
3	8 (accidents)	7.5	10.5	13.5
10	8 (sediment plume)	16.5	19.5	22.5
3	7	7.4	10.2	13
10	4 (possible toxics)	15.8	17.4	19
10	4 (possible toxics)	15.8	17.4	19
10	6 (sediment plume)	16	18	20
10	6 (sediment plume)	16	18	20
10	6 (sediment plume)	13	15	17
2	2 (fishing and litter)	2.4	3.2	4
10	5 (modified currents, fishing, and litter)	12.7	14.1	15.5
10	8 (removal of estuarine or intertidal habitat)	21.6	24.8	28
10	6	13.1	15.3	17.5
2	4	4.9	6.7	8.5
1	2 (fishing and litter)	3.4	4.2	5
8 (destruction of substrate structure or structural, epibenthic species, e.g., corals)	4 (sediment plume; loss of habitat for other species)	17.1	19.3	21.5
3 (destruction of structural, epibenthic species, e.g., corals)	3 (loss of habitat for other species)	11.8	14.4	15
2	2	4.4	5.2	6
1	2	2.4	3.2	4
9 (destruction of benthic species)	6 (possible toxics)	15	17	19
1	2	2.4	3.2	4
2	1	4.2	4.6	5
5 (disruption of estuarine functions)	3	8.5	9.5	10.5
2 (removal of detrital sources)	2	4.3	4.9	5.5
8 (smothering with bark debris, anoxia)	2	12.4	13.2	14
8 (biological community disruption)	4 (bycatch)	16.4	17.2	18
6	3 (bycatch)	10.3	10.9	11.5
4	2 (bycatch)	8.2	8.6	9
4	2 (bycatch)	6.2	6.6	7
8 (biological community disruption)	4 (bycatch)	18.4	19.2	20
4	3 (predator control)	7.3	7.9	8.5
1	2 (predator control)	2.2	2.6	3
0	0	1	1	1
0	4 (waste and chemical dispersion; potential exotic species escapes)	3.7	5.1	6.5
4	3 (disturbance)	7.5	8.5	9.5
0	4 (site avoidance; reduced feeding and reproduction opportunities)	4.7	6.1	7.5

weighting value.

more the marine protected area is generally protected. We gave indirect impacts an arbitrarily range of reduced weightings (0.1–0.5) relative to direct impacts (Table 4), but while this changed the overall magnitude of the PC calculated, it did not change the relative rankings of overall protection by marine protected area type. Here, we evaluate PCs for marine protected areas in B.C. only, as we did not have details of the legislations under which other provincial and territorial marine protected areas were established in Canada. Environment Canada's national wildlife areas had the highest score, followed by a tied score between national parks and B.C.'s ecological reserves (Table 5). B.C.'s provincial parks and wildlife management areas ranked quite well, with Environment Canada's MBSs ranking quite low. Most of these protected area types, however, did not restrict fishing, which is the single activity that many people associate with a high degree of marine resource protection. As a specific impact, the habitat score associated with fishing is similar to other individual habitat impact scores (e.g., resource extraction). However, because there is also a species impact score

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Table 5. Examples of protection coefficient (PC) values for marine protected areas in B.C.

Jurisdiction	Marine protected area type	Excluded human activities	Habitat PC value (w = 0.5)	Species PC value (w = 0.5)	Total PC value		
					w = 0.1	w = 0.3	w = 0.5
B.C.	Ecological reserve[a]	Resource extraction Ocean dumping Dredging Land reclamation Logbooming Aquaculture Hunting Behaviour disturbance	244.5	36	212.9	246.7	280.5
	Provincial park[a]	Resource extraction Ocean dumping Dredging Land reclamation Log booming Aquaculture	244.5	19	200.7	232.1	263.5
	Wildlife management area[b]	Resource extraction (only sand and gravel) Ocean dumping Dredging Land reclamation Log booming	185.5	0	145.1	165.3	185.5
	Designated wildlife reserve[a]		0	0			0
	"Protected" area[a]		0	0			0
Federal	Marine protected area[c]		0	0			0
	National wildlife area[a]	Resource extraction Ocean dumping Dredging Land reclamation Logbooming Fishing Aquaculture Hunting Behaviour disturbance	287	101.5	305.7	348.1	388.5
	Migratory bird sanctuary[a]	Hunting (seasonal) Behaviour disturbance (seasonal)	0	17	12.2	14.6	17
	National park[a]	Resource extraction Ocean dumping Dredging Land reclamation Logbooming Aquaculture Hunting Behaviour disturbance	244.5	36	212.9	246.7	280.5
	National marine conservation area[c]		0	0			0

Note: Data partially derived from Jamieson and Lessard (2000). w, weighting value.

[a]Generic activities excluded through an Act and therefore characteristic of all marine protected areas of this type.

[b]Only activities compatible with wildlife management are permitted, and so while an Act may not specifically exclude many activities, interpretation of the Act by the site's managing director would preclude the occurrences of activities negatively impacting habitat.

[c]There are no specific human activities excluded through the relevant Act itself, with specific restricted activities determined on a site-by-site basis and then established through regulation. However, fish habitat alteration and disruption and deposition of a deleterious substance are prohibited under the Fisheries Act (see What does "protected" mean? section).

associated with this activity, fishing does in fact have a proportionately high protection value associated with its exclusion from a protected area. Because restrictions for some marine protected area designations are determined on a site-by-site basis (e.g., DFO's MPAs and Parks Canada's NMCAs), theoretically anything can be protected, but no specific thing

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is always protected. Individual sites of these marine protected area types, when established, may potentially rank quite high, but generically, the designation type ranks low, as no protection of any kind is assured.

Future literature may use different relative impact scores or weightings, but if any such changes are described, reference in the literature to relative rankings of marine protected areas proposed here can be compared. At the least, we hope that this evaluation will provoke discussion and recognition as to the actual protection associated with the different types of protected area designations.

The exclusion of fishing by fishery closures for a few individual species in specific marine protected areas has also not been included here as a measure of protection, since such restrictions can be changed relatively easily by regional authorities through variation orders. Existing fishing restrictions may not necessarily be maintained over time scales meaningful for protection of longer lived (50+ years) species in particular, such as rockfish and some shellfish.

This proposed ranking approach has the implementation advantage of only needing to know those impacts that legislation excludes rather than all the possible impacts that may actually be occurring. By comparing the actual impact values for different activities, it is possible to compare the impacts of quite different activities, or even pairs of impacts such as land reclamation and trawling or liquid sewage discharge and dredging. With this proposed approach, different marine protected areas can therefore be evaluated in a number of ways. These include the level of relative protection offered for either habitat or species, or for both combined, and the level of impacts for activities that are known to be occurring, again for either habitat or species or for both combined.

Finally, we have not considered the time period during which the legislated protection may have been in existence for specific sites, even though this may be a crude measure of whether the local environment is now once again relatively pristine. Duration of past protection is too dependent on site-specific information. Factors important here are the species involved and their biologies, the environmental conditions that they occur in, the relative size of the protected area, and a host of other non-marine protected area considerations, including continuing upland impacts, transport of pollutants from outside the area into it, and so on.

Conclusions

The conceptual value of and need for marine protected areas are now well established and broadly accepted by both resource managers and the general public in Canada and in most areas of the world. Nevertheless, many fishers still have concerns that restrictions on fishing will affect their economic incomes. This issue will only likely be adequately addressed through documentation of the consequences in established protected areas, as while theoretical studies may suggest sustainable yields, documented evidence is the best persuader. The beginnings of a coordinated approach to human activity restrictions within protected areas by both the provincial and federal governments are now underway in Canada. However, these efforts to date, at least in B.C., are only just beginning to result in effective renewable marine resource protection through marine protected areas. Difficulties here are a lack of understanding and appreciation as to what might result from use of the different legislative tools available for establishing marine protection and concern that any government restriction of ongoing harvesting will have negative economic consequences. The first MPA in Canada, XwaYeN (Race Rocks) MPA, is a 251-ha no-harvest MPA whose boundaries will exactly match the existing B.C. Race Rocks Ecological Reserve. For renewable resource conservation in other areas, the primary management tool remains fishery closure regulations, quotas, and other traditional stock management measures. In Canada, a process to broaden the establishment of Oceans Act MPAs beyond the five candidate MPAs announced in 1998 is still being developed. Obtaining support from all relevant sectors (First Nations, commercial and recreational fishers, and other resource users) is an important component.

Nomenclature is an issue that needs special attention, as there remains much ambiguity around the use of names (parks, reserves, sanctuaries, etc.) to describe the various areas where protection has been claimed. Provinces establishing protection do not have the mandate or resources to effect protection of renewable marine resources, which the general public would expect from the designated name. In part to address this concern, we proposed a quantitative approach for ranking marine protected areas based on the defined restrictions in the Acts under which they were legislated. Environment Canada's national wildlife area designation offers the most protection, followed by a tied score for National Parks' and B.C.'s ecological reserves. However, as we pointed out, having restrictions designated as laws is separate from having laws enforced, and illegal harvests are a problem everywhere if only enforcement officers monitor human activity. Support and ongoing monitoring by people in local communities are essential if real protection is to be provided in any protected area, whether on land or in the water. This realisation is why so much effort is currently being devoted to obtaining community consensus for boundaries and levels of protection within candidate and existing marine protected areas and why the process of establishing functional marine protected areas has become so time-consuming. It is a complex challenge, one that only time and a will to ultimately succeed can address.

Actual no-take areas of sufficient number, size, and scale to offer functionally significant marine ecosystem protection are almost nonexistent in Canada. Consequently, there are inadequate Canadian field studies of the full benefits that might be obtainable from such reserves, although there have been a number of theoretical analyses. Long-term assessment of the effectiveness of protected areas in meeting conservation or fisheries objectives is required. This should involve (*i*) some ongoing monitoring of biodiversity and the abundances of targeted species, (*ii*) examination of geographical scale relationships of biogeographic assemblages against those of protected areas, (*iii*) evaluation of the functional role(s) of conserved species within the protected ecosystem, and (*iv*) evaluation of relevant dynamic hierarchical relationships and feedbacks among relevant marine ecosystems. None of these are trivial tasks, but if a scientific analysis of the performance of marine protected areas in meeting defined objectives is desired, then consideration of the above is required.

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