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MANAGEMENT DIRECTION FOR THE BOWIE SEAMOUNT MPA:

LINKS BETWEEN CONSERVATION, RESEARCH, AND FISHING

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FINAL REPORT

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1.0 INTRODUCTION

1.1 Background

Bowie Seamount is a rare, discrete, and diverse marine ecosystem. Rising to within 25 metres (m) of the surface from a depth of over 3000 m, Bowie Seamount's shallow-water habitat 180 kilometres (km) from the Queen Charlotte Islands coast is uncommon in the open ocean. The distance of the seamount from shore limits biological exchange, making the Bowie Seamount area relatively isolated ecologically. This rare habitat, coupled with the upwelling and turbulent mixing of water that is characteristic of seamounts, gives rise to a biologically diverse and productive ecosystem that has supported commercial fisheries for Pacific halibut *(Hippoglossus stenolepis),* sablefish (black cod) *(Anoplopoma fimbria),* and rockfish, primarily rougheye rockfish *(Sebastes aleutianus).* Not surprisingly, Bowie Seamount has raised the interest of scientists since the first known oceanographic research program began at Bowie Seamount in 1969.

In 1998, Fisheries and Oceans Canada (DFO) identified Bowie Seamount as a pilot marine protected area (MPA) (Anderson 1998). Subsequently, the area of interest has expanded to include the northwest neighbouring Hodgkins and Davidson Seamounts. Since that time, work has progressed on establishing an advisory team; exploring shared management agreements with the Haida Nation, which has made claim to the offshore area extending to the 200-nautical-mile (nm) limit of Canada's exclusive economic zone (EEZ), including Bowie, Hodgkins, and Davidson Seamounts; consulting with stakeholders; compiling an ecosystem overview; delineating possible boundaries; and creating a draft management plan. As with many MPAs, the advisory team and DFO have wrestled with reconciling the plurality of management issues: conservation, scientific research, and fishing.

1.2 Objectives

The overall intent of this research paper is to address the requirements for and interrelation of conservation, research, and fishing within an ecosystem-based management regime. World Wildlife Fund Canada (WWF) anticipates that this research paper will expedite the Bowie Seamount MPA designation process.

The specific objectives of this paper are as follows:

- Summarize the current knowledge and research being undertaken with respect to ecological integrity and fisheries management in the Bowie Seamount area
- Examine the management regimes of other protected seamounts around the world

- Review the overarching goals of the Bowie Seamount MPA as defined in the Draft Bowie Seamount Marine Protected Area Management Plan (DFO 2001b) within the context of a vision for the MPA
- Assess the ecological rationale of each of the three boundary options as presented in the draft management plan (DFO 2001b) with respect to conservation, research, and fishing
- Assess the ecological rationale for a harvest refugium as part of the Bowie Seamount MPA
- Assess the DFO Science Branch proposal for the Bowie Seamount MPA (Beamish and Neville In prep.) as an experimental research area with respect to conservation, research, and fishing
- Examine how a collaborative relationship with the fishing community could benefit conservation goals

2.0 ECOLOGICAL INTEGRITY OF BOWIE SEAMOUNT

2.1 Ecological Integrity

Conservation of ecological integrity of marine ecosystems, species, and habitats is the main objective of DFO's MPAs programs (DFO 1998b). Underlying this objective is the need to have a common understanding of ecological integrity. Specific definitions vary in the literature. However, the general intent is to recognize whole and complete biological systems, including landscape elements, physical processes, species composition, and functional organization. Terms such as "balanced," "stable," "healthy," "naturally structured," and "optimized" are often associated with ecological integrity, implying a state of sustainability and persistence of a natural, and in some cases historic, habitat (Karr and Dudley 1981; Noss 1990; Woodley 1993; Calicott et al. 1999). In a recent report on ecological integrity of national parks, Parks Canada has revised its definition in an attempt to make it unambiguous, scientifically defensible, and relevant to park managers:

> An ecosystem has integrity when it is deemed characteristic for its natural region, including the composition and abundance of native species and biological communities, rates of change and supporting processes. In plain language, ecosystems have integrity when they have their native components (plants, animals and other organisms) and processes (such as growth and reproduction) intact (Parks Canada 2000).

While previous Parks Canada policy concerning ecological integrity contained the clause "unimpaired by human-caused stressors," more recently this notion has been de-emphasized to recognize that humans are part of ecosystems and not necessarily incompatible with ecological integrity (Parks Canada 2000).

With respect to the Bowie Seamount area, a complete picture of its ecosystem is gradually being brought into focus from over 30 years of research in the area and from research and management of other seamounts (Section 2.2). Fishing activity in the area and at other seamounts is discussed in Section 2.3, in keeping with an inclusive definition of ecological integrity. Research activities are discussed throughout.

2.2 Seamount Ecosystem and Conservation Values

The world's oceans contain an estimated 30,000 seamounts (Rogers 1994). Very few of them have received any level of protection or have been the subject of resource management studies (Table 1). In fact, "overall, the habitats of seamounts, their values, and their relationship with the surrounding waters and seabed are not well understood" (Commonwealth of Australia 2002). Bowie, Hodgkins, and Davidson Seamounts are no exception.

Over 30 years of research and fishing activity in the Bowie Seamount area has gradually produced a body of knowledge concerning such aspects as their bathymetry, oceanography, fisheries resource, and species assemblages (Canessa et al. In prep.). Only recently, however, with the announcement of a pilot MPA, have efforts focused on examining ecological linkages (Beamish and Neville In prep.; Canessa et al. In prep.; Dower et al. 2002).

The following sections summarize the current knowledge of the Bowie Seamount area within the context of the elements of ecological integrity referred to above, namely, landscape elements, physical processes, species composition, and functional organization.

Table 1. Summary of seamount management regimes around the world (AXYS 1999)

Protected or Otherwise Managed Seamounts	Area	Conservation	Research	Fisheries	Other Management
Tasmanian Seamounts Marine Reserve	▪ 370 km^2 ▪ 14 seamounts	▪ Highly Protected Zone (500 m below surface to 100 m below seabed) protects integrity of benthic ecosystem	▪ Non-invasive research techniques are allowed, by permit, in highly protective zone	▪ Longline commercial fishing for tuna is allowed in Managed Resource Zone (to a depth of 500 m)	▪ Management performance assessment system is in place ▪ Management plan is re-evaluated and revised regularly
Cordell Bank National Marine Sanctuary	▪ 1362 km^2 ▪ Area surrounding the seamount plus a large buffer zone	▪ Resource protection goal to protect environment and resources is highest management priority	▪ Sanctuary research goal is to learn about seamount environment and resources	▪ Fishing is currently regulated by the groundfish and salmon fishery management plans (FMPs) ▪ Gillnet fishing has been prohibited in the area	▪ Public awareness goal is to develop interpretive programs that improve public awareness ▪ Visitor management goal is to encourage commercial and recreational use of the sanctuary that is compatible with resource protection
Saba Marine Park	▪ All of Saba Marine Park's offshore waters and two offshore seamounts	▪ Primary purpose of park is to control activities of dive boats and charter boats	▪ No specific research initiatives have been undertaken	▪ Fishing is allowed in multiple use and recreational zone only	▪ 4-level zoning system is used to manage user conflicts and reduce impacts on the marine environment
Kimbe Bay	▪ Network of protected areas within the bay	▪ Multipronged conservation program was developed to protect area and its resources	▪ Limited access is allowed for research monitoring	▪ No-take zones have been established	▪ Community education program exists ▪ Some dive tourism takes place
Antarctic Sites of Special Scientific Interest	▪ 35 SSSIs in Antarctica, 5 of them entirely subtidal	▪ Environmental protection measures include area and species protection ▪ 5 subtidal SSSIs are designated to protect	▪ Primary objective is to safeguard research opportunities from human interference during experiments	▪ Effective control mechanisms are in place to manage commercial exploitation of marine resources	▪ All 5 subtidal SSSIs have been recommended for improved management ▪ Some sites may be re-designated as Antarctic specially protected areas or Antarctic specially managed areas in

Protected or Otherwise Managed Seamounts	Area	Conservation	Research	Fisheries	Other Management
(SSSIs)		sublittoral benthic habitats			the future
New Zealand Seamount Fisheries	▪ 800 seamounts within or near its EEZ	▪ Conservation occurs through improved fisheries management practices	▪ Fisheries stock assessment studies are conducted	Several levels of management were developed, including subarea and/or depth restrictions and fishing methods restrictions	▪ N/A
Hawaiian Ridge Seamount Fisheries	▪ N/A	▪ Moratorium is in place on commercial harvest of seamount groundfish stocks at Hancock Seamount	▪ N/A	▪ Limited access FMP applies to bottomfish and seamount groundfish	▪ N/A

2.2.1 Landscape

Davidson, Hodgkins, and Bowie Seamounts are part of a linear array of seamounts stretching southeast from the Aleutian Trench. The bathymetry of Bowie Seamount was first surveyed in 1969 (Scrimger and Bird 1969). In 2000, detailed multibeam bathymetry of Bowie and Hodgkins Seamounts was collected through a collaborative effort between the Canadian Hydrographic Service of DFO and the Hydrographic Surveys Division of the U.S. National Oceanographic and Atmospheric Administration (NOAA) (NOAA 2000). A bathymetric model derived from the multibeam data provides a fairly detailed representation of the morphology of the seamounts, which is described in Canessa et al. (In prep.). Bowie Seamount rises from a bottom depth of nearly 3100 m to a peak of 24.3 m from the surface, over an area of approximately 25 km by 55 km (1375 km^2). It is characterized by a remarkably flat summit, two distinct terraces dotted with smaller pinnacles, and an extensive ridge structure falling steeply to the base. A saddle at a depth of approximately 2300 m connects Bowie Seamount to Hodgkins Seamount about 30 km to the northwest. Hodgkins Seamount rises to 596 m from the sea surface, over an area of approximately 12 km by 32 km (384 km^2). The summit surface of Hodgkins Seamount is rougher and far more irregular than that of Bowie Seamount and has more distinct pinnacles. Also, compared with Bowie Seamount, Hodgkins Seamount rises less steeply from its base and appears to be more undulating. Approximately 40 km to the northwest of Hodgkins Seamount lies Davidson Seamount rising to 350 m from the sea surface. Detailed bathymetry is not available for Davidson Seamount.

2.2.2 Physical Processes

The types of water flow phenomena at Bowie Seamount have not been studied specifically. However, comparison with Cobb Seamount, which is of similar depth and proximity to the sea surface and has been more extensively researched, provides the following key inferences, which have strong implications for ecological productivity:

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- Internal wave action occurs over the seamount with a concomitant increase in turbulent mixing of water.
- A potentially permanent closed eddy (Taylor cone) penetrates within the euphotic zone, drawing cold, nutrient-rich water (Dower and Fee 1999).

More detailed but limited information on surface water properties was acquired as part of a seabird observation cruise in 1998. Temperature and salinity measurements at the summit of Bowie Seamount show a patch of water with cooler temperatures, higher salinity, and lower chlorophyll, expected characteristics in upwelling or enhanced turbulent mixing of water. However, this snapshot of data is insufficient to draw conclusions on the physical effect of the seamount on water properties.

On a larger scale, the seamounts are subject to regional eddies originating from the west coast of the Queen Charlotte Islands and carrying coastal waters rich in fish, plankton, and nutrients such as nitrate and iron (Crawford 2001; DFO 2001a). Of 15 such Haida Eddies studied since 1992, 11 have passed over Bowie Seamount and, in fact, may linger over the seamounts for as long as three months (John Dower, Department of Biology, University of Victoria, Pers. comm.; Dower et al. 2002). These eddies may provide some insight into the ecosystem functioning of the three seamounts. For example, these eddies are larger in width than a single seamount. Therefore, an eddy stalled over Bowie Seamount may equally influence Davidson and Hodgkins Seamounts, leading to the hypothesis that the ocean's large physical processes, such as currents and eddies, interact with a small seamount chain as a single feature, ecologically linking the three seamounts. Furthermore, it is thought that the eddies function as an episodic recruitment mechanism of rockfish to the seamounts (Dower et al. 2002).

Similar phenomena have been noted for the Tasmanian Seamounts Marine Reserve. It was established in 1999 to protect pristine seamount habitat (Commonwealth of Australia 2002). The 370-km^2 reserve 170 km south of Hobart encompasses 15 of 70 seamounts in the area at ocean floor depths of 1000 m to 2000 m and peaks of 660 m to 1940 m (Koslow and Gowlett-Holmes 1998). The Tasmanian seamount communities appear to be sustained by prey swept past the seamounts from the vast Southern Ocean (Koslow 1997; Koslow et al. 1998).

One of the first studies in the development of the Tasmanian Seamounts Marine Reserve was designed to define the seamount ecosystem and determine the nature of the relationships of the organisms and ecosystems in the water column by studying physical oceanographic processes (Koslow et al. 1998). The researchers concluded that in seamounts rising up to 650 m below the sea surface, the seamount-associated ecosystem could be defined as the waters below 500 m, where the seamount community resides. This conclusion is based on a defined upper water mass that penetrates to approximately 500 m, defining the physical limit to the direct influence of the atmosphere on the ocean in this region. A deeper water mass to extends to 1500 m and a third water mass occurs below 1500 m. The water masses are responsible for two entirely different communities with very different ecologies at the upper slope (200–500 m) and mid-slope (700–1500 m) (Koslow et al. 1998). Studies further determined that pelagic fish do not penetrate into depths greater than about 500 m and deep-water fish do not venture into the upper waters, even to feed (Koslow 1997). The rich seamount ecosystem thus relied on deep-water prey produced over a large area, rather than what is produced in the water column immediately above (Koslow et al. 1998). While the lateral bounds of the seamount-associated system are broad and diffuse, 500 m appears to be the effective upper depth limit of the ecosystem, as determined on the basis of the physical and biological considerations of water mass boundaries and the distributional limit of the community

(Koslow et al. 1998). It was on this basis that the Tasmanian Seamounts Marine Reserve was zoned vertically (see Section 3.1.1.)

Some notable differences appear in landscape and oceanographic processes of the Tasmanian seamounts compared with the Bowie Seamount area. Bowie, Hodgkins, and Davidson Seamounts are much shallower than the Tasmanian seamounts; therefore, the atmospheric influence is likely to be greater in the Bowie Seamount area. In addition, the local water circulation and water mass boundaries have not been studied in the Bowie Seamount area to determine the presence and ecological implications of distinct water masses. The Tasmanian seamounts, furthermore, are smaller and unusually close to each other (Hill et al. 1997). Fifteen seamounts occur within the 370-km^2 reserve. Bowie Seamount itself has a basal area of 1375 km^2.

2.2.3 Species Composition

2.2.3.1 General Description

No systematic research or comprehensive monitoring has been done on the flora and fauna of Bowie Seamount to reliably determine species composition. However, as with other seamounts (Richer de Forges et al. 2000; Koslow and Gowlett-Holmes 1998; Rogers 1994; U.S. Department of Commerce 1989; Wilson and Kaufmann 1987), mounting evidence indicates that Bowie Seamount supports a rich diversity of species exemplified by the juxtaposition of oceanic species (e.g., salps), deep-water species (e.g., prowfish, squat lobsters), and intertidal and shallow subtidal species (e.g., California mussel, split-leaf laminarian kelp) (Austin 1999). A compilation of taxonomic records reveals over 155 plant and animal taxa found on Bowie Seamount and the surrounding waters (Table 2). Almost a third of taxonomic records are fish, most likely because more directed research has been done of fish in comparison with other groups. Isolated research efforts have also focused on zooplankton, benthic habitats, and seabirds (Table 3). Information on marine mammals relies on incidental observations.

Table 2. Species richness of biota observed at or near Bowie Seamount (Canessa et al. In prep.)

Taxonomic group	Number of taxa
Algae	
Brown algae	4
Red algae	10
Protozoa	3
Invertebrata	
Porifera (sponges)	1+
Cnidaria (anemones, jellyfish, hydroids)	7+
Annelida (polychaete worms)	2
Bryozoa (moss animals)	1+
Mollusca (snails, octopus, squid, chitons, bivalves)	6
Arthopoda (barnacles, crabs, amphipods, copepods)	30
Echinodermata (sea stars, brittle stars, sea cucumbers)	6
Urochordata	
Larvacea and Thaliacea (salps)	4
Vertebrata	
Chondricthyes (sharks, skates)	7
Osteichthyes (flounders, soles, rockfish, sculpins)	53+
Aves (albatrosses, auklets, puffins, petrels, shearwaters)	13+
Mammalia (seals, sea lions, dolphins, whales)	8+
TOTAL	**155+**

Table 3. Summary of research on species composition at Bowie Seamount (Canessa et al. In prep.)

Species Group	Research Activities
Zooplankton	▪ Sampling at Bowie Seamount as part of 2000 eddy study (Dave Mackas, Head of Plankton Productivity, Institute of Ocean Sciences, DFO)
Benthos and Benthic Habitat	▪ First Bowie Seamount survey in 1969 (Scagel 1970) ▪ Examination of National Geographic Society video footage (Austin 1999)
Fish	General: ▪ First Bowie Seamount survey in 1969 (Herlinveaux 1971) ▪ Multidisciplinary research survey 2000 ▪ Catch logs ▪ Biological samples collected under fishing permits Rockfish: ▪ Widow rockfish (*Sebastes entomelas*), age and size structure 1969 and 2000 ▪ Rougheye rockfish age structure 1992, 1995, 1996, 1997, 1998, and 2000 (Pacific Biological Station, DFO, groundfish database) ▪ Yelloweye rockfish age structure 1980s ▪ Genetic analyses of yelloweye rockfish 1999 and 2000 Sablefish: ▪ Sablefish tagging studies at Bowie Seamount and coastal areas 1985 to 2001 ▪ Sablefish age structure from otolith measurements in 1988 and 1994 (Pacific Biological Station, DFO, groundfish database) ▪ Parasite tagging studies of sablefish 1987/88 ▪ Genetic samples of sablefish 1999 and 2000 (not yet analyzed) (See also Section 2.3 on fisheries management)
Seabirds	▪ Sightings in the vicinity of the Bowie Seamount summit in June 1997 and June 1998 (Ken Morgan, Pelagic Seabird Biologist, Canadian Wildlife Service, Environment Canada) ▪ Incidental sightings (Ken Morgan, Pelagic Seabird Biologist, Canadian Wildlife Service, Environment Canada)
Marine Mammals	▪ Incidental sightings

Species composition studies at other seamounts point to high levels of endemism and the discovery of previously unknown species. For example, surveys of Tasmanian seamounts found 279 species comprising 242 species of invertebrates and 37 species of fish (Koslow et al. 2001; Koslow and Gowlett-Holmes 1998). The surveys revealed about 60 species that are believed to be previously unknown to science (Koslow and Gowlett-Holmes 1998). Furthermore, comparison studies of seamounts in the southern Pacific Ocean demonstrate a high level of endemism of the Tasmanian seamounts (Richers de Forges et al. 2000). These results underscore the need for more detailed surveys of the Bowie Seamount area to clarify its conservation value in terms of biodiversity and the variation in communities among the three seamounts in terms of depth, topography, and oceanographic processes. This need has been similarly recognized in conservation efforts of New Zealand seamounts where the composition and degree of endemism of seamount benthic fauna and flora has yet to be comprehensively assessed (Brodie and Clark 2002).

2.2.3.2 Fish

As was mentioned previously, more information is known about the composition of fish species, specifically the two commercial species, rockfish and sablefish, than other species.

The fish community at Bowie Seamount is dominated by 21 species of rockfish (Canessa et al. In prep.). This is due to the species life-history strategy of giving birth to live young, a strategy that provides this species more opportunity to settle over the seamount than would laying eggs (Yamanaka et al. 2000). Vertical distribution of rockfish varies with age, the larger, older fish typically occupying deeper habitats (Yamanaka and Richards 1993; Lea et al. 1999). For example, the maximum size of yelloweye rockfish *(Sebastes ruberrimus)* has been observed around 200 m (100 fathoms) (Gerald Dalum, G.P Dalum Enterprises, Pers. comm.). While this appears to be the case for yelloweye rockfish, it has been suggested that the reverse is true for rougheye rockfish, of which more mature fish have been observed in shallower waters and younger fish occupy deeper waters (Gerald Dalum, G.P Dalum Enterprises, Pers. comm.).

A key question is whether rockfish reproduce locally on the seamount or rely on external recruitment. Studies show that some rockfish species, such as widow rockfish *(Sebastes entomelas),* may be self-recruiting and represent reproductively stable populations around the seamount, while others, such as the yelloweye rockfish, may be dependent on recruitment from the coast (Canessa et al. In prep.). Localized distribution of rockfish larvae have been observed around Bowie Seamount (Carter and Leaman 1981). This finding is supported by research on Cobb Seamount that concluded that *Sebastes* larvae were produced locally and, furthermore, dominated the ichthyoplankton community within 30 km of the seamount (Dower and Perry 2001). Age and size distribution studies of widow rockfish conducted in 1969 and 2000 suggest that a self-supporting population exists on the seamount. In contrast, age profiles of rougheye rockfish conducted since 1992 indicate a population composed of very old fish, in comparison with rougheye rockfish in coastal areas (Beamish and Neville In prep.). Similarly, age profiles of the yelloweye rockfish population gathered from scientific permits in the 1980s show comparatively few fish younger than about 15 years (Yamanaka et al. 2001).

In comparison with rockfish, more is known about sablefish at Bowie Seamount, due in particular to tagging studies on dispersal behaviour and recruitment patterns, and a few studies on age composition. Sablefish occupy a wide range of depths, and the vertical distribution of this species varies with age and sex. Spawning occurs below 300 m, after which larval sablefish move to the surface (Mason et al. 1983). Juvenile sablefish travel offshore at intermediate depths (< 1000 m) (Alton 1986). Larger, older fish generally occupy deeper waters (DFO 2002). Adults typically occupy depths down to 1500 m and have been collected from depths close to 3000 m, although adults are reported most abundant between 600 m and 800 m (McFarlane and Beamish 1983a). However, mixing of age classes may more readily occur in areas, such as seamounts, with precipitous slopes because of limits on habitat availability (Saunders et al. N.d.). Age structures of sablefish at Bowie Seamount derived from otolith measurements in 1988 and 1994 show few young-age-class fish found on the seamounts and an older average age of fish compared with coastal fish (Beamish and Neville In prep.). It is also interesting to note that a preponderance of male sablefish was observed on seamounts, and males tended to occur in shallower waters than females (Murie et al. 1996).

While movement of adults is considered to limit contribution to recruitment (Beamish and McFarlane 1988), juvenile sablefish (age 3+) are known to be highly migratory, travelling as far as the Gulf of Alaska and Bering Strait from Hecate Strait (DFO 2002). The evidence of dispersal to and from Bowie Seamount is varied. Parasite tagging studies in 1987/88 indicate that the sablefish on Bowie Seamount are discrete from sablefish in coastal areas and distant seamounts, namely, Union and Dellwood Seamounts (Kabata et al. 1988; Whitaker and McFarlane 1997). This finding is supported by studies on other northeast Pacific Ocean seamounts that led researchers to conclude that once mature sablefish recruit to a seamount they remain there (Alton 1986). However, longer term tagging studies of seamount and coastal sablefish between 1985 and 2001 do indicate movement of sablefish both onto *and* off the seamount, with more significant evidence of recruitment to the seamounts from coastal stocks (McFarlane and Beamish 1983a; Murie et al. 1995; Smith et al. 1996; Downes et al. 1997; Kronlund et al. 2002; Beamish and Neville In prep.; Mark Saunders, Head of Applied Technology Section, Stock Assessment Division, DFO). The Bowie Seamount area is likely on the route from nursery grounds in Hecate Strait and Queen Charlotte Sound to the Gulf of Alaska (McFarlane and Beamish 1983b; McFarlane and Saunders 1983). Age structure analysis in 1988, 1994, and 1998 suggests that sablefish recruitment at Bowie Seamount occurs intermittently (Beamish and Neville In prep.). It is not known whether sablefish spawn on the seamount since spawning occurs during January and March, a period during which little, if any, data has been collected (Mark Saunders, Head of Applied Technology Section, Stock Assessment Division, DFO). Furthermore, no evidence exists of immature sablefish on the seamount (Beamish and Neville In prep.).

2.2.4 Functional Organization

Beamish and Neville (In prep.) undertook the first published attempt to map trophic relationships at Bowie Seamount using an Ecopath model to explore the impact of excessive fishing on key species (Figure 1). In the absence of extensive reliable information on biomass, production rates, consumptions rates, and diet, these authors estimated production and consumption rates on the basis of those reported in other ecosystems. The authors describe the functional organization as follows:

> The trophic system at Bowie Seamount is simpler than the typical coastal ecosystems because of the apparent diminished presence of the small pelagic community on the seamount relative to the number of species at the highest trophic levels … The top predators at the Seamount all tend to be long lived, perhaps suggesting that the habitat is suitable for the survival of these species but less suitable for reproduction. The apparent high abundance of sablefish and rockfish would support this possibility as these species grow very slowly and thus their production relative to their biomass is low. Halibut, however, are large, fast growing predators, which would suggest that they prey heavily on the other species in the Bowie Seamount ecosystem. The large size of the halibut fished in 1990 may indicate that they may remain on the Seamount for many years because of the abundance of prey such as crab, sablefish, rockfish, and perhaps squid. If this interpretation is approximately correct, there must be an abundant food source available to these halibut. (Beamish and Neville In prep., p8.)

It is important to note that the trophic model does not include seabirds and marine mammals, which may use Bowie Seamount as a destination feeding ground, as has been observed at other seamounts such as Cobb Seamount and Cordell Bank. As higher trophic level predators, seabirds prey on plankton, jellyfish, squid, crustaceans, and pelagic fish, and marine mammals prey on krill, squid, octopus, groundfish, and pelagic fish.

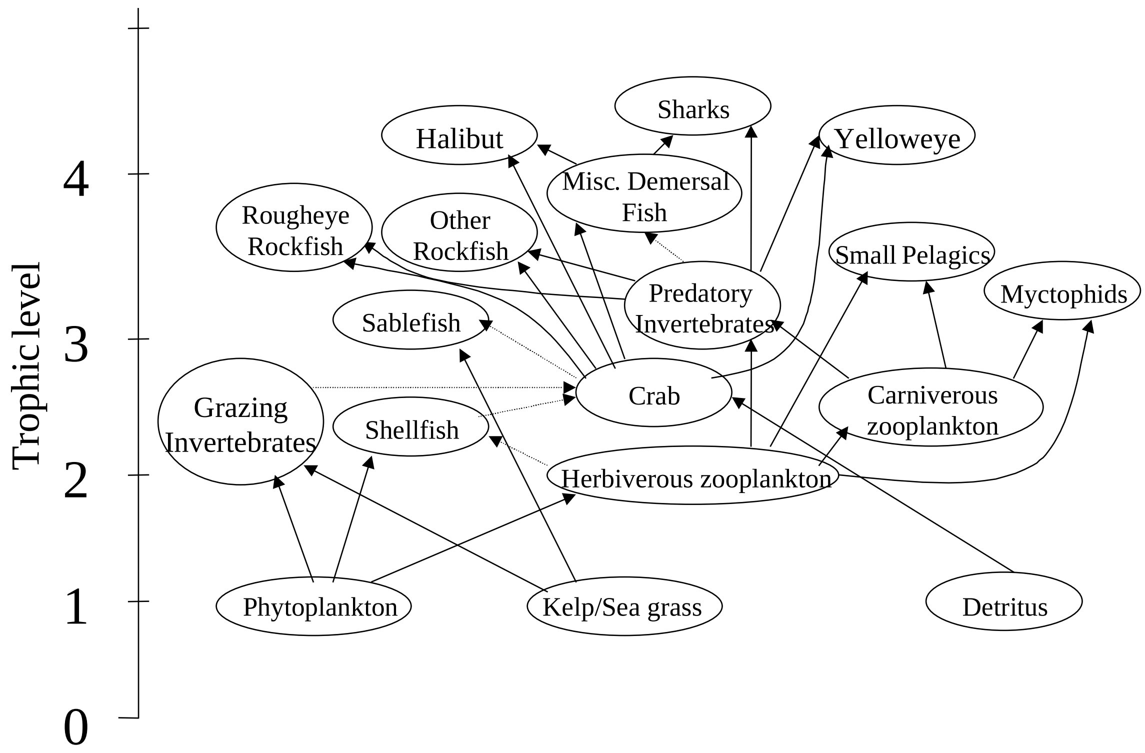

Figure 1. Trophic relationships at Bowie Seamount (Beamish and Neville In prep.)

2.2.5 Summary and Conclusions

This section focused on the ecological integrity of the Bowie Seamount area as defined by landscape, physical processes, species composition, and functional organization. The characterization of the Bowie Seamount area ecosystem is patched together from 30 years of research and observations, model simulations, and studies of other seamounts. The majority of the research has been conducted at Bowie Seamount, and considerably less is known about Hodgkins and Davidson Seamounts. It is known that Bowie and Hodgkins Seamounts and, most likely, Davidson Seamount are connected topographically and possibly oceanographically by mesoscale eddies. (Eddies are vortices of water that are characterized by less saline, warmer waters, and increased sea surface height in relation to surrounding waters. Mesoscale eddies are large eddies, having a scale of 50 to 100 km, and correspond dynamically to high and low pressure systems in the atmosphere). Bowie Seamount supports a rich diversity of species, some of which may be endemic and previously undescribed. The vertical distributions may be less pronounced in steep slope communities like the seamounts due to restricted habitat availability. Some rockfish species may be self-recruiting and represent reproductively stable populations around the seamount, while others may be dependent on recruitment from the coast. Stronger evidence indicates recruitment to the seamounts from coastal stocks rather than vice versa, and no evidence exists of sablefish spawning on the seamount. The apparent diminished presence of the small pelagic community on the seamount and prevalence of long-lived top predators suggest a relatively simpler trophic system than is typical in coastal communities and habitat that is more suitable for survival than for reproduction.

Our knowledge of seamounts is limited in terms of describing and understanding the conservation values, the processes that contribute to those values, the threats to those values, and the need and means to protect them.

These key areas require particular attention:

- Topography of Davidson Seamount
- Localized oceanographic properties, particularly water circulation and water masses around the three seamounts
- Detailed biological surveys of the three seamounts to determine the presence of unique species, variation of habitat and species assemblages with depth, and similarities or differences among the three seamounts
- Distribution of rockfish larvae and immature fish
- Confirmation of recruitment of rockfish and sablefish to and from the seamount
- Interactions and energy flow between pelagic and benthic species
- Systematic understanding of migratory seabirds and marine mammals

2.3 Fisheries Management and Research

Due to their typically high biological productivity and diversity, seamounts around the world have been the target of commercial fisheries (Brodie and Clark 2002). Deep-water species that aggregate on seamounts and have remote pelagic juvenile stages and probably complex recruitment mechanisms are very susceptible to overexploitation and likely to have limited resilience to recover from overfishing (Koslow et al. 2000; Clark 1999; Koslow and Gowlett-Holmes 1998; Rogers 1994). Despite active management of seamount fisheries through total allowable catch (TAC) and quotas, seamount fish stocks continue to decline. Koslow and Tuck (2001) suggest that stock collapse is due to random recruitment variability, when recruitment of deep-water fish such as *Sebastes* spp. is deemed to be highly episodic. Furthermore, Koslow and Gowlett-Holmes (1998) found no evidence to suggest that the seamounts are nursery grounds for fish of commercial importance. However, results of studies within the Cordell Bank National Marine Sanctuary emphasize the importance of rocky substrates as refugia for early life stages of many commercially important species (National Ocean Service 2001).

Almost exclusively, the research on seamount fishing has focused on the impacts of trawling (Fock et al. 2002;

Koslow et al. 2001; National Ocean Service 2001). While fishing in the Bowie Seamount area is conducted with hook and line or with traps, relevant lessons can be learned from other experiences with seamount fisheries. For example, a study of 14 seamounts both fished and unfished in Australia concluded that fauna on unfished seamounts is very similar to that of lightly fished seamounts in the same depth range. However, the benthic biomass of unfished seamounts was found to be 106% higher than that of heavily trawled seamounts (Koslow et al. 2001). The actual and potential impact of fishing, particularly trawling, on benthic communities has been the driving force in protecting seamounts to restore the habitat and populations at those seamounts that have been heavily fished and to maintain in pristine condition those that have not been fished (Brodie and Clark 2002; Commonwealth of Australia 2002; National Ocean Service 2001).

Section 2.3.1 describes seamount fisheries management strategies around the world. Section 2.3.2 describes fishing activity and management in the Bowie Seamount area.

2.3.1 Examples of Seamount Fisheries Management

As was mentioned previously, seamounts throughout the world are targeted and/or explored for commercial fisheries. Some of these seamounts have been encompassed within MPAs (e.g., Tasmanian Seamounts Marine Reserve [Australia], Cordell Bank National Marine Sanctuary [United States], Saba Marine Park [Netherlands Antilles], Kimbe Bay [Papua New Guinea]) or in specific management plans (e.g., New Zealand seamounts, Hawaiian seamounts fisheries). Other seamounts have been proposed for protection (e.g., Banco Gorringe, Galicia Bank, Josefine Bank) and others have been extensively researched (e.g., Great Meteor Seamount, Cobb Seamount). Many of these examples are in the early stages of protection, and formal management plans may not be in place or are evolving as new information becomes available.

2.3.1.1 <u>Tasmanian Seamounts Marine Reserve</u>

The Tasmanian Seamounts Marine Reserve was selected to be protected in part on the basis of the results of a study that indicated that the fauna were highly vulnerable to trawling and likely to have limited resilience, as their slow growth and low natural mortality are adapted to an environment with little natural disturbance (Koslow et al. 1998). On the basis of these conclusions and prior to designation, the fishing industry voluntarily agreed not to trawl a 370-km^2 area of deep, previously unmapped and unfished seamounts pending identification of their conservation importance (Environment Australia 1998). These unfished seamounts were used as a control in a study to determine the impact of trawling on seamounts. The study concluded that while fish stocks were seriously affected by trawling, longline fishing for tuna was believed not to be affecting the stocks (Koslow et al. 2001). This finding became the basis of the seamount fisheries management strategy.

Fishing is not permitted within most of the Tasmanian Seamounts Marine Reserve below a depth of 500 m (Commonwealth of Australia 2002). However, within 500 m of the surface all fishing methods are allowed other than trawl and Danish seine, although fishers within the reserve predominantly use dropline methods (Commonwealth of Australia 2002). This strategy is based on a determination that the removal of tuna has minimal impact on the seamount communities. In addition, due to the length of tuna longlines (up to 130 km), it was deemed impossible to restrict access of tuna fishers to the surface water of the reserve without excluding them from a very large surrounding buffer area (Environment Australia 1998). The non-trawl fishery is regulated by quota management arrangements incorporating an annual TAC and individual transferable quotas (Commonwealth of Australia 1999). In Tasmania, fishers are regulated through a permitting system until a fishery plan comes into force in 2003 (Commonwealth of Australia 2002). Trawl vessels fishing adjacent to the reserve are required to have a vessel monitoring system to track vessel movements (Commonwealth of Australia 2002).

The declaration of the reserve by the Australian government followed extensive consultations with the community, including the fishing industry and conservation groups. This collaboration continues in the management of the reserve. The Australian Fisheries Management Authority has strong partnerships with the regional management advisory committee. In addition, the reserve management authority is developing a framework to encompass the collaborative efforts of the authority and stakeholders (Environment Australia 1998).

2.3.1.2 Cordell Bank National Marine Sanctuary

Cordell Bank is the northernmost seamount on the California continental shelf and is located about 80 km northwest of San Francisco. The bank rises to within 35 m of the sea surface; water depths of 2000 m are only a few kilometres away. In 1989, a 1360-km^2 area surrounding the highly productive seamount was designated as a national marine sanctuary. On the bank are 38 identified varieties of fish, including sablefish and 14 varieties of rockfish.

Cordell Bank supports commercial fisheries targeting rockfish, flatfish, salmonids, groundfish, and albacore tuna *(Thunnus analunga)*. It also supports recreational fisheries targeting rockfish, lingcod, salmon, and albacore tuna (National Ocean Service 2001). No specific commercial fisheries management plan (FMP) has been developed for the Cordell Bank area (Anne Walton, [U.S.] National Oceanic and Atmospheric Association Pers. comm.). Instead, fishing is currently regulated by groundfish and salmon FMPs developed by the Pacific Fishery Management Council (PFMC). PFMC is a regional fisheries management council that develops management plans for fisheries conducted in federal waters off the coasts of California, Oregon, and Washington. The salmon

FMP uses tools such as season length, quotas, and bag limits to manage the resource and is revised annually on the basis of salmon abundance estimates (PFMC, Fisheries Management, Salmon website http://www.pcouncil.org/salmon/salback.html). The groundfish FMP incorporates conservation areas, season, and depth restrictions to rebuild stocks, and gear modifications have been prescribed to reduce by-catch of these species. Gillnetting is prohibited in the area. PFMC is also considering the use of marine reserves as part of their management plan for groundfish along the west coast (PFMC, Fisheries Management, Groundfish website http://www.pcouncil.org/groundfish/gfback.html). Studies have been conducted in the Cordell Bank National Marine Sanctuary on how different fishing gear types affect hard bottom habitats, and the National Marine Fisheries Service has been assessing juvenile rockfish recruitment and surveying adult fish populations (National Ocean Service 2001).

2.3.1.3 New Zealand Seamount Fisheries

Within or near New Zealand's EEZ are over 800 seamounts that are very productive and have high fish and invertebrate densities. These seamounts are the focus of very deep (600–1200 m) trawl fisheries for orange roughy *(Hoplostethus atlanticus),* black oreo *(Allocyttus niger),* and smooth oreo *(Pseudocyttus maculatus)* (Smith N.d.). Stock assessments were conducted in the late 1980s and indicated that the current catch levels could not be sustained. The target species were all long-lived and slow growing, and concern arose that the fish stocks could take decades or centuries to recover if current fishing levels were maintained. In 1986, an individual transferable quota (ITQ) management system was introduced for coastal and deep-water New Zealand fisheries. ITQs provided individuals with a transferable right to harvest a specific proportion of the total allocated surplus production of a stock (Smith N.d.).

Catch rates continued to decline until 1999 when the New Zealand Ministry of Fisheries developed a draft strategy to manage the adverse effects of commercial fishing on seamounts. Several levels of management were developed, including subarea and/or depth restrictions on specific seamounts, restricting fishing within 50 m of the seabed, closure to trawling, and closure to all fishing methods. Key seamounts were then identified and assigned the most appropriate management level. In 2000, 19 representative or unique seamounts around New Zealand were selected for inclusion in a seamount management strategy. A range of management measures was considered to minimize the impact on the fishing industry while protecting seamount habitat. These measures included closure to all forms of fishing, water column restrictions, fishing method restrictions, and area restrictions on individual seamounts, a chain of seamounts, or hill structures (Brodie and Clark 2002). However, the enforcement of these approaches was limited and knowledge of seamount ecosystems was lacking, particularly knowledge about the importance of seamounts, the role seamounts play in the aquatic environment, and the biology, abundance, and distribution of species associated with seamounts (Brodie and Clark 2002).

Nevertheless, the need for a prudent management strategy was recognized.

The prudent management strategy was to close the seamounts to all forms of trawling. In the meantime, the seamount management strategy will evolve incrementally as the state of knowledge improves on the biological and physical characteristics of seamounts and the effects of trawling on seamount invertebrates and seamount biodiversity, and as the adequacy of existing measures is reviewed (Brodie and Clark 2002).

The seamount closures do not have the support of the fishing industry. Fisheries stakeholders were given the opportunity to identify alternatives to the closure of the 19 seamounts identified. These shareholders suggested no alternatives, perhaps because the fishing industry questioned the necessity for management action, given that only some of the vast number of seamounts in New Zealand are fished, and of those seamounts fished, some can be fished only on certain parts (Brodie and Clark 2002). The lack of support was also a possible contributing factor to the implementation of regulatory measures over preferred voluntary measures to implement the seamount closures. The fishing industry was not able to develop a code of practice that incorporated auditing and performance monitoring, and thus regulatory measures were legislated (Brodie and Clark 2002). In New Zealand, the fishing industry pays for the cost of a large proportion of fisheries research and management, either through direct sponsorship of research or through government levies to cover their expenditure on commercial fisheries (Orange Rougheye Company website http://www.orangeroughynz.com/research.html). However, the relative contribution of funding by government and industry for seamount research is being challenged by the fishing industry since some seamount research relates to impacts of fishing while other projects are geared toward increasing knowledge about seamounts. No information is available on the extent to which the fishing industry participates otherwise in collaborative management.

2.3.1.4 Hawaiian Ridge Seamount Fisheries

The Hawaiian Ridge seamount groundfish complex consists of three species (pelagic armorheads [*Pseudopentaceros richardsoni*], alfonsins [*Beryx splendens*], and ratfish [*Hyperoglyphe japonica*]). These species dwell at depths of 200 m to 600 m on the submarine slopes and summits of seamounts. This area has seen a large-scale foreign seamount groundfish fishery that resulted in a collapse of the seamount groundfish stocks (NOAA–Western Pacific Fishery Management Council website http://www.wpcouncil.org/). In August 1986, the Western Pacific Regional Fishery Management Council developed a limited access FMP for the bottomfish and seamount groundfish fisheries. This plan was developed over time, undergoing a series of amendments as regulatory and public reviews took place. The main objective of the FMP is to ensure long-term productivity of bottomfish stocks while maintaining fishing opportunities for small-scale commercial fishers. A moratorium on the commercial harvest of seamount groundfish stocks at Hancock Seamount and the implementation of a permit system for fishing for bottomfish in the EEZ around the northwestern Hawaiian Islands are two of the main components of the plan. The management framework for the plan includes catch limits, size limits, area and seasonal closures, fishing effort limitation, gear restrictions, access limitation, reporting requirements, and a rules-related notice system.

2.3.1.5 Summary and Conclusions

Experience in the management of seamount fisheries in both protected and unprotected seamounts is varied (Table 4). In the four examples examined, all but one, the Cordell Bank National Marine Sanctuary, prohibits trawling. Research on fishing impacts and general seamount biodiversity is a fundamental component of three of the examples examined. Limited information is available on the extent of collaboration by the fishing industry. Collaboration appears to be most successful in the Tasmanian Seamounts Marine Reserve; however, only previously unfished seamounts were included in the reserve. In contrast, industry collaboration is lacking in the New Zealand seamount fisheries where fished seamounts were closed to fishing.

Table 4. Comparison of seamount fisheries management

Seamount	Marine Protected Area	Fisheries Management	Research	Industry Collaboration
Tasmanian Seamounts Marine Reserve	Yes	▪ Trawling and Danish seining closures on selected seamounts, ▪ Non-trawl fishing within vertically zoned area managed by TAC and ITQ	▪ Impacts of fishing on seamounts ▪ Benthic–pelagic linkages	▪ Only regarding previously unfished seamounts included in reserve
Cordell Bank National Marine Sanctuary	Yes	▪ No specific commercial FMP ▪ Regional fisheries management prohibiting gillnetting, managed by season length, quotas, depth restrictions, and gear modification	▪ Impacts of different gear types ▪ Juvenile rockfish recruitment	▪ Unknown
New Zealand Seamount Fisheries	No	▪ Closures on selected seamounts	▪ Biological and physical characteristics of seamounts ▪ Trawling impacts on seamount invertebrates ▪ Seamount biodiversity	▪ No industry support
Hawaiian Ridge Seamount Fisheries	No	▪ Groundfishing closures on selected seamounts ▪ Permit system for bottomfishing ▪ Management by catch limits, size limits, area and seasonal closures, fishing effort limitation, gear restrictions, and access limitation	▪ Unknown	▪ Unknown

2.3.2 Bowie Seamount Fisheries Research and Management

Regionally, vessels from both Canada and the United States[1] conduct commercial fisheries over about a dozen seamounts in the Pacific Ocean, including Bowie and Hodgkins Seamounts. The fisheries at Bowie Seamount have existed on a limited basis for groundfish such as rockfish (*Sebastes* spp.), sablefish, and Pacific halibut and more migratory species such as albacore tuna. Additionally, test fisheries for neon flying squid *(Ommastrephes bartrami)* have included the Bowie Seamount area (DFO 1998a). Once it was determined that Bowie Seamount was home to at least two commercially important fish species, rockfish and sablefish, research into stock assessment, age structure, and population dynamics ensued. Some data have been collected from research trips and some from catch statistics from commercial vessels. Nevertheless, adequate stock assessment and maximum sustainable yield data for fishery resources in the seamount area generally are lacking (DFO N.d.[c]; Beamish and Neville In prep.; Dale Gueret, Area Chief, Oceans and Community Stewardship, North Coast Area, DFO).

Table 5 summarizes the fishing activity at Bowie Seamount. Table 6 summarizes fishery management and research at Bowie Seamount.

2.3.2.1 Sablefish Fishery

Fishing Activity

A formalized experimental sablefish seamount fishery, including the collection of biological samples, commenced in 1983 with the issuance of scientific permits. Bathymetry, feed, and abundance of fish have focused fishing effort on Bowie Seamount rather than Hodgkins and Davidson Seamounts (Bruce Turris, Canadian Sablefish Association [CSA] Pers. comm.). The cumulative catch from 1987 to 2000 was approximately 1452 tonnes (metric tons, t) with an average annual catch for the same period of approximately 104 t (Beamish and Neville In prep.). The sablefish fishery at Bowie Seamount peaked in 1991 at over 300 t and has fluctuated since then but with levels generally well below 100 t. In 1991, the increase in sablefish catch corresponded to an increase in the number of vessels fishing, traps deployed, and the length of time the fishing gear is in the water (hours soaked). The catch-per-unit-effort (CPUE) trend is continuing to decrease, and the sablefish catch was approximately 10 t in 1998 although it rose again to close to annual average levels in 1999 and 2000 (Beamish and Neville In prep.).

[1] The discussion focuses exclusively on the Canadian commercial fishery in the Bowie Seamount area as information on the U.S. commercial fishery is not readily available.

Between 1996 and 2001, an annual average of four seamount sable fishery permits were issued and used over a six-month period at Bowie Seamount (Archipelago Marine Research 1997, 1998, 2000, 2001; Canessa et al. In prep.). Traps on Bowie Seamount have been set in depth ranges of 240 m to 1330 m, although predominantly between 925 m and 950 m (Canessa et al. In prep.).

Fishery Management

The current seamount fishery is conducted on the basis of a limited draw whereby one vessel per month is drawn from the pool of K (sablefish/blackcod) licensed vessels at random, and the vessel is then issued a permit to fish the Northern Offshore Seamount area (DFO N.d.[c]). The limited draw does not represent an actual overall reduction in vessel trips. Bowie Seamount is the only seamount fished for sablefish in the Northern Offshore Seamount area. All permitted vessels must carry either an electronic monitoring system or a certified observer and must collect biological samples for research purposes. Fishing for sablefish on the seamounts is permitted only by trap and/or hook and line gear (DFO N.d.[c]). Canadian sablefish catches from the seamount fishery are not included in the TAC for the fishery or in individual fisher quotas, and vessels are permitted to retain all sablefish caught each trip (DFO N.d.[c]).

Table 5. Summary of fishing activity at Bowie Seamount

Fishery	History of Activity	Level of Effort	Tonnage	Gear	Depth
Sablefish	▪ Limited experimental sablefish seamount fishery occurred in 1983 ▪ Commercial activity documented 1987–2000	▪ 45 commercial fishing trips have been made to Bowie since 1990 ▪ 1–8 trips take place per year ▪ Average number of trips per year is 4	▪ 1987–2000 cumulative catch at Bowie Seamount was 1452 t ▪ Average annual catch was 104 t ▪ Maximum catch was just over 300 t in 1991	▪ Trap ▪ Hook and line	▪ Trap depth range 242–1326 m ▪ Average depth 860 m
Rockfish	▪ Taken incidentally in sablefish fishery ▪ Directed fishery started in 1992 under scientific licence ▪ Fishery closed after 1999 season	▪ Level of effort at Bowie Seamount is uncompiled	▪ 1993–2000 cumulative catch at Bowie Seamount was 105 t ▪ Average annual catch was 165 t ▪ Maximum catch occurred in 1999	▪ Hook and line	▪ 175–550 m
Pacific halibut	▪ Some halibut fishing has occurred at Bowie Seamount since 1950s ▪ Limited fishing activity has occurred from 1980	▪ Halibut fishing activity has been low to non-existent for area around Bowie Seamount since 1980 ▪ 5 boat landings of	▪ Total weight was just under 63,050 kg 1984–92	▪ Hook and line	▪ Unknown

	▪ No commercial records since 1991 exist	fish were caught 1984–92			
Albacore tuna	▪ Harvest records show harvests have occurred within Canada's 200-nm EEZ since at least 1952 ▪ No specific data is available for Bowie Seamount	▪ 2 boats fished in 1980 ▪ Other information is unavailable	▪ Unknown	▪ Hook and line	▪ Surface
Squid	▪ Experimental flying squid fishery was examined in early 1990s ▪ Experimental management plan for flying squid was established 1996 ▪ Catches of neon flying squid at Bowie Seamount were attempted 1998	▪ Level of effort is low	▪ TAC of 1500 t set in 1996 ▪ Experimental fisheries produced low catches in Bowie Seamount area	▪ Single-hook jig line	▪ Surface to 9.14 m

Table 6. Summary of fishery management and research at Bowie Seamount

Fishery	Licensing	Current Fishery Management	Fishery Management Research
Sablefish	▪ Previously, as scientific permit ▪ Currently, as limited draw, 1 vessel per month from K pool	▪ Fishery takes place within Northern Offshore Seamount management area ▪ Seamount fishery catches are not included in TAC or individual fisher quotas ▪ 2003 seamount fishery will be open 1 May 2003–31 October 2003 ▪ Fishing on seamounts is by trap and/or hook and line gear only ▪ By-catch issues are being addressed by DFO and CSA, e.g., escape rings for traps and mandatory seabird avoidance measures and devices for the longline fleet ▪ Permissible rockfish by-catch is limited according to gear and % of sablefish landed weight	▪ Vessels are required to carry either electronic monitoring system or certified observers ▪ Biological samples are required for research purposes ▪ Sablefish stock identification studies were conducted in 1987/88 ▪ Ongoing analysis is done of CPUE data and biological samples
Rockfish	▪ Fishery with an Outside Category ZN licence with 1 of 4 annual harvesting options: A, B, C, or D ▪ Scientific permit rockfish	▪ Overall management goal is to conserve and rebuild rockfish stocks ▪ Bowie Seamount area was closed to the rockfish fishery	▪ At-sea observer is required on every trip during scientific permit fishery ▪ Dockside monitoring and logbook programs are in place for entire

Fishery	Licensing	Current Fishery Management	Fishery Management Research
	fishery for seamounts 1993–99 ▪ No permits for Bowie Seamount since close of 1999 season	following 1999 season ▪ Rockfish by-catch management methods are in place for other fisheries	fleet ▪ Genetic diversity studies of Bowie Seamount rockfish were conducted 1998–2001 ▪ Survey methods have been developed for directly estimating inshore rockfish abundance using the 2-person submersible DELTA in 2000
Pacific halibut	▪ Commercial halibut vessels under a Category L or a Category FL commercial communal licence ▪ In 2000, pilot program for combination fishing privileges between halibut and Outside Category ZN licence holders (also known as Option D)	▪ Commercial fishery season dates are set by International Pacific Halibut Commission (IPHC) each year, and generally season is open 15 March–15 November ▪ Currently, no restrictions prevent halibut fishery activity in Bowie Seamount area ▪ By-catch issues are being addressed by DFO and Pacific Halibut Management Association, e.g., mandatory seabird avoidance measures and devices (DFO N.d.[a]) ▪ Vessels are allocated individual species and aggregate allocations of rockfish available to the halibut fleet (DFO N.d.[a]) ▪ Port samplers interview vessel masters regarding by-catch species (DFO N.d.[a])	▪ At-sea observer is required on every trip, with a 25% coverage level ▪ Dockside monitoring and logbook programs are in place for entire fleet ▪ Stock assessments are conducted by IPHC for entire fleet ▪ No known fisheries research is being conducted specifically at Bowie Seamount
Albacore tuna	▪ Fishing under A, C, G, K, L, N, R, S, T, or W licence categories	▪ Tuna fishery for entire Canadian fisheries of Pacific Ocean was open 1 April 2002–31 March 2003 ▪ No specific management of seamount tuna fishery takes place ▪ By-catch in the jig fishery is estimated to be less than 2% (Bailey et al. 1996) ▪ No specific by-catch management provisions exist (DFO N.d.[d])	▪ Entire fleet is required to submit logbooks and fish slips for tuna fishing ▪ No active Canadian research programs are under way
Squid	▪ 3-year experimental fishery in Pacific Ocean in place 1999–31 March 2002 requiring a scientific licence	▪ N/A	▪ Logbooks and fish slips are required ▪ Onboard observer is required on request by DFO

Beamish and Neville (In prep.) argue that due to being long-lived and slow growing to maturity, sablefish are susceptible to overfishing, particularly on Bowie Seamount. CPUE for sablefish on the seamount has declined

(Beamish and Neville In prep.), and the decrease in CPUE and total catch to 1993 suggested that the population of sablefish on Bowie Seamount was not sustainable at current fishing levels (Murie et al. 1996). Owing to these declines, the seamount fishery was restricted in 1992 to April to November and again in the mid- to late 1990s to May to October (DFO N.d.[c]). Uncertainty remains regarding whether the "abundance of sablefish populations are being depleted within a fishing season of any one year or the availability of the fish changed during the year through recruitment or increased aggregation of sablefish on the seamount" (DFO N.d.[c] p. 12). CSA has indicated that in years when ocean conditions, such as weaker offshore currents, do not favour a strong population on the seamounts, CSA may not conduct as many fishing trips as in other years (Bruce Turris, CSA, presentation to the Bowie Seamount Area Pilot MPA Advisory Team Meeting, 5 September 2001). Sablefish fishers also have not observed increased sablefish harvests in years following those when fishing was not conducted on the seamount (Bruce Turris, CSA, presentation to the Bowie Seamount Area Pilot MPA advisory meeting, 5 September 2001). Furthermore, any fisheries management measures at Bowie Seamount are based on the absence of information on the seamount ecosystem rather than on specific sablefish fisheries concerns (Dale Gueret, Area Chief, Oceans and Community Stewardship, North Coast Area, DFO, discussion at the Bowie Seamount Area Pilot MPA advisory meeting, 5 September 2001). However, data from the DFO groundfish catch database and logbooks show catch in every year between 1987 and 2000 (Beamish and Neville In prep.)

DFO and CSA work cooperatively in monitoring, research, assessment, and management of the commercial sablefish fishery. The Seamount Program is one of nine initiatives currently included in the joint project agreement. Other programs include the Biological Sampling Program, Biological Data Collection Program, and Stock Assessment Program (DFO N.d.[c]). The annual CSA budget for sablefish science and management is approximately $1,200,000, and includes DFO salaries, benefits, charters, and contracts (CSA website http://www.canadiansablefish.com). The budget is funded by sablefish licence holders through CSA and covers a variety of activities, including the following:

- A tagging program to determine annual exploitation rates; CSA members conduct tagging charters with contracted scientific technicians onboard; CSA contracts an independent firm to process tagging data monthly
- Random collection of biological samples to determine age, sex, maturity, and stomach contents assessment conducted by an independent firm contracted by CSA and co-authored by DFO scientists
- Dockside monitoring contracted by CSA and certified by DFO to monitor compliance with individual vessel quotas, and by-catch limits and documentation (CSA website http://www.canadiansablefish.com)

Each of these activities contributes to the Objective-Based Fisheries Management Initiative, a pilot fisheries management program based on defining conservation and ecosystem limits (DFO N.d.[c]).

Research

CSA and DFO have been working collaboratively on sablefish research and the development of integrated FMPs. Research on sablefish prompted by fishery management has been described in Section 2.2.3 and above. This research has included tagging and parasite studies to determine migration and recruitment patterns and otolith measurements to derive age structures. Biological information for sablefish is also acquired from samples obtained from every sablefish seamount trip as a research requirement for the fishery. In addition, research is being conducted on the relationship of climate and ocean productivity regimes and sablefish year classes.

A review and analysis of data gathered from the sablefish seamount is being considered as part of the 2003/2004 Pacific Scientific Advice Review Committee (PSARC) planning process to assess the impacts of sablefish fishing on the seamount ecosystem (DFO N.d.[c]). One of the main topics to be considered is whether the abundance of sablefish populations is being depleted within a fishing season of any one year or the availability of the fish changed during the year through recruitment or increased aggregation of sablefish on the seamount (DFO N.d.[c]). Beamish and Neville (In prep.) predict that a 90% overfishing of sablefish on the seamount would increase the abundance of crab and rockfish, which would become available to halibut.

2.3.2.2 Rockfish Fishery

Fishing Activity

Rockfish were taken incidentally in the sablefish fishery until 1992 when a directed fishery was permitted with reported higher CPUE than the inshore fisheries (Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.). The rockfish fishery expanded owing to the express objective of one vessel targeting these underused species on the seamounts (Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.). Nevertheless, only one operator has predominated the rockfish fishery on Bowie Seamount because of the travel distance, the weather, the value of the species, and the dark colour associated with seamount rockfish due to the black volcanic sand and rock on Bowie Seamount (Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.). The rockfish fishery in the Bowie Seamount region focused exclusively on Bowie Seamount. Neighbouring seamounts were not fished due to sufficient available resources at Bowie Seamount (Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.). The target depth for rougheye rockfish on Bowie Seamount was 145 m to 460 m. Generally, the shallow waters (145–275 m) produced larger rougheye rockfish than deeper waters. Yelloweye rockfish, fished primarily for research purposes, were targeted in waters shallower than 90 m (Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.). Fishing effort on Bowie Seamount focused primarily on three specifically targeted areas (Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.).

The cumulative catch from Bowie Seamount between 1993 and 2000 was 1430 t, with an annual average of about 130 t (Beamish and Neville In prep.). There are no indications of a significant change in the size of rockfish over this period (Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.). The rockfish landing data from 1993 to 2000 indicate that rougheye rockfish comprise the bulk of the catch and have been the targeted species in recent years. Confidentiality provisions prevent reporting catch data in years in which fewer than three vessels fished; however, the rockfish catch at Bowie Seamount between 1998 and 2000, including the decadal high in 1999, was considerably higher than the annual average (Beamish and Neville In prep.). In 1999, Bowie Seamount accounted for about 20% of the total Canadian rougheye rockfish catch (Beamish and Neville In prep.). The catch dropped to 10% in 2000.

Fishery Management

Commencing in 1992, the Bowie Seamount rockfish fishery was regulated by scientific permit requiring vessels to have an observer onboard, approved and under contract to DFO. Bowie Seamount is located within management area 142, which is a Queen Charlotte Islands Rockfish Quota Management Area. However, the seamount fishery was not incorporated into the Rockfish Hook and Line Fisheries Management Plan. The catch of rockfish on Bowie Seamount was additional to the commercial rockfish TAC, and no limit was placed on the catch. The management objectives for the 2002/03 season are to ensure conservation and protection of the species through application of scientific management principles and to continue implementing measures identified in the Inshore Rockfish Conservation Strategy to protect and rebuild inshore rockfish stocks. Some of the rockfish protection measures include implementing rockfish mortality accountability, increasing at-sea observer coverage, further reducing commercial TAC for inshore rockfish, continuing the implementation and expansion of rockfish protection areas, and improving stock assessment programs (DFO N.d.[b]). Although Bowie Seamount is not included as a rockfish protection area, no further scientific permits for the rockfish fishery at Bowie Seamount were issued after the end of the 1999 season. However, a charter fishery was undertaken in 2000 as part of a research program (Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.). Since 2000, rockfish have not been fished at Bowie Seamount except as by-catch.

Rockfish by-catch is a key concern in the FMP, and rockfish by-catch management methods are in place for other fisheries. In the sablefish fishery, rockfish by-catch is permitted up to 10% of the landed weight of sablefish for vessels with trap gear and up to 40% of the landed weight of sablefish for vessels with hook and line gear (DFO N.d.[c]). Although there have been no recent landings of halibut from Bowie Seamount, it is important to note that halibut vessels are allocated individual species and aggregate allocations of rockfish available to the halibut fleet. These rockfish allocations are transferable to accommodate the variance in by-catch by area, season, and individual (DFO N.d.[a). Specific data on by-catch at Bowie Seamount is currently being summarized for the Bowie Seamount ecosystem overview. Anecdotal evidence indicates that the by-catch from the rockfish fishery itself was “low, except for halibut and sablefish” (Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.).

Research

Little research activity occurred at Bowie Seamount until the early 1980s when two exploratory trips were taken to investigate rockfish resources using experimental hook and line gear and gillnets, and to collect biological data on the two prominent species present: rougheye rockfish and yelloweye rockfish (Carter and Leaman 1982; DFO 1998a). The Deep Sea Trawlers Association of British Columbia conducted an exploratory trawl survey of Bowie Seamount in 1993, in a joint initiative with DFO and the British Columbia Ministry of Agriculture, Fisheries and Food (Canessa et al. In prep.).

As was discussed in Section 2.2.3, previous research into rockfish prompted by fisheries management included age and size structure of widow rockfish, age profiles of yelloweye and rougheye rockfish, and genetic studies of yelloweye rockfish. In addition, the scientific permit required vessels to take a designated number of samples (50–100 fish per trip [Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.]) that were processed for age, size, sex, and sexual maturity.

Genetic studies have been conducted to determine genetic variation within yelloweye rockfish, particularly studies of the dark and bright phenotype, in the coastal waters of British Columbia (Yamanaka et al. 2000). The results show that samples of the dark yelloweye rockfish phenotype from Bowie Seamount are not genetically differentiated from samples of the bright phenotype from the same or other sites (Yamanaka et al. 2000).

In August 2000, the DFO Pacific Biological Station, together with Gwaii Haanas National Park Reserve and Haida Heritage Site (Parks Canada), the International Pacific Halibut Commission (IPHC), the commercial ZN fishing industry, the Universities of British Columbia and California (Santa Barbara), and the Canadian Wildlife Service (Environment Canada) conducted a multidisciplinary research cruise to Bowie Seamount and Gwaii Haanas. Primary research included the development of in situ survey methods for directly estimating inshore rockfish abundance using the two-person (observer and pilot) submersible DELTA. This research included a sampling of rockfish populations to obtain stock assessment data, as well as data regarding fish health (DFO 2000; Environmental Science Strategic Research Fund 2000).

G.P. Dalum and Associates was involved in the 2000 research cruise by harvesting rockfish along the same transects as those surveyed using the submersible. In addition, the company has offered to collaborate further in seamount fisheries research by providing a vessel for scientific research and funds to analyze research data (G.P. Dalum, G.P. Dalum and Associates, Pers. comm.).

Beamish and Neville (In prep.) are conducting the most direct research on stock assessment and the impact of overfishing on Bowie Seamount. By estimating biomass, production rates, composition rates, and diet of species or groups of species with a balance (Ecopath) model, these researchers can develop various scenarios of excessive fishing on key species. A 90% reduction of rougheye rockfish is estimated to cause a "major imbalance" in the model, reducing prey for sablefish and halibut to a level that would not support the existing populations. The authors hypothesize that sablefish and halibut would either feed heavily on crab or leave the seamount.

2.3.2.3 Pacific Halibut Fishery

Fishing Activity

Halibut fishing in the Bowie Seamount area has been conducted since approximately the 1950s, but no records of early removals exist (Bruce Leaman, Director, IPHC; Beamish and Neville In prep.) Significant consecutive annual harvests have been rare. Between 1984 and 1992, five boat landings from Bowie Seamount were recorded, totalling just over 63,000 kg. Since 1991, no records of commercial halibut landings from Bowie Seamount have been recorded (Keri Taylor, Archipelago Marine Research Ltd.; John Davidson, DFO, Pers. comm.).

Halibut fishing techniques include bottom trawls and longline sets. The season dates for the commercial fishery for halibut are set by IPHC each year. Generally, the season is open from 15 March to 15 November. Since halibut spawn at depths of from 183 m to 457 m along the continental shelf, some scientists speculate that Bowie Seamount may provide important spawning grounds (DFO 1998b).

Fishery Management

No specific assessments have been done of the total biomass for halibut at the seamount (Beamish and Neville In prep.) Currently, no restrictions prevent halibut fishery activity in the Bowie Seamount area beyond scientific permit and onboard observer requirements (DFO Bowie Seamount Committee Meetings, 19 February 2002).

DFO and the Pacific Halibut Management Association are addressing by-catch issues, including mandatory seabird avoidance measures and devices (DFO N.d.[a]).

Research
Beamish and Neville (In prep.) estimated that a reduction of halibut by 90% would increase the abundance of sablefish, rockfish, and crab.

2.3.2.4 Albacore Tuna Fishery

Albacore tuna harvest records show that harvests have occurred within the Canadian 200-nm EEZ since at least 1952 (DFO 1999). While harvests generally have occurred closer to the Queen Charlotte Islands, albacore tuna have been caught at Bowie Seamount, particularly when warm water moves north (William Shaw, Hook and Line Biologist, Pacific Biological Station, DFO; Pers. Comm.; Billy de Greef, Pacific Coast Fishing Vessel Owner's Guild, Pers. Comm.). At least two boats fished for tuna at Bowie Seamount in September 1980 (Billy de Greef, Pacific Coast Fishing Vessel Owner's Guild, Pers. comm.). Over the years, U.S. fishers have been known to come south from their Alaska salmon fishery and try tuna fishing off Bowie Seamount, although the size of their catches is unknown (Billy de Greef, Pacific Coast Fishing Vessel Owner's Guild, Pers. Comm.). Albacore trolling is conducted near the sea surface away from bottom habitat.

By-catch in the jig fishery is estimated to be less than 2% (Bailey et al. 1996), and no specific by-catch management provisions exist (DFO N.d.[d]).

2.3.2.5 Squid Fishery

The potential for a squid fishery throughout B.C. waters and at Bowie Seamount has been explored for many years. Jamieson and Heritage (1986) describe some of the efforts undertaken to determine the feasibility of this fishery in Pacific waters. In 1990 and 1991, a coast-wide exploratory squid-jigging program took place, some of it near but not over Bowie Seamount (William Shaw, Hook and Line Biologist, Pacific Biological Station, DFO). A second experimental fishery for neon flying squid also took place in 1990 and 1991 as part of a joint venture fishery between DFO and a Japanese cooperative using commercial Japanese jig vessels (DFO 1998c). An official experimental management plan for flying squid was established in 1996 with a TAC of 1500 t. Catches of neon flying squid at Bowie Seamount were attempted in two sets in the 1998 fishery, resulting in very low catches. The fishing procedure for squid involves the use of single-hook jig lines that generally are sent down only to about 9 m. These lines are mechanically "jigged" back to the surface and returned to a predetermined depth.

2.3.3 Summary and Conclusions

Although there has been interest in a variety of commercial species, fishing activity at Bowie Seamount has targeted sablefish and rougheye rockfish using traps and hook and line gear. Unlike other seamounts, Bowie, Hodgkins, and Davidson Seamounts have not been subjected to bottom trawling. In both fisheries, little if any activity has taken place on Hodgkins and Davidson Seamounts owing to their bathymetry and abundance at Bowie Seamount.

Seamount fish stocks have been managed separately from other stocks, and different approaches have been taken with rockfish and sablefish seamount fisheries. CPUE for rockfish was reportedly higher for the seamount rockfish fishery than for inshore fisheries. Nevertheless, the seamount rockfish fishery was closed after 1999 as a precautionary approach. CPUE for sablefish is reportedly declining, which resulted in an increasingly narrowed season. Although excluded from TAC, the sablefish seamount fishery is effectively controlled by limited access, currently one vessel per month.

Uncertainty remains regarding the response of the seamount fish population to fishing effort. A key consideration in the management of the fisheries is recruitment patterns, that is, whether they are self-sustaining or subject to episodic recruitment. In addition, given Bowie Seamount's distance offshore, collaboration between DFO and the fishing industry will also be key to successful research and management. Both industry and DFO support continued cooperation in seamount fisheries research and management.

3.0 DEFINING A MANAGEMENT REGIME FOR BOWIE SEAMOUNT

This research paper defines five specific topics related to developing a management regime for Bowie Seamount: vision and goal, boundaries, harvest refugium, experimental research area, and collaborative fishery management. The topics are discussed in turn in subsequent sections, building on the groundwork laid in Section 2 and on additional insight gained from other seamount examples. It is recognized that these topics do not encompass all components of a management regime. Components such as the governance structure, monitoring, and enforcement, among others, which are key to a management plan, are outside the scope of this paper.

3.1 Overarching Goal

Clearly defined objectives consistent with an overall vision for an MPA are crucial in setting the management direction and monitoring the effectiveness of an MPA. Prior to examining the management direction for the proposed Bowie Seamount MPA, it is relevant to examine the management direction of two other seamount MPAs, the Tasmanian Seamounts Marine Reserve and Cordell Bank National Marine Sanctuary.

3.1.1 Examples of Seamount MPA Management Direction

3.1.1.1 <u>Tasmanian Seamounts Marine Reserve</u>

The Tasmanian Seamounts Marine Reserve is guided by five overarching strategic objectives:

- Protect the unique and vulnerable benthic communities of the seamounts
- Protect the conservation values of the reserve from human-induced damage
- Manage the reserve as part of Australia's National Representative System of Marine Protected Areas
- Contribute to the protection of overall conservation values of the southern Tasmanian seamounts' ecosystem
- Use the reserve as a research site to increase knowledge of seamount ecosystems generally and of the endemic species of the southern Tasmanian seamounts (Commonwealth of Australia 2002)

In addition to these overarching objectives, the management direction for the reserve is embedded in the International Union for the Conservation of Nature and Natural Resources (IUCN) protected area categories, which are intended to provide international consistency in MPAs and provide guidance to managers (IUCN 1994). IUCN has developed six categories ranging from wilderness areas to managed resource protected areas (see Appendix B). The Tasmanian Seamounts Marine Reserve is managed overall according to IUCN Category

IA (strict nature reserve — protected area managed mainly for science).

Category IA is defined as an area of land and/or sea possessing some outstanding or representative ecosystem, geological or physiological features, and/or species available primarily for scientific research and/or environmental monitoring (IUCN 1994). Seven objectives are defined for this category:

- Preserve habitats, ecosystems, and species in as undisturbed a state as possible
- Maintain genetic resource in a dynamic and evolutionary state
- Maintain established ecological processes
- Safeguard landscape features or rock exposures
- Secure examples of the natural environment for scientific studies, environmental monitoring, and education, including baseline areas from which all avoidable access is excluded
- Minimize disturbance by careful planning and execution of research and other approved activities
- Limit public access (IUCN 1994)

The guidelines also include these suggestions:

- The area should be large enough to ensure the integrity of its ecosystems and to accomplish the management objectives for which it is protected.
- The area should be significantly free of direct human intervention and capable of remaining so.
- The conservation of the area's biodiversity should be achievable through protection and not require substantial active management or habitat manipulation (IUCN 1994).

The Category IA designation of the Tasmanian Seamounts Marine Reserve embodies and directs the vision for the reserve.

It is important to note that the categorization applies to the primary management objective, but an MPA may contain zones that have other objectives. For the purpose of categorization, at least 75% of the MPA must be managed for the primary objective and the management of the remaining area must not conflict with that primary objective. The Tasmanian Seamounts Marine Reserve has been vertically zoned internally such that from the surface to a depth of 500 m is a managed resource protected area (IUCN Category VI) and from 500 m to 100 m below the seabed is managed as a strict nature reserve (IUCN Category IA) (Commonwealth of Australia 2002). Following from the IUCN categories, the Highly Protected Zone is managed to protect the integrity of the benthic ecosystem and prohibits all fishing and petroleum and/or mineral exploration. Consistent with the scientific emphasis of Category IA, scientific research is permitted in the Highly Protected Zone (with a permit), preferably using non-invasive techniques in order to "increase knowledge of the natural environments, for scientific purposes and management improvement of the seamounts within the Reserve" (Commonwealth of Australia 2002). The goal of the managed resource zone is to ensure the long-term protection and maintenance of biological diversity while allowing regulated levels of longline commercial fishing for tuna at the surface.

In terms of balancing conservation, research, and fishing, the emphasis of the vision and objectives is clearly placed on conservation values with a recognition that additional research is required to understand those conservation values fully. In fact, the designation process was founded on scientific research and is the key to continued conservation. While the establishment of the reserve was prompted by a concern about the impacts of trawl fishing on seamount ecosystems, the 15 seamounts selected for the reserve were not subject to fishing pressure. In selecting these seamounts, the intent was not to restore fish populations on those seamounts but rather to conserve a relatively pristine seamount environment. Hence, commercial resources are not highlighted in the vision or objectives. Nevertheless, restricted fishing is permitted in the reserve.

3.1.1.2 Cordell Bank National Marine Sanctuary

Similarly, a management plan was developed for the Cordell Bank National Marine Sanctuary that identifies goals and objectives for the marine reserve (U.S. Department of Commerce 1989). The sanctuary goals and objectives provide the framework for developing the management strategies. The goals and objectives direct sanctuary activities toward the dual purposes of public use and resource conservation. The four main goals are as follows:

- Resource protection goal — to protect the marine environment and resources of the sanctuary (it is assigned the highest priority for management
- Sanctuary research goal — to improve understanding of the Cordell Bank environment and resources and to resolve specific management problems
- Public awareness goal — to develop interpretive programs that improve public awareness and understanding of the significance of the sanctuary and the need to protect its resources
- Visitor management goal — to encourage commercial and recreational use of the sanctuary compatible with the primary goal of resource protection

In terms of balancing conservation, research, and fishing, the primary objective is on protecting marine resources; the secondary emphasis is on research. The continuance and even encouragement of commercial and recreational use is embodied in the fourth goal, and fishing activity, with the exception of gillnetting, is permitted within the sanctuary. It is assumed that the level of fishing is compatible with resource protection. This may not be the case, however, since lack of funding has limited the extent to which the management plan has been implemented (National Ocean Service 2001). More detailed information was sought from Anne Walton, the coordinator of the Cordell Bank National Marine Sanctuary management plan, on the status of its implementation, but no detailed response was received.

3.1.2 Bowie Seamount Management Direction

The management direction for the proposed Bowie Seamount MPA is defined by an overarching goal, broad objectives within the context of the Oceans Act, and specific management objectives.

The draft management plan for Bowie Seamount (DFO 2001b) specifies an overarching goal, expressed as a vision, for the Bowie Seamount MPA:

As an MPA, the Bowie Seamount Area contributes towards the protection and conservation of a representative shallow seamount ecosystem in the Northwest Pacific Ocean, with its dynamic marine ecosystem, unique habitat, geographically isolated species, regionally valued commercial fisheries resources, high biodiversity and biological productivity. (DFO 2001b, p. 6 as amended at the Bowie Seamount Area Pilot MPA Advisory Team meeting of 19 February 2002)

In addition, the Oceans Act defines three broad MPA objectives that the Bowie Seamount MPA is intended to address, along with three specific management objectives defined in the draft management plan.

The three broad management objectives emanating from the Oceans Act are as follows:

1. The conservation and protection of unique habitats of the area
2. The conservation and protection of the area as a marine area of high biodiversity and biological productivity
3. The conservation and protection of commercial and non-commercial fishery resources of the area

Furthermore, the following three specific management objectives are identified in and form the basis of the draft management plan:

Management Objective 1: Conserve and protect the unique habitat, the biological productivity and diversity, and the commercial and non-commercial fishery resources in the Bowie Seamount area (with specific reference to the protection and conservation of ecological integrity)

Management Objective 2: Develop and implement a research and outreach strategy

Management Objective 3: Monitor compliance and the state of the ecosystem

3.1.3 Summary and Conclusions

In both the Tasmanian Seamounts Marine Reserve and the Cordell Bank National Marine Sanctuary, conservation, supported by research, takes a lead role. In the Tasmanian Seamounts Marine Reserve, this is particularly reinforced through adoption of IUCN Category IA, that is, a strict nature reserve — protected area managed mainly for science. In neither area is fishing considered to be incompatible with the vision and objectives, although no fishing is permitted within the defined seamount ecosystem of the Tasmanian Seamounts Marine Reserve. This was relatively easy to accomplish since the seamounts selected had not been subject to fishing pressure. Thus, within a research framework, the Tasmanian Seamounts Marine Reserve functions as a control for studies of pristine seamount ecosystems and of the impacts of fishing on seamounts.

The objectives for the proposed Bowie Seamount MPA have not been ranked. However, with the original announcement of selection of Bowie Seamount as a candidate MPA (Anderson 1998), an indication of the balance between conservation, research, and fisheries is emerging that can guide boundary delineation (Section 3.2), harvest refugium zonation (Section 3.3), research (Section 3.4), and fisheries management (Section 3.5). The emphasis is clearly on conservation as stipulated in the overarching goal, general management objectives, and Management Objective 1. Both Management Objectives 2 and 3 speak to the scientific, rather than conservation, value of establishing the Bowie Seamount MPA, that is, to its being an opportunity to conduct and disseminate research directed at ecological integrity. The goal and objectives do not directly mention maintaining fisheries but rather conserving fishery resources.

Thus, the emerging balance and management direction is one in which conservation drives science and science drives fisheries.

3.2 MPA Boundary

This section focuses on the ecological rationale of the proposed MPA boundary within the context of the vision of the proposed Bowie Seamount MPA. First, boundary delineation of several seamounts is examined and, subsequently, specific attention is paid to the proposed Bowie Seamount MPA boundary.

3.2.1 Examples of Seamount Management Boundaries

3.2.1.1 Tasmanian Seamounts Marine Reserve

The boundaries of the Tasmanian Seamounts Marine Reserve were designed to protect some of the 70 seamounts, particularly the pristine, unfished deep seamounts, and to minimize the possibility of indirect impacts from trawling in areas adjacent to the reserve (Commonwealth of Australia 2002). However, at the time of the reserve's designation, and still today, hard data, such as data on the trophic linkages between pelagic and benthic communities and on recruitment patterns, as well as data on which to base a definition of ecologically sound boundaries, is lacking (Tony Koslow, Commonwealth Scientific and Industrial Research Organisation [Australia], Pers. comm.). Therefore, an adaptive management approach was adopted. An interim protected area covering 370 km^2 and encompassing 15 seamounts was established in 1995 on the basis of a combination of ecological and fishing industry considerations. This was followed by a three-year official closure (the seamounts had not, however, been the target of commercial fishing) to allow time for research to be carried out to assess the diversity and depth distribution of the seamount benthic community, and the impact of trawling on it, as the biological basis for assessing the size and depth requirements of a proposed marine reserve (Koslow et al. 1998). While these studies have been successful in terms of understanding the seamount ecosystem, the process of describing the ecosystem is ongoing. In the meantime, the Tasmanian Seamounts Marine Reserve was formally designated in 1999 with the same boundaries as the interim protected area.

3.2.1.2 Cordell Bank National Marine Sanctuary

Several boundary options were considered for the Cordell Bank National Marine Sanctuary primarily on the basis of the distribution of living organisms and management logistics (U.S. Department of Commerce 1989). The existing boundary (and largest proposed) centres the single seamount rising from 1800 m to within 35 m of the sea surface within 1360 km^2 extending from a depth of 55 m to a depth of 1800 m, providing the bank with an extensive buffer (U.S. Department of Commerce 1989).

3.2.1.3 New Zealand Seamount Fisheries

In defining boundaries to protect the country's seamounts, the New Zealand government has taken a different approach from that used for the Tasmanian Seamounts Marine Reserve. Rather than designating an MPA encompassing several seamounts, the government chose 19 representative or unique seamounts for fisheries research and management. These seamounts are distributed throughout New Zealand's EEZ. The seamounts vary in size from 1 km^2 to 35,000 km^2 and range from an elevation of 170 m to 3600 m (Brodie and Clark 2002). Discrete boundaries for each seamount were established and defined by drawing a box centred on the seamount that was large enough to provide a buffer area of sufficient size to preclude vessels manoeuvring trawl gear over the seamount. The perimeter of the seamount was defined by the point at which the seamount met the general contour of the surrounding seabed (Brodie and Clark 2002). In total, 40,000 km^2, or just over 1% of the area of New Zealand's EEZ, are protected.

3.2.2 Bowie Seamount Boundary

The proposed Bowie Seamount MPA boundary extends to the northern limit of Canada's EEZ (adjoining the boundary between Canada and the United States) covering approximately 14,000 km^2. The proposed MPA is vastly larger than existing seamount MPAs. While the original intent was to include only Bowie Seamount in the MPA, participants at a workshop to review the ecosystem overview recommended that all three seamounts — Bowie, Hodgkins, and Davidson — be incorporated into an MPA to capture more of an ecosystem approach (AXYS 2000). Therefore, the full extent and configuration of the boundary are intended to be large enough to achieve an ecosystem approach to protecting the ecological integrity of seamount ecosystems by including the connected deeper seamounts, and to facilitate management by being delineated in a fairly regular, rather than convoluted, shape.

Most scientists consulted (Richard Beamish, Fisheries Scientist, DFO; Ron Kronlund, Fisheries Scientist, DFO; Bill Crawford, Research Scientist, DFO) indicated that current knowledge is insufficient to judge the ecological rationale of the proposed boundary. While ecosystem-based management is the main reason for including all three seamounts, little if anything is known about the ecological linkage among the seamounts and only slightly more is known about the ecological linkage between Bowie Seamount and coastal ecosystems with respect to recruitment and eddy transport. Nevertheless, some comments can be made.

First, arguments have been made for the need for larger protected marine areas, in comparison with terrestrial areas:

> In marine areas because of the open nature of the system, protection of some communities and fragile habitats may only be achieved by making protected areas sufficiently large so that the impacts are adequately buffered or diluted, this leaving some part of the critical community relatively undisturbed. (Kelleher and Kenchington 1992)

Sloan (2002) also argues for larger protected areas:

> Given the scale and connectivity of ocean processes and ecosystems, large wilderness areas are optimal for marine conservation … unpopulated continental coasts, offshore islands, and the high seas

are sound, large, contiguous candidates for marine wilderness areas.

Therefore, a case has been presented to err on the side of large boundaries for offshore MPAs. However, the buffer provided by the current proposed boundary extends to the northwest and southwest abyssal plains, whereas the source of eddies and potential coastal recruitment is from the east and southeast direction. Extending the boundaries in these directions may provide a more effective, although not necessarily more practical, ecological buffer.

Second, as discussed in Sections 2.2.1 and 2.2.2, the three seamounts can be seen as a single topographic and oceanographic feature (John Dower, Department of Biology, University of Victoria, Pers. comm.). Evidence suggests that seamounts in clusters or along ridge systems function as “island groups” or “chains.” A study of seamounts in the Tasman Sea and southeast Coral Sea revealed that little overlap occurs in species composition between sites sharing the same habitat at similar latitude and depth and only about 1000 km apart, leading to highly localized species distributions and apparent speciations between groups or ridge systems that is exceptional in the deep sea (Richer de Forges et al. 2000). Circulation cells in the vicinity of seamounts and along seamount chains have been shown to facilitate recruitment to seamounts within relatively close proximity of each other and along ridge seamounts (Mullineaux and Mills 1997; Lutjeharms and Heydorn 1981). These seamounts appear to be isolated marine systems (Richer de Forges et al. 2000). Furthermore, hypotheses of north and central Pacific seamounts, focused on the faunistic links among seamounts in a “stepping stones” configuration where seamounts occur along an extensive ridge, were relatively homogeneous (Wilson and Kaufmann 1987; Hubbs 1959). For example, in studies of the Tasmanian seamounts it has been suggested that the clustered 70 Tasmanian seamounts and their associated biota are fairly homogenous and are therefore considered as a single ecological community (Commonwealth of Australia 2002). These findings lead one to suggest that Bowie, Hodgkins, and Davidson Seamounts could also be viewed as a single ecological feature.

3.2.3 Summary and Conclusions

Examples from other seamounts provide diverse topographic and ecosystem circumstances for comparison with the Bowie Seamount area. Although it is recognized that the Tasmanian seamounts are subject to regional oceanographic influence, research on the seamount ecosystem focused on more localized benthic habitat, and apparently no attempt was made to encompass these regional influences within the reserve boundary. As was mentioned previously, the small size and density of the Tasmanian seamounts enable the reserve to encompass several seamounts within a relatively small area. Protection of the New Zealand seamount fisheries took a contrasting approach in which isolated seamounts distributed throughout the EEZ were protected within a buffered boundary. An extensive buffer was also applied to the Cordell Bank National Marine Sanctuary.

For both the Tasmanian and New Zealand seamounts, the lack of knowledge of seamount ecosystems was acknowledged but did not represent an obstacle to protection and management. As Kelleher and Kenchington (1992) warn,

> It is nearly always a mistake to postpone a decision at one of the early decision-making stages [e.g., establishment of boundaries, zoning] until all the information necessary for a later decision-making stage [e.g., planning and regulation] is obtained.

In both cases a precautionary and impact prevention approach to boundary delineation was adopted. In addition, an adaptive approach to management was coupled with a supporting research program to examine post facto the ecological rationale of the Tasmanian Seamounts Marine Reserve boundary.

The current proposed boundaries of the Bowie Seamount MPA encompass an area that is considerably larger than that of the Tasmanian Seamounts Marine Reserve, the Cordell Bank National Marine Sanctuary, or any one of the seamounts within the New Zealand Seamount Management Strategy. However, it has been shown that large offshore MPAs are appropriate given oceanic dynamics and the need to establish buffers. Furthermore, the theoretical basis is strong, albeit unproven as yet, for considering Bowie, Hodgkins, and Davidson Seamounts as a single ecological and physical feature. However, it cannot be overemphasized that until further research is undertaken, the ecological linkage among the three seamounts and in the water column and seabed beyond their immediate perimeter remains theoretical. Therefore, a prudent or precautionary approach in establishing the proposed boundaries is warranted, particularly if an adaptive management approach is adopted.

3.3 Harvest Refugia

Three harvest refugium options have been proposed for the Bowie Seamount area. This section discusses the theory and practice of harvest refugia, how they have been implemented in the management of other seamounts, and the ecological benefits of the proposed refugium options.

3.3.1 Theory and Practice

3.3.1.1 Purpose and Benefits

The terms harvest refugium, no-take zone, or reserve are often used interchangeably to describe an area in which the removal or disturbance of resources, particularly due to commercial harvesting, is prohibited. Marine reserves typically are set aside for one of two reasons: fishery management or conservation management. The objective of a fishery reserve is to increase abundance, biomass, and size of fishery species within the reserve in order to sustain reserve populations and to supply harvest areas outside the reserve boundary. Conservation reserves are established primarily to maintain diversity and abundance within the reserve area. A successful conservation reserve may, however, indirectly benefit neighbouring fisheries. Harvest refugia, no-take zones, and reserves address more than one species and play a role in both fishery management and conservation. In contrast, a fishery closure is a fisheries management tool applied to a single species. The aims of harvest refugia or reserves are as follows:

- Facilitate, as a replenishment area, local recovery of depleted stocks
- Provide spillover benefits beyond the boundary of the refugium
- Preserve genetic stock
- Restore habitat
- Serve as a site to reintroduce native species
- Provide control areas for determining natural mortality rates for different life-history stages
- Serve as comparison sites for studies on human impacts

In addition, increasing attention is being paid to the role of harvest refugia in providing insurance against the inherent uncertainty in managing living natural resources or buffering potential failures of conventional management. In essence, closures provide a risk-averse strategy for meeting management directions (Lauck et al. 1998).

The effectiveness of harvest refugia has been the subject of numerous studies, most of which have focused on small isolated reserves that are closed to fishing (National Academy of Sciences 2001). In a study of 76 reserves, Halpern (2003), found that local density, body size, biomass, and biodiversity of resident animals were higher than in unprotected sites. However, it is not surprising that such success is not uniform and depends on the level of exploitation, length of time of closure, replenishment potential from outside the area, life-history characteristics, and predator–prey relationships (National Academy of Sciences 2001). Similarly, numerous studies have focused on the replenishment of fish stocks on fishing grounds due to spillover from reserves. Drawing strong conclusions from empirical or modelling studies, however, is notably difficult (Crowder et al. 2000; National Academy of Sciences 2001).

Although fishery management issues provide much of the justification for reserves, some recent studies have examined more general conservation arguments such as protection of migratory species and habitat protection and restoration. Fully protected reserves are particularly beneficial in providing a high level of protection to core areas, such as sensitive habitats or sites important to vulnerable species. Dayton et al. (2000) suggest more broad-based, ecosystem-related benefits of refugia not necessarily associated with fisheries management. Refugia may offer benchmarks and safeguard ecosystem structure, function, and integrity. These authors further argue that, in the world's oceans, there are virtually no areas north of the Antarctic that have exploitable resources where scientists can study natural marine systems (Dayton et al. 2000).

3.3.1.2 Refugia Design

The size and location of a refugium depend on its objective, its dispersal and recruitment patterns, its species mobility and vulnerability, and the level of protection, management, and intensity of use and impact beyond the refugium boundaries. Numerous studies have been conducted to determine the optimal size for marine reserves, with results varying primarily on the basis of the objective of the reserve. In terms of increasing stocks of overexploited fish populations, reserves between 20% and 40% of the fishing grounds showed the best examples of fishery recovery (Gell and Roberts 2002). Fishery reserves smaller than 10% of the fishing grounds have proven to be effective in stabilizing populations, but in terms of catch, a larger size seems to be necessary to benefit fisheries.

Providing insurance against overfishing and protecting nursery areas, spawning aggregation sites, or migration bottlenecks may require reserves covering a larger fraction of a given region. Some models have suggested values between 30% and 60% of the management area, and as high as 80% closure when highly mobile and migratory species are considered and no other management measures are applied (National Academy of Sciences 2001).

To represent and replicate habitats adequately in a reserve system designed for conserving biodiversity, reserves covering more than 10% of the seas are likely to be required. Twenty per cent is widely quoted as an appropriate value but is criticized as being arbitrary and unscientific (National Academy of Sciences 2001). For the purpose of protecting representative biodiversity, habitat, and species assemblages, various studies consider an area of 10% to 40% to be appropriate (National Academy of Sciences 2001).

Current marine reserves range in size from less than 1 km^2 to hundreds of square kilometres, with the median reserve size variously estimated at 4 km^2 (PISCO 2002) or 16 km^2 (McClanahan 1999); these reserves represent less than 1% of the world's oceans (Carr et al. 2003).

To be successful, reserves should be large enough to support the persistence (continued existence) of the species within them. Refugia must encompass an area that harbours one or more self-sustaining target species populations of sufficient size to enable those species to withstand both the large fluctuations in reproductive success characteristic of these species and current levels of environmental change (Yamanaka et al. 2001). In addition, persistence of species depends on dispersal and recruitment patterns. Modelling results for reserves of different sizes and species with different dispersal characteristics indicate that persistence generally is ensured if reserve breadth exceeds the dispersal distance of resident species by 1.5 times (Hastings and Botsford 1999).

Refugia design also requires balancing and in some cases trading off large areas with many smaller reserves; design also varies with dispersal characteristics. For example, fisheries for species with low to moderate dispersal potential will be better served by smaller reserves spread out across a management area (National Academy of Sciences 2001). This finding is supported by a recent propagule (spores, eggs, and larvae) dispersal study that indicated that the dispersal distance for coastal species is typically either less than 1 km or greater than about 20 km. Shanks et al. (2003) therefore suggested that the optimal coastal configuration for a marine reserve would be a series of small reserves, 4 to 6 km in diameter, spaced approximately 10 to 20 km apart. One effect of establishing many small reserves instead of one large reserve is the increase in the perimeter-to-area ratio effect (Dahlgren and Sobel 2000). This can lead to higher rates of spillover into outlying areas, which could have a positive or negative effect depending on the main objectives of reserve. If the populations in question are limited largely by planktonic events and episodic recruitment, than static, relatively small reserves are not likely to enhance populations in the short term (Dayton et al. 2000). Almost all discussions of the design of systems of reserves emphasize the importance of preserving the same species and habitats through replication in several reserve sites (National Academy of Sciences 2001).

Ideally, refugia are sited in essential habitats for fertilization, larval growth survival and dispersal, settlement/nurseries, growth, and survivorship of adults. In addition, it is important to recognize the potential for source–sink population dynamics to affect the success of a reserve (Crowder et al. 2000). In particular, refugia located in biological source areas are more effective, and Dayton et al. (2000) argue that biological sinks as refugia are counterproductive. Crowder et al. (2000) take the argument further, suggesting that the placement of refugia in sink habitats has the potential to harm rather than help fish populations. Unfortunately, it is exactly such areas that are offered as reserves because of lack of opposition from fishers (Dayton et al. 2000). Halpern (2003), on the other hand, shows that values for four biological measures (density, biomass, size of organisms, and diversity) are significantly higher inside reserves than they are outside reserves. Halpern's results also suggest that almost any marine habitat could benefit from the implementation of a reserve.

It is suggested that the benefits of refugia are optimized when refugia are permanent features of MPAs and that their conservation and fishery benefits will be greatly diminished if protection is only temporary (National

Academy of Sciences 2001).

3.3.2 Examples of Seamount Refugia

3.3.2.1 Tasmanian Seamounts Marine Reserve

As was mentioned in previous sections, a harvest refugium is in place below 500 m on all 15 seamounts within the Tasmanian Seamounts Marine Reserve. This accounts for 21% of the seamounts in the Tasman Sea area or approximately 15% of the seamount region (Environment Australia 1998). The objective of the refugium is to protect these pristine habitats and to provide a baseline against which to assess impacts from fishing activity. Fitting its IUCN category 1a, research is a key component of the management plan and the Highly Protected Zone will be managed primarily for scientific research and environmental monitoring (Commonwealth of Australia 2002). As part of the plan, the adverse impacts of research — such as damage to habitat, removal of species, and pollution from boats — on both the benthic and pelagic ecosystems has been rated as being low. Furthermore, a research and monitoring program for the reserve is being developed that favours the use of non-invasive research techniques (Commonwealth of Australia 2002). A strict permitting process has been established to conduct research, including fisheries research, within the reserve. The permit requires applicants to identify steps taken to minimize adverse impacts on any native species or ecological community (Commonwealth Marine Parks and Reserves: Permit application for research). The types and numbers of specimens to be collected, as well as the location where they are to be kept, must be identified. In addition, the likely short- and long-term impacts on individuals, populations, species as a whole, and the ecological community must be described.

3.3.2.2 Cordell Bank National Marine Sanctuary

Within the Cordell Bank National Marine Sanctuary, no harvest refugia exist and no fishing restrictions have been established beyond normal commercial and recreational fishing regulations. Scientific research is a critical component of the Cordell Bank National Marine Sanctuary and requires a permit. Extractive research, including trawling and plankton tows, are permitted and have been undertaken (National Ocean Service 2001; U.S. Department of Commerce 1989). Remotely operated vehicles (ROVs) and the Delta submersible are used to characterize the benthic habitats, and observer surveys are used for marine mammal and seabird studies (National Ocean Service 2001). The imbalance of research and fishing regulations was evident when one research permit in the Cordell Bank National Marine Sanctuary was denied because of concern about anchor damage in a heavily trawled area (Dayton et al. 2000).

3.3.2.3 New Zealand Seamount Fisheries

The New Zealand seamount management strategy has established a no-take zone on 2% of the seamounts greater than 100 m in the EEZ, amounting to just over 1% of the area of New Zealand's EEZ. The objective of the seamount management strategy is to provide a scientific basis to protect the benthic habitat and diversity, yet still enable fishing to continue (Brodie and Clark 2002). The no-take zones themselves provide a means to study the ecology and functioning of seamount ecosystems and the impact on them of trawling. While no evidence was found about restrictions on extractive research within the closed seamounts, descriptions of research undertaken focus on remote studies using still and video photographic equipment (Brodie and Clark 2002).

3.3.3 Bowie Seamount Refugium

The Draft Bowie Seamount Marine Protected Area Management Plan (DFO 2001b [August]) makes reference to the inclusion of a harvest refugium or no-take zone, and discussion has ensued at the Bowie Seamount Area Pilot MPA Advisory Team meetings, particularly in relation to fishery closures and non-extractive scientific research (17 October 2001 and 19 February 2002).

Three harvest refugium options are proposed. Option A includes Bowie Seamount only down to the 3000 m isobath. Option B includes Bowie and Hodgkins Seamounts. Option C includes the entire MPA.

An assessment of the ecological rationale for a harvest refugium in the proposed Bowie Seamount MPA and the relevant merits of the three options with respect to conservation, research, and fishing is impeded by a lack of defined objectives for the refugium and limited knowledge of ecosystem structure, function, and processes. Section 3.3.3.1 discusses appropriate objectives for a harvest refugium at the proposed Bowie Seamount MPA and proposes some assumptions that guide the discussion in Section 3.3.3.2 on the relative benefits with respect to conservation, research, and fishing.

3.3.3.1 Harvest Refugium Objectives

As was discussed in Section 3.3.1.1, fisheries harvest refugia or reserves can be established as a multispecies fisheries management tool or to offer insurance against uncertainty in managing living resources and thereby protect biodiversity. They also provide benchmarks to study natural marine systems with minimal, if any, human intervention which can benefit both fisheries management and conservation objectives.

Section 2.3.2 describes fisheries management at Bowie Seamount and provides a basis for assessing the need for a harvest refugium as a fisheries management tool with respect to sablefish and rockfish. With respect to fisheries management, a fishery closure can be considered for either species. There is evidence of declining CPUE for sablefish, which previously has been addressed by narrowing the season and limiting access. Between 1996 and 2001, an annual average of four sablefish fishery permits was used at Bowie Seamount. The current limited draw is limited to one vessel per month in the northern seamount area, but the actual level of effort is not reduced. However, it is important to note that abundance of fish at Bowie Seamount in part contributes to minimal fishing at Hodgkins and Davidson Seamounts. Nevertheless, as mentioned in Section 2.3.2.1, the impact of sablefish fishing on the seamount ecosystem is the subject of a proposed PSARC project.

The majority of evidence suggests that sablefish recruit to the seamount but do not reproduce on the seamount. Therefore, the seamount most likely acts as a biological sink for sablefish and possibly as a stop on the migratory route to the Gulf of Alaska and Bering Strait. Little information is available on the benefits of a fishery closure to a migratory fish species, but it is possible that migratory species such as sablefish may benefit by having safe havens on their migration route. The merits of establishing a fishery closure in a biological sink have been disputed (Dayton et al. 2000; Crowder et al. 2000) but do not negate the benefit to broader biodiversity conservation.

With respect to rockfish, a fishery closure is essentially in effect because no permits have been issued for targeting seamount rockfish since 2000. Prior to the restrictions, total rockfish catch from the seamount increased considerably between 1996 and 1999, and no reduction in the size of rockfish was observed over this period (Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.). While there is no indication of declining rockfish stocks, a fishery closure at Bowie Seamount, if deemed necessary, would be more effective as a fisheries management tool since evidence indicates that a self-sustaining population of widow rockfish exists on the seamount. However, no evidence suggests that the populations of rougheye rockfish, the predominant species caught, are self-sustaining since seamount populations are characterized by few young-age-class fish and an older average age of fish compared with coastal fish (Beamish and Neville In prep.)

Fisheries closures or multispecies harvest refugia offer insurance against uncertainty in managing living resources. This appears to be the underlying principle in closing the seamount to rockfish fishing. In the Bowie Seamount area, this uncertainty relates to the response of commercial fish stocks to fishing, which is compounded by concerns of potential limited resiliency of seamount stocks to overfishing (Koslow and Tuck 2001).

Perhaps more uncertainty exists about the response of other seamount populations to harvesting of commercial stocks, particularly in relation to pelagic–benthic energy flow. Beamish and Neville (In prep.) have attempted to model seamount predator–prey relationships. These authors suggest that overfishing of sablefish would increase abundance of crab and rockfish, which are prey for halibut. This in turn would decrease abundance of crab and rockfish prey. Overfishing of rockfish would deplete prey for sablefish and halibut causing a "major imbalance." Completing the food web model, overfishing of halibut would increase the abundance of sablefish, rockfish, and crab and decrease the abundance of their prey. These conclusions are based on energy models simulating 90% overfishing. Managers of the Tasmanian Seamounts Marine Reserve and the New Zealand Seamount Management Strategy – have faced similar uncertainty about the ecosystem. In response, commercial harvest refugia were implemented in portions of unfished seamounts in Australia and complete harvest refugia were implemented in some fished seamounts in New Zealand.

Another benefit of a harvest refugium in the Bowie Seamount area is to establish a benchmark to study natural marine systems over time with minimal, if any, human intervention. Dayton et al. 2000 argue that without natural systems important questions cannot be studied — for example, how the ecosystem roles of various species can be assessed, how they can be managed in a sustainable manner, and how we can evaluate resilience or relative rates of recovery. The lack of natural systems for fisheries research is noted for both rockfish and sablefish. With respect to rockfish, current stock assessment is noted to be poor due to lack of fishery independent abundance estimates (DFO N.d.[b]). Similarly, Saunders et al. (N.d.) comment that few observations are available of sablefish distribution in what could be considered an undisturbed or natural setting. This is the case in Australia, where the 15 unfished seamounts in the Tasmanian Seamounts Marine Reserve are used as control sites for fishing impact studies. Since most of the fishing impact studies on seamounts relate to trawl fishing, the Bowie Seamount area provides an excellent opportunity for a comparative study on non-trawl fisheries on seamounts. Because of its remoteness and the limited human activity beyond fishing and research that occurs in the Bowie Seamount area, it is an ideal candidate for this type of harvest refugium. In particular, Davidson Seamount, which has not been subjected to fishing activity, and Hodgkins Seamount, which has been subjected to only limited sablefish fishing, can function as controls for fishing impact studies on other seamounts such as Dellwood Seamount and even Bowie Seamount Seamount. Davidson and Hodgkins Seamounts are also important sites to study the roles of non-fished species and non-anthropogenic biodiversity trends (i.e., those not caused by human activity) in marine ecosystems. Bowie Seamount has experienced more sustained fishing activity and therefore is perhaps less suitable as a pristine, benchmark environment. This seamount, however, warrants consideration as a harvest refugium because of its unique characteristics — its shallow depth, the juxtaposition within it of coastal and deep-water species, the extensive amount of research available about it in comparison with that available about Hodgkins and Davidson Seamounts, and its potential role as a destination feeding ground for seabirds, marine mammals, sablefish, and possibly other species.

As was mentioned in Section 3.3.1.1, harvest refugia generally prohibit the removal or disturbance of resources, particularly due to commercial harvesting. But what of the role of scientific harvesting? In all but the most protected wilderness areas, MPAs and refugia are viewed as conduits for research and education (Dayton et al. 2000; Sloan 2002). Research and monitoring in refugia provide a better understanding of refugia design, deeper knowledge of complex marine ecosystems and the ways that human activities affect these systems, and development and application of marine management methods that are cost-effective in achieving specific goals (National Academy of Sciences 2001). Accepting these benefits, it is important to define acceptable methods of research in a refugium. Fundamentally, research should not defeat the objectives of the MPA and zones within an MPA, such as refugia for which the IUCN categories provide guidance. For example, wilderness areas (IUCN Category IB) are intended to preserve intact natural systems. Therefore, extractive research activities that could damage natural systems within such a wilderness area are not compatible with the primary objective for which it was established. In contrast, scientific research, including permitted scientific take, is appropriate and, to a certain degree, required in a strict nature reserve — protected area managed mainly for science (IUCN Category IA). Nevertheless, steps must be taken to minimize the level of perturbation that almost inevitably arises from ecological research.

These perturbations might include samples taken for taxonomic and voucher purposes, genetic studies, and life-history, growth, sex, and fecundity measurements. The National Academy of Sciences (2001) concluded that to prohibit such research denies some of the principal values of MPAs. On the other hand, excessive destructive sampling violates the purpose of the MPA. A balance is struck by promoting the use of non-invasive and observational techniques, such as ROVs and video photography, as have been used in the Tasmanian Seamounts Marine Reserve, Cordell Bank National Marine Sanctuary, and at various New Zealand Seamounts, as well as at Bowie Seamount itself. In addition, a tightly controlled permitting system requiring a detailed application and review process is necessary to document and minimize the impact of research activities on the natural environment.

3.3.3.2 Comparison of Refugium Options

An assessment of the relative conservation, research, and fishing benefits of each refugium option depends fundamentally on having sufficient information to differentiate them. As has been stated previously, "overall, the habitats of seamounts, their values, and their relationship with the surrounding waters and seabed are not well understood" (Commonwealth of Australia 2002). This statement certainly applies to Bowie Seamount and more so to Hodgkins and Davidson Seamounts. Therefore, this assessment can at best be based on informed generalizations.

Conservation benefits might include biogeographic and habitat representation; protection of vulnerable life stages and habitats, species, or populations of special conservation, economic, or recreation value; protection of ecosystem linkages; and protection against human threats. Little is known of the conservation values of Hodgkins and Davidson Seamounts. All the research has been undertaken on Bowie Seamount, as the more unique and shallowest seamount of the three. Bowie Seamount also serves as a feeding area for migratory seabirds and for marine mammals, a phenomenon associated with shallow seamounts such as Cobb Seamount and Cordell Bank. Due to their more profound depths, Hodgkins and Davidson Seamounts may not serve the same role. The bathymetry of Hodgkins and Davidson Seamounts may not be suitable habitat for rockfish, at least not in terms of making them abundant enough for commercial harvesting. In contrast, juvenile sablefish migrating at intermediate depths may recruit to Hodgkins and Davidson Seamounts, as is suggested by evidence of a limited sablefish fishery on Hodgkins Seamount. Finally, as the most accessible of these seamounts, Bowie Seamount is also most under threat from human activity.

The key conservation values of Bowie Seamount are encompassed in all three refugium options. Therefore, the issue to be addressed is this: in the absence of more detailed information on conservation values on the other seamounts in the Bowie Chain, what can be deduced about the relative conservation benefits of Options B and C, which include more than just Bowie Seamount itself (Option A).

As was discussed in Section 3.3.1.2, it is recommended that refugia or reserves established for the conservation of representative biodiversity should comprise 10% to 40% of non-reserve areas for given protected habitats and species. Option B encompasses 2 of 19 non-reserve areas, or approximately 10% of seamounts shallower than 1000 m in Canada’s EEZ. Option C encompasses 3 of 19 non-reserve areas, or 15% of such habitats. While the percentages are not based on area coverage, it provides a point of comparison with recommended refugia goals. In addition, by encompassing all three seamounts, Option C protects the ecological integrity of the seamounts as defined by topography and possibly oceanographic processes, as discussed in Sections 2.2.1 and 2.2.2. Even though interest in fishing Hodgkins and Davidson Seamounts is apparently small or nonexistent, Option C provides the opportunity to ensure that natural habitats that are minimally affected by anthropogenic disturbances remain so. Finally, some proponents of reserves or refugia suggest that generally larger reserves are preferred (PISCO 2002), particularly if populations are limited largely by planktonic events and episodic recruitment. While a recommended refugium breadth of 1.5 times the dispersal distance is impossible to achieve given recruitment patterns of seamount species, larger offshore refugia are preferable. As a result, Option C, with an area of 14,000 km^2, is preferable to Option B (6530 km^2) or Option A (1890 km^2).

Research benefits might include studies on life-history requirements, dispersal and recruitment, genetic connectivity, regional and local oceanographic influences, natural biodiversity, natural mortality, refugia design and effectiveness, and human impact. Many of these studies, such as life-history requirements, dispersal and recruitment, genetic connectivity, and regional oceanographic influences, can take place and have been taking place at Bowie Seamount without the designation of a refugium. However, as discussed in the previous section, a refugium offers an opportunity for additional research on natural systems, refugia design and effectiveness, and human impact from non-trawl fishing.

Option A limits the ability to conduct research on human impacts from non-trawl fishing since this option would close off the only seamount subject to consistent fishing activity. Furthermore, Option A may relocate fishing activity to Hodgkins and Davidson Seamounts if sufficient stock abundance is confirmed. Relocating fishing activity to Davidson Seamount, in particular, would intrude on the most pristine and least disturbed of the three seamounts, eliminating the opportunity to conduct research on natural systems. In this respect, Option B is similar, although it further restricts the opportunity to compare the impacts of level of fishing effort, for example, lighter fishing effort on Hodgkins Seamount compared with heavier fishing effort on Bowie Seamount. As was mentioned in the previous section, however, it is important to keep in mind that fisheries management is a tertiary objective of a refugium and only if it does not conflict with the conservation and science values of the MPA. Option C is the only option that would allow benchmark research to study natural marine systems, although this option also includes the inherent research shortcomings of Options A and B. Similarly, in studying the effectiveness of harvest refugia, comparison sites with different restrictions must be examined. Other seamounts, such as Dellwood Seamount, may be considered, but focusing this line of research within an MPA is more effective and cost-efficient than developing a more comprehensive seamount research program in Canada's EEZ.

As argued in the previous section, benefit to fisheries is not a critical factor in establishing a refugium. No evidence exists to indicate that stocks need to be replenished and, unlike in trawl fisheries in Australia and New Zealand, habitat restoration or recovery is unnecessary. Given the depth-dependent pattern of fishing activity, limited habitat availability due to slope, and the size of the proposed refugium, the refugium would also not likely provide spillover benefits. Research on genetic variation within yelloweye rockfish shows that samples from Bowie Seamount are not genetically differentiated from samples taken elsewhere. Genetic evidence of rockfish and recruitment patterns of sablefish may offer one fisheries benefit from a harvest refugium, that of preservation of genetic stocks, particularly in light of conservation efforts for rockfish through rockfish protection areas. The lack of knowledge about fish stocks and the impact of fishing on the seamount ecosystem lends weight to the argument for establishing a refugium to provide insurance against uncertainty. However, because the seamount fisheries are managed separately from other stocks, the benefits of such insurance can be accrued only through systematic and rigorous research on stock assessments and fishing impacts in an experimental setting, which would include keeping at least part of Bowie Seamount open for fishing (see Section 3.4 below). Bowie Seamount is the only one of the three seamounts subject to consistent fishing activity. Since Bowie Seamount is included in all three options, the cost to the seamount fishing industry is the same for all three options. Option C, which encompasses a larger area than the other options, will unnecessarily exclude fishing activity in open ocean areas to the northeast and southwest, and such exclusion may provide no direct benefit to the seamount ecosystem.

3.3.3.3 Summary and Conclusions

For the purpose of evaluating the relative benefits of the three proposed harvest refugium options with respect to conservation, research, and fishing, the suggested objective of a harvest refugium in the proposed Bowie Seamount MPA is to protect and study the natural seamount ecosystem as a benchmark with minimal perturbation and to assess the impact of a non-trawl seamount fishery. This objective is in keeping with the overall vision presented in Section 3.1.3 — conservation driving science driving fisheries. It is also assumed that a harvest refugium would not exclude extractive research but that this type of research would be strictly controlled.

Option C provides the greatest benefit to conservation values in the proposed Bowie Seamount MPA. As the largest refugium, it encompasses 15% of shallow seamounts in Canada’s EEZ, protects the ecological integrity of the seamount system defined by topographic and, potentially, oceanographic processes, and provides the opportunity to ensure that natural habitats continue to undergo minimal anthropogenic disturbance.

While recognizing that fisheries management is only a tertiary objective, by including Bowie Seamount, none of the options provide opportunity to study the impacts of non-trawl fishing on seamount ecosystems and other fisheries management research. Although the entire MPA is not currently subjected to fishing activity, only Option C provides the opportunity to control for natural marine systems with limited, if any, human disturbance.

None of the refugium options are likely to provide direct benefits to fisheries. Indirect benefits may include protection of genetic stocks and insurance against uncertainty. The predominance of fishing activity on Bowie Seamount and lack of information on Hodgkins and Davidson Seamounts make arriving at conclusions on the relative benefits of each of the options difficult, with the exception that Option C excludes fishing activity in a broader area that may not have any consequence to the seamount ecosystem.

Alternatives to these three options can be explored by considering horizontal and vertical zonations. In this regard, a shallower refugium may be established on the seamounts to protect rockfish larvae while permitting off-bottom hook and line fishing. Vertical zonation may also be applied above 1000 m to protect juvenile sablefish. Alternatively, a refugium might include Davidson Seamount to ensure protection of the most pristine seamount, and portions of Hodgkins and Bowie Seamounts to enable studies on refugium effectiveness, human impact studies, and fisheries management. At this stage, it is impossible to determine whether a north/south or east/west division of each seamount is most appropriate; this determination should be made in consultation with the fishing industry. These options, while avoiding alienating the fishing industry, also present additional enforcement implications.

3.4 Experimental Research Area

Beamish and Neville (In prep.) have recently proposed that Bowie Seamount be established as an experimental research area (ERA).[2] Their concept of an ERA is to develop a strictly controlled living laboratory as a basis for developing ecosystem-based management approaches and protected ecosystem function. They suggest that Bowie Seamount offers ideal conditions for an ERA owing to its relatively pristine, contaminant-free environment subject only to fishing activity. As such, Bowie Seamount provides a plethora of opportunities for research and monitoring in relation to

- Large-scale climate impacts
- Ecological forecasting
- Stock assessment
- Acceptable catch of target species
- Impact of removal of target species on population dynamics
- Linkages among fishing, ocean dynamics, and climate change
- Migratory species

Furthermore, Beamish and Neville propose that an ERA would broaden the research scope by not limiting opportunities to DFO researchers, instead encompassing diverse yet integrated research proposals from a wide range of researchers who together contribute to the understanding of a whole ecosystem. In addition, these authors foresee the Bowie Seamount MPA as representing one within a network of ERAs.

The following summarizes how this ERA proposal addresses the management issues of conservation, research,

[2] Alternatively referred to as ecosystem research area and experimental ecosystem research area.

and fishing.

To assess the concept of an ERA, it is important to understand the differentiation between a refugium, an ERA, and an MPA within the context of Bowie Seamount. Beamish and Neville do not discuss the specific relationship of the ERA to the proposed boundary options of the MPA and harvest refugia. Nor do they discuss appropriate vertical or horizontal extents of an ERA. However, they make the distinction that an ERA would allow some fishing. Hence, an ERA and a refugium should not be considered synonymous. To provide some measure of comparison for fishery impact assessment, it is assumed that fishing levels in some part of the ERA would need to approximate that of a commercial fishery. At a Bowie Seamount Area Pilot MPA Advisory Team Meeting, Dale Gueret, Area Chief, Oceans and Community Stewardship, North Coast Area, DFO, indicated that DFO is seeking to establish an ERA within the MPA, illustrating again that an ERA and an MPA are not synonymous. The ERA is also endorsed in the Sablefish Integrated Fisheries Management Plan as a means to advance understanding of interactions between human activities and the ecosystem (DFO N.d.[c]). Furthermore, research staff are developing a discussion paper, for PSARC review, to identify the key requirements for taking an ERA approach.

Combining the above interpretations, we propose that the concept of an ERA comprises a refugium, or several refugia, centred on the seamounts to a specified depth, within an ERA potentially encompassing all three seamounts, within a broader MPA that provides some buffer and allows multifunctional management. This is consistent with the alternative refugium option presented in Section 3.3.3.3, in which a refugium encompasses Davidson Seamount and portions of Hodgkins and Bowie Seamounts, within an ERA that includes the remaining portions of Hodgkins and Bowie Seamounts within the full extent of the MPA. It is recognized that control of fishing and research activities through, for example, vertical or even horizontal zonation will be considerably limited by logistical and financial constraints on monitoring and enforcement in such a distant and isolated area.

Incorporating a harvest refugium, or several, within an ERA provides the opportunity to implement management approaches to optimize conservation within a precautionary approach since the intention is to have strictly controlled fishing and research activities. Indeed, Beamish and Neville are confident that an "experimental ecosystem provides advocates of marine protected areas an opportunity to integrate their objectives with [those of] fisheries managers'." In keeping with the management direction of conservation driving science driving fisheries, it may be more appropriate to reverse the emphasis such that fisheries management is integrated into conservation objectives.

Beamish and Neville have demonstrated that Bowie Seamount offers a bounty of research opportunities, both empirical and applied. However, whether the realization of such opportunities will lead to increased understanding and protection of ecological integrity is dependent on a well-structured research plan that addresses and can assess each of the four components of ecological integrity discussed in Section 2.0: landscape, physical processes, species composition, and functional organization. The scientific benefits will also depend on dissemination of data and knowledge accrued within the research program. An efficient information compilation and sharing protocol needs to be established if research efforts are truly to contribute to the "wholeness" of the MPA. Finally, while it is appealing to contemplate the notion of a living laboratory, such as the Bowie Seamount ERA, and even a network of such ERAs, as has been noted at Bowie Seamount Area Pilot MPA Advisory Team meetings, its implementation will challenge the financial and logistical resources currently available.

An ERA is consistent with current international approaches to seamount ecosystem management in which uncertainty is acknowledged and incorporated into a rigorous research program geared toward adaptive management. As such, the results of ongoing research can be used to refine a management plan. This is now an increasingly emphasized practice in which, as much as possible, reserves are designed to accommodate adaptive management through experimental research (Walters 1992; Murray et al. 1999; Dayton et al. 2000). This approach is an alternative to customary management approaches. As McClanahan (1999) argues, conservation science "needs to better determine the relationships between multiple and often interacting restrictions and their effects on protected area ecology and biodiversity ... and turn the present … trial and error management restrictions into a management science."

3.5 Collaborative Fishery Management

This section examines how a collaborative arrangement among fisheries stakeholders could benefit conservation goals. Based on the draft management plan for the proposed Bowie Seamount MPA, the conservation objective is to

conserve and protect the unique habitat, biological productivity and diversity, and the commercial and non-commercial fishery resources in the Bowie Seamount Area (with specific reference to the protection and conservation of ecological integrity). (DFO 2001b)

As was mentioned in Section 2.1, this objective aims to maintain a natural and sustainable seamount ecosystem. While much must still be learned about the Bowie Seamount ecosystem, on the basis of existing research and evidence from other seamounts it can be said that the ecosystem is held in natural balance by local oceanographic processes (e.g., upwelling), recruitment (e.g., rockfish reproduction), and energy flow (e.g., habitat, sablefish, rockfish and crab predator–prey relationship) and by regional oceanographic processes (e.g., mesoscale eddies) and migration (e.g., of sablefish, seabirds, and mammals). This natural balance may still be maintained with human activity. For example, results from a study in the Tasmanian Seamounts Marine Reserve show that the biomass of fauna on unfished seamounts is very similar to that of the biomass of fauna on “lightly” trawled seamounts in the same depth range (Koslow et al. 2001). Due to its isolation, the Bowie Seamount area is not subject to much direct human perturbation that intervenes in the natural balance. Currently, the main human activities there are sablefish fishing and research activities.

Although fishing draws on the biological resources of the seamounts, the industry can also play a vital role in contributing to the conservation objective. This is best achieved through a collaborative arrangement among industry, government, and scientists. A collaborative arrangement would increase involvement of the fishing industry not only in fisheries management, but also as it relates to the common goal of conservation of the seamount ecosystem, even though the participants may have different motives. Collaboration would facilitate information exchange among all three groups and the development of a common information base on which to make management decisions and build trust.

The review of the international seamount fisheries management experience undertaken for this report provides a little insight into the implementation of collaborative management. In the Tasmanian Seamounts Marine Reserve, the fishing industry was consulted in selecting unfished seamounts to be included in the reserve (see Section 2.3.1.1). The reserve management authority is developing a framework to encompass the collaborative efforts of the authority and stakeholders. However, no details were available on the structure or implementation of the framework. No specific fisheries management occurs for the Cordell Bank National Marine Sanctuary (see Section 2.3.1.2). The fishing industry was consulted in the New Zealand Seamount Management Strategy, but lack of support from the industry has limited the implementation of collaborative management (see Section 2.3.1.3). In fact, the fishing industry is challenging its financial contribution to seamount research that does not relate directly to impacts of fishing.

In terms of the Bowie Seamount area, industry, government, and scientists appear to have collaborated more willingly and for a longer period than is the case with other seamounts. A contributing factor is the condition placed on scientific permits issued regarding Bowie Seamount that requires the collection of samples. In addition, Gerald Dalum, the main rockfish fisher on Bowie Seamount, has used his vessels for research trips, most recently in 2000 for the multidisciplinary research cruise to Bowie Seamount. He has also offered funds to use for analyzing sample data (see Section 2.3.2.2). CSA works cooperatively through a joint project agreement in monitoring, research, assessment, and management of the commercial sablefish fishery, including the seamount fishery (see Section 2.3.2.1). The seamount program is one of nine initiatives currently included in the joint project agreement. CSA has been involved in tagging studies, biological sampling, and stock assessments through the collection of samples and provision of funds for data analysis.

The fishing industry has expressed concern that the designation of an MPA and a potential fishery closure will result in loss of opportunities for fishing, in which the industry has invested heavily over time (Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.; minutes from 2 August 2001 public presentation on the proposed Bowie Seamount MPA). To address these concerns, representatives of the fishing industry are members of the Bowie Seamount Pilot Area MPA Advisory Team. In addition, both the rockfish and sablefish fishing industries have recognized the need for and expressed a willingness to participate in a research program for the area. Industry, government, and scientists have expressed the need for such a research program to be systematic and tightly controlled, have well-defined objectives, and be supported by adequate funding (Richard Beamish, Senior Scientist, DFO; Gerald Dalum, G.P Dalum Enterprises, Pers. comm.; John Dower, Department of Biology, University of Victoria; Bruce Turris, CSA, Pers. comm.).

Being more regularly at the site, members of the fishing industry, along with onboard scientists if necessary, are well placed to gather biological and oceanographic data that will be useful in achieving conservation goals. The data collected can then be used to determine:

- Source–sink pathways among the seamounts offshore and onshore through tagging studies
- Age composition and variation with depth, slope, and benthic habitat
- Species abundance
- Current status of residual, reproducing, and transient stocks and
- Seabird and marine mammal location and abundance

In addition, fishers have years of field observations and detailed familiarity with the seamount to the extent that preferred fishing areas within Bowie Seamount can be identified (Gerald Dalum, G.P. Dalum Enterprises, Pers. comm.). This knowledge should be captured systematically to supplement and guide the implementation of a research program.

As described above, already several elements of consultation and collaboration are in place with respect to seamount fisheries research and management. These would be enhanced by

- Establishing a fisheries research committee with broad representation from industry organizations, regulators, and scientists

- Providing input into the establishment of refugium boundaries and zonation
- Contributing to the research objectives of the ERA
- Jointly developing results-based research objectives
- Comparing current rockfish biomass and abundance with those prior to fishing restrictions
- Jointly developing a seamount FMP that is reviewed annually
- Documenting and incorporating local fishers' knowledge of the area
- Expanding scientific sampling requirements included in the seamount permits in accordance with the seamount FMP
- Sharing information in a transparent forum, reporting back on results of research activities, and integrating data on fishing effort, distribution, and catch

4.0 RECOMMENDATIONS

The following key recommendations are intended to provide direction for the development of a management plan for the proposed Bowie Seamount Area MPA with respect to balancing conservation, research. and fisheries within an ecosystem-based management regime.

Ecosystem Integrity

Recommendation 1: To increase understanding of ecosystem integrity, particular research attention should be focused on

- **Davidson Seamount topography**
- **Localized oceanographic properties**
- **Detailed biological surveys of the three seamounts**
- **Source–sink dynamics**
- **Interactions and energy flow between pelagic and benthic species**
- **Migratory seabirds and marine mammals**

Overarching Goal

Recommendation 2: Following the example of the Tasmanian Seamounts Marine Reserve, the management for the proposed Bowie Seamount Area MPA should be guided by IUCN Category 1A (strict nature reserve — protected area managed mainly for science) to reflect a "conservation driving science driving fisheries" vision, with consideration of the IUCN-recommended 75% minimum MPA area as a primary objective.

MPA Boundary

Recommendation 3: Recognizing the topographical and the potential oceanographic linkages among Bowie, Hodgkins, and Davidson Seamounts, the MPA boundary should incorporate all three seamounts and be sufficiently large in order to provide the most effective ecological buffer and oriented to consider offshore oceanic dynamics.

Recommendation 4: Given the poor understanding of seamount ecosystems and the ecological links between Bowie, Hodgkins and Davidson seamounts, the appropriateness of the proposed boundaries should be evaluated through an adaptive management approach.

Harvest Refugium

Recommendation 5: Following from the overarching goal and vision, the objective of a harvest refugium in the proposed Bowie Seamount MPA should be to protect and study the natural ecosystem as a benchmark with minimal perturbation and to assess the impact of a non-trawl seamount fishery.

Recommendation 6: To maximize protection of natural habitats and research on human impacts, the refugium should encompass Davidson Seamount and portions of Bowie and Hodgkins Seamounts.

Recommendation 7: Management plans for other protected seamounts make provisions for scientific research, even in harvest refugia, and acknowledge the role that research plays in evolution of management plans; therefore, research, including tightly controlled scientific take, should be permitted in refugia

Experimental Research Area

Recommendation 6: An ERA is consistent with current international approaches to seamount ecosystem management, and the ERA should be founded on experiment-based adaptive management.

Collaborative Fisheries Research and Management

Recommendation 7: Existing collaborative fisheries research and management would be enhanced by

- **Establishing a fisheries research committee with broad representation from industry organizations, regulators, scientists, fishers and the ENGO community. This committee could then work together and assist in:**

- **Providing input into refugium boundaries and zonation**
- **Contributing to the research objectives of the ERA**
- **Jointly developing results-based research objectives**
- **Comparing current rockfish biomass and abundance with those prior to fishing restrictions**
- **Jointly developing a seamount FMP that is reviewed annually**
- **Documenting and incorporating local fishers' knowledge of the area**
- **Expanding scientific sampling requirements included in the seamount permits in accordance with the seamount FMP**
- **Sharing information in a transparent forum, reporting back on results of research activities, and integrating data on fishing effort, distribution, and catch**

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APPENDIX A: Recommendations on Ecological Integrity from the Report of the Panel on the Ecological Integrity of Canada's National Parks (Parks Canada 2000)

Recommendation

We recommend this revised definition of ecological integrity:

> An ecosystem has integrity when it is deemed characteristic for its natural region, including the composition and abundance of native species and biological communities, rates of change and supporting processes.

In plain language, ecosystems have integrity when they have their native components (plants, animals, and other organisms) and processes (such as growth and reproduction) intact.

For national parks, this characteristic state must respect the following criteria:

- Ecological integrity should be assessed with an understanding of the regional evolutionary and historic context that has shaped the system.
- Because ecosystems are dynamic, conservation strategies should maintain or restore key ecological processes within their natural range of variability.
- Ecosystems are multiscaled and conservation should be considered at many scales. National parks are part of larger ecosystems and must be managed in that context.
- Functional connections between parks and equivalent protected areas within the regional ecosystem should be maintained or restored, to allow wildlife movement.
- Populations of species should be managed to levels that have a high likelihood of persistence.
- Ecosystems have characteristic rates of change. Understanding rates and direction are critical to understanding the system.
- Parks have a finite capacity to withstand use. Human use and facilities should be compatible with park ecosystem protection in type, amount, and timing.
- Ecological integrity must be assessed and understood at a landscape scale. While ecological integrity cannot be assessed at the scale of a single forest stand, campground, or parking lot, it can be compromised at any scale. Even small-scale impacts can have cumulative effects and should be considered in this light.
- The goal of conserving ecological integrity is best addressed by maintaining or restoring the diversity of genes, species, and communities native to the region. This goal is simply consistent with the vision of integrity, which is "wholeness"; if parts are missing, the ecosystem is not whole.

APPENDIX B: IUCN Protected Area Categories System (IUCN 1995, Kelleher and Kenchington 1992)

Category I: Strict Nature Reserve/Wilderness Area
Protected Area Managed Mainly for Science or Wilderness Protection
Category IA: Strict Nature Reserve — Protected Area Managed Mainly for Science
Category IB: Wilderness Area — Protected Area Managed Mainly for Wilderness Protection

Category II: National Park
Protected Area Managed Mainly for Ecosystem Protection and Recreation

Category III: Natural Monument
Protected Area Managed Mainly for Conservation of Specific Natural Features

Category IV: Habitat/Species Management Area
Protected Area Managed Mainly for Conservation through Management Intervention

Category V: Protected Landscape/Seascape
Protected Area Managed Mainly for Landscape/Seascape Conservation and Recreation

Category VI: Managed Resource Protected Area
Protected Area Managed Mainly for the Sustainable Use of Natural Ecosystems

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature by:

- conserving the world's biological diversity;
- ensuring that the use of renewable resources is sustainable;
- promoting the reduction of pollution and wasteful consumption.

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