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Recommendations for indicator selection for Sgaan Kinghlas Bowie Seamount Marine Protected Area

Recommandations concernant la sélection d'indicateurs pour la zone de protection marine du mont sous-marin Bowie (Sgaan Kinghlas)

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ABSTRACT

In support of the Health of the Oceans Initiative, DFO Science has been asked to recommend scientifically defensible indicators to monitoring the achievement of the conservation objective for the Sgaan Kinghlas-Bowie Marine Protected Areas (SK-B MPA). This paper outlines a five step Stressor Based Indicator Identification Framework to monitor human induced stressors and the ecosystem reference state. This framework evaluates human activities using a Pathways of Effects (PoE) approach to understand the extent and nature of the impacts of potential stressors on the ecosystem. All known human activities have been identified for the SK-B MPA, and simplified PoEs have been carried out on each activity. These PoEs were provided as examples for discussion and future more in-depth evaluation is required to complete these PoEs and subsequent risk assessments. The broad nature of the conservation objective for the SK-B MPA needs to be refined to operational level objectives that are measurable to determine candidate indicators for monitoring. This paper recommends that the development of scientifically defensible indicators for monitoring the achievement of the conservation objective for SK-B MPA: following the Stressor Based Indicator Identification Framework as described in this document to assess risks to the MPA and to select appropriate indicators for monitoring; collect baseline data to evaluate natural and stressor based changes; and develop a comprehensive reporting system to evaluate the nature and extent of human activities.

RÉSUMÉ

Pour soutenir l'initiative *Santé des Océans*, on a demandé au secteur des Sciences de Pêches et Océans Canada (MPO) de recommander des indicateurs défendables sur le plan scientifique en vue de surveiller l'atteinte de l'objectif de conservation de la zone de protection marine du mont sous-marin Bowie (Sgaan Kinghlas) (ZPM B-SK). Le présent document présente un cadre en cinq étapes d'établissement des indicateurs associés aux facteurs de stress, conçu pour surveiller les facteurs de stress d'origine anthropique ainsi que l'état de référence de l'écosystème. Ce cadre évalue les activités humaines à l'aide d'une approche de séquences des effets dans le but de comprendre l'étendue et la nature des impacts des facteurs de stress possibles sur l'écosystème. On a déterminé toutes les activités humaines connues dans la ZPM B-SK et on a exécuté des séquences des effets simplifiées pour chaque activité. Ces séquences des effets ont servi d'exemples aux fins de discussion, mais des évaluations futures plus approfondies seront nécessaires pour parachever ces séquences et les évaluations subséquentes des risques. Il importe de répartir la vaste nature de l'objectif de conservation de la ZPM B-SK en objectifs opérationnels mesurables afin de déterminer les indicateurs possibles à surveiller. Le présent document recommande donc les démarches suivantes : établir des indicateurs défendables sur le plan scientifique afin de surveiller l'atteinte de l'objectif de conservation de la ZPM B-SK; suivre le cadre d'établissement des indicateurs associés aux facteurs de stress décrit dans le présent document afin d'évaluer les risques auxquels est exposée la ZPM et de choisir les indicateurs pertinents à surveiller; recueillir des données de référence en vue d'évaluer les changements naturels et les changements associés aux facteurs de stress; élaborer un système exhaustif de déclaration pour évaluer la nature et l'étendue des activités humaines.

1 INTRODUCTION

Marine protected areas (MPAs) are designated by Fisheries and Oceans Canada (DFO) under the 1996 Ocean's Act to conserve biodiversity and protect the ecosystem function of a specific habitat or habitats. The establishment of an MPA is used as a management tool to complement or enhance existing tools used by managers to achieve DFO policies and legislation requirements for fishery and habitat management. Once an MPA is designated, the conservation objectives established for the MPA define the components of the ecosystem that are vulnerable to human activities and help define the indicators to monitor.

The goal of a monitoring plan is to assess the achievement of the conservation objectives. Science-based monitoring can be defined as the systematic collection of data and information on a regular basis for an extended period of time to determine the degree of achievement of some goal, standard or objective (Kenchington 2010). For both science and management purposes it is imperative that the conservation objectives are measurable, relevant to current policies, and sensitive to meaningful thresholds (Failing and Gregory 2003). To monitor MPAs effectively, the selection of indicators must be scientifically defensible, and provide information that is relevant to the conservation objectives of the MPA. A Stressor Based Indicator Identification Framework is intended to address only biological/ecological aspects of monitoring, and will focus on threat monitoring and monitoring trends in the ecosystem state through time. This information will be incorporated into a broader MPA management framework, which would also include socio-economic considerations. Other branches within DFO or other federal departments may be responsible for compliance monitoring, enforcement of regulations and developing the appropriate indicators for this work.

A workshop was held December 2008 to discuss the conservation objective and science monitoring for the SK-B MPA (Kucera 2008). Participants identified that the outcomes of the workshop were constrained by the lack of clearly defined operational objectives (Kucera 2008).

This paper represents the first step in the development of indicators and monitoring protocols for the *Sgaan Kinghlas*-Bowie MPA. The focus of this working paper is to:

- Develop a framework that will lead to indicator selection to allow for monitoring the effects of human activities on meeting conservation objectives.
- Conduct a preliminary Pathways of Effects (PoE) evaluation on the human activities that have the potential to stress the ecosystem and identify their likely effects; and,
- Describe current activity-based monitoring programs that may provide support to the development of a monitoring plan for the SK-B MPA.

1.1 DESCRIPTION OF THE MARINE PROTECTED AREA

The *Sgaan Kinghlas*-Bowie MPA is located 180km west of Haida Gwaii (Queen Charlotte Islands). The MPA is 6,000km² in size and its boundary encompasses three seamounts: Bowie, Hodgkins and Davidson (Figure 1). The seamounts are part of the Kodiak-Bowie chain of seamounts found in the North Pacific that extend from the Aleutian Islands to the Bowie seamount west of Haida Gwaii. The seamounts within the SK-B MPA have intricate natural features, including pinnacles, plains and ridges which create numerous habitats. The Bowie seamount is the largest of the three submarine mountains in the MPA, and rises from depths of 3,000m to within 24m of the ocean surface. The summit of the Bowie seamount is within the phototrophic zone creating a unique ecosystem that contains both deep water species such as Prowfish (*Zaprora silenus*), and coastal species such as Harlequin (*Sebastes variegates*) and

Yelloweye rockfish (*Sebastes ruberrimus*). The area is rich in species diversity, including SARA listed species such as ancient murrelets (*Synthliboramphus antiquus*), Steller Sea Lion (*Eumetopias jubatas*), Killer Whale, offshore population (*Orcinus orca*) and Bocaccio rockfish (*Sebastes paucispinis*). The area is influenced by regional eddies, known as 'Haida Eddies' that forms off Cape St. James (Haida Gwaii) and drifts into the Gulf of Alaska each winter (Levings C.D. and Foreman 2004). The Haida Eddies are anti-cyclonic vortices that can be 200 km in diameter and are characterized by sea surface height anomalies, warmer than surrounding waters below top 100 m and normally less saline than surrounding waters (Crawford 2002). Canessa et al. (2003) provides a detailed description of the physical and biological components of the seamount ecosystem, as well as a summary of past human activities in the area. The Bowie seamount is culturally significant to the Haida First Nation and they refer to the area as Sgaan Kinghlas, meaning "supernatural being looking outward". In 2007 a memorandum of understanding for co-management was signed by DFO and the Council of Haida Nation (CHN) to allow cooperative management and planning within the MPA. A DFO – Haida management board was established in 2009. The correct naming convention for the MPA that recognizes the co-management of the area is *Sgaan Kinghlas-Bowie Protected Area (SK-B MPA)*.

1.2 DESCRIPTION OF THE CONSERVATION OBJECTIVE

The gazetted *Sgaan Kinghlas-Bowie* MPA conservation objective is to:

Conserve and protect the biodiversity and biological productivity of the area's marine ecosystem, which includes the Bowie, Hodgkins, and Davidson seamounts and their surrounding waters, seabed and subsoil.

The conservation objective for SK-B MPA is broad, in part due to the complexity of the seamount ecosystem. This objective will guide the development of a management plan for the MPA and provides the basis from which to develop specific operational objectives that are measurable. At this time, a management plan for the SK-B MPA has not been finalized, and more specific operational objectives have not been defined. These operational objectives will be essential to the development of a monitoring program that will measure ecosystem parameters that are useful, and relevant for management of human-induced threats in the area.

The lack of clearly defined objectives inhibits the ability to identify and defend specific monitoring requirements without appearing to be an arbitrary selection. Measurable objectives are needed to: complete statistical tests on collected data; determine reference points for the selected indicators; and develop decision points for management actions. For indicators to support management decision making, this relationship between the value of the indicator and the operational objective needs to be understood (Jennings 2005).

1.3 DESCRIPTION OF MANAGEMENT OF THE MARINE PROTECTED AREA

For management purposes the MPA is divided into three zones (Figure 1). The photic zone at the peak of the Bowie submarine seamount to the 250 fathom (457m) bathymetric contour is Zone 1. Zone 2 contains the remainder of the Bowie seamount. The Hodgkins and Davidson seamounts comprise Zone 3.

The management plan for SK-B MPA will elaborate on the regulations to achieve the conservation objectives for the MPA. It will address matters such as monitoring, enforcement and compliance, and will provide the details required to ensure that the rationale for management decisions, prohibitions, controls and approvals is clearly understood. According to

the regulations, activities in the MPA are managed through (1) specific exceptions to the general prohibitions according to specified conditions; and (2) the submission and approval of plans for specified activities according to specified conditions.

The SK-B MPA regulations state that *'no person shall disturb, damage or destroy, or remove... any living marine organism or any part of its habitat; disturb, damage or destroy or remove... any part of the seabed; or carry out any activity... that is likely to result in the disturbance, damage, destruction or removal of a living marine organism or any part of its habitat'* with the following exceptions:

- Activities for the purpose of public safety, law enforcement, national security, national defense or emergency response are permitted to ensure the safety of Canadians.
- Scientific research for the conservation, protection and understanding of the area may be approved throughout the MPA under specific conditions.
- Fishing by Aboriginal Peoples in accordance with the *Aboriginal Communal Fishing Licenses Regulations* is permitted.
- Commercial fishing within the MPA will be allowed as long as this is carried out in accordance with subsection 7(1) of the *Fisheries Act* and is administered through the Integrated Fisheries Management Plan (IFMP), annual variation order, and licence conditions. At present the only existing fishery in the SK-B MPA is the sablefish fishery. The fishery is restricted to Zone 2 of the MPA, to only one vessel per month (over a six-month period) and to the use of trap gear only.
- Recreational fishing in accordance with the *Fisheries Act* and its regulations.
- Travel or transport is permitted pursuant to the *Canada Shipping Act, 2001* and foreign vessel travel pursuant to the *Canada Shipping Act, 2001* and the *Coasting Trade Act*.

Although the regulations allow for activities that are necessary to ensure national security there currently are no Canadian Naval or Air Force activities that take place in the MPA.

2 ASSESSMENT

2.1 STRESSOR BASED INDICATOR IDENTIFICATION FRAMEWORK

The development of a monitoring program will require appropriate indicators to monitor the achievement of the conservation objective. The framework for the identification of indicators includes the following steps:

1. Use the Pathways of Effects (PoE) approach to identify the stressors that result from each activity and their potential effect on the ecosystem.
2. Conduct a risk assessment using an ecological risk analysis framework (ERAF) on the effects that have been identified through the PoE evaluation.
3. Refine conservation objective into measurable operational objectives.
4. Identify candidate indicators and protocols to monitor the effect of stressors from activities that have been assessed or prioritized, through the ERAF, to warrant monitoring (i.e. sufficient risk to achievement of the conservation objectives).
5. Identify candidate indicators and protocols to monitor the ecosystem reference state to serve as baselines for comparison to indicators relevant to stressors.

Pathways of effects (PoE) models or diagrams describe the type of cause-effect relationships that are known to exist, and the mechanism by which stressors ultimately lead to effects in the

aquatic environment (DFO 2010b). For each human activity there are known stressors to the environment. Each of these stressors may have one or more effects on biodiversity (species, populations and communities), habitat or ecosystem form and function. This relationship can be described in the following schematic:

Activity → Stressor → Effect

For each cause-and-effect relationship, a pathway is created by connecting the attributes of the stressor to some ultimate effect on the ecosystem (Boutillier et al. 2010). For fishing activities, the pathways of effects that describe the stressor of removal of target species would be described by the following schematic:

Fishing → Removal of target species → Loss of biodiversity

In above example the activity is fishing, the stressor to the ecosystem is the removal of target species, and the potential effect could result in loss of biodiversity at the genetic, species and ecosystem level. This is only one of several pathways for this activity and is not a complete assessment of all the stressors nor all potential effects. Each pathway represents an area where mitigation measures can be applied to reduce or eliminate a potential effect (DFO 2010b). Where mitigation measures cannot be applied, or cannot fully address a stressor, the remaining effect is referred to as a residual effect (Boutillier et al. 2010). Figure 2 illustrates an example of a pathway of effect diagram that has been developed by DFO to communicate potential effects of marine seismic activities on fish and fish habitat.

Once the pathways of effects have been outlined an ecological risk assessment of human activities is needed to determine the level of risk that residual effects pose to the ecosystem. This type of assessment will categorize risks to the ecosystem by examining the scale and intensity of negative effects associated with human activities and the sensitivity of biodiversity, habitat and ecosystem form and function within the MPA. An understanding of the risks is necessary to select indicators for monitoring.

Indicators can be grouped into one of two categories; those that monitor the impact of human activities, and those that monitor the ecosystem reference state. For the SK-B MPA the selection of appropriate and meaningful indicators is not possible until the conservation objective is refined into measurable terms, or operational objectives. The outputs from the pathways of effects and ecological risk assessment processes will help inform and refine the conservation objectives for the area. Specific operational objectives that are measurable and describe conservation priorities will need to be defined before potential indicators can be proposed.

2.2 IDENTIFICATION OF POTENTIAL STRESSORS

The stressors and their effects caused by human activities that take place within the MPA may compromise the achievement of the conservation objective and the more specific operational objectives. Key activities that may impact the MPA were identified in an ecosystem overview report (Canessa et al. 2003) and a SK-B MPA science monitoring workshop (Kucera 2008). The effects on biodiversity, habitat and ecosystem form and function from these activities (fishing, vessel traffic, tourism, scientific research) and the present management protocols used to mitigate the stressors from these activities are described below. In addition some of the environmental forcings that are driven by complex processes occurring at larger spatial scales are also discussed in term of natural stressor and their potential effects. N.B. Oil and mineral

exploration or extraction where not included as activities in this exercise because the regulations for the MPA prohibit these activities in this area.

This section will outline the PoEs but does not assess the likelihood of negative effects, frequency of activities or priority for monitoring. It is important to note that not all effects from human activities are negative, and that further assessments by experts may be necessary to characterize the level of risk to the biodiversity, habitat and ecosystem form and function from each of the activities described.

2.2.1 Fishing

Within the regulations for SK-B MPA this broad activity is to be broken down further into four sub-components: Aboriginal communal fishing, sport fishing, commercial fishing and scientific research.

- Aboriginal communal fishing is permitted within the MPA, however it does not take place at this time (Jason Thompson, Haida Fisheries biologist).
- Recreational fishing is permitted within the MPA and is managed under the sport-fishing regulations.
- Commercial fishing in the SK-B MPA area has taken place since the 1980's. At the present time the only existing commercial fishery is for sablefish which is administered through the Integrated Fisheries Management Plan (IFMP), annual variation order, and licence conditions. The fishery is restricted to Zone 2 of the MPA (Figure 1), along the Bowie seamount at depths below 250 fathoms (457m), to only one vessel per month (over a six-month period) and to the use of trap gear only (DFO 2010a). The sablefish trap fishery employs a series of conical Korean traps set as a string on a ground-line that is both anchored at both ends and marked with floats at the surface (Figure 3).
- Research sample collection is controlled through permitting although there are not any conditions applied to the permit except for foreign vessels.

Fishing activities have a direct effect on the biodiversity of fish assemblages through the harvest of target and non-target species (Table 1) (Hall et al. 2000; Lynch et al. 2004). Fishing pressure can cause local stress on populations, reduce spawning biomass and may produce changes in species abundance and community structure. Fishing can alter predator-prey interactions by removing individuals (whether target or non-target). Trophic effects from the reduction of populations may cascade through the ecosystem through impacts on top predators or by the elimination of prey (Hall et al. 2000). These stressors can affect fish populations by altering biomass, size structure and diversity of communities (Jennings et al. 1998). In addition to the loss of biodiversity and trophic effects, discards of target and non-target species can affect the normal flow of nutrients in the ecosystem and impact the benthos (Hall et al. 2000). Accumulations of discards may either be a food source for scavenger species or bacteria and result in higher biological oxygen demand requirements for the ecosystem or an anoxic environment.

Fishing activities can also impact the benthic habitat when bottom gear contacts the seabed by either direct loss of biodiversity or indirect effects from the destruction of biogenic species that create complex habitat. The effects of fishing gears on habitat depend on a number of factors, including the nature, magnitude and frequency of the impact, and the recovery time of the habitat and biological community affected by the gear (Johnson 2002). Traps can affect seafloor habitat when they settle to the bottom; while soaking, traps with buoy lines of insufficient length may bounce or drag along the seafloor during rough seas; and during haul-

back operations, the gear may be dragged along the bottom. These movements of the longline will increase the amount and areal extent of damage. The extent of the damage is dependent on the amount of geological structures (boulders, cobbles, etc.) and biogenic structures (corals, sponges, etc.) that create complex habitat, as well as the frequency and intensity of contact (Jennings et al. 1998). Bottom contact can also impact the physical and chemical properties of surrounding water by causing sediment suspension and impacting several different trophic levels (Auster and Langton 1998). It is unknown how often traps encounter live substrate at Bowie seamount (e.g., stony corals, gorgonians, sponges), or the degree to which ecosystem structure and productivity have been affected by historical fishing.

Table 1. Pathways of effects for fishing activities

Activity	Stressor	Effect
Fishing	Removal of target & non-targeted species	Loss of biodiversity
		Trophic effect from the reduction of populations (predator &/or prey) that cascade through the ecosystem
	Discards of target & non-targeted species	Loss of biodiversity
		Trophic effect from the reduction of populations (predator &/or prey) that cascade through the ecosystem
		Increase nutrients to the ecosystem which may result in higher biological oxygen demand requirements (anoxia)
	Habitat damage	Loss of biodiversity
		Indirect effects on biodiversity from the destruction of biogenic species that create complex habitat

2.2.2 Vessel Traffic

The majority of vessel traffic in the area consists of tankers transporting crude oil and other commercial products shipped to and from ports throughout the Pacific. The potential stressors to the area include vessel groundings, oil spills, and the unintentional transport of aquatic invasive species from ballast water. Other potential stressors that may alter habitat include contamination introduction, waste water, debris, garbage and loss of cargo. Harassment of marine mammals and seabirds may occur due to vessel noise and lights and vessel strikes on marine mammals. There is also the potential alteration of habitat from anchoring, however given the offshore location of this MPA vessels visiting the area are more likely to drift than to anchor.

Fishing vessel and recreational boats may also visit the area for fishing and diving opportunities (Canessa et al. 2003; Kucera 2008) the stressors associated with fishing are described above in the fishing section (2.2.1) and the stressors associated with recreational activities are described below in the tourism section (2.2.3).

Table 2. Pathways of effects for vessel traffic

Activity	Stressor	Effect
Vessel Traffic	Groundings	Alteration of habitat
	Tanker oil spill	Loss of biodiversity
		Alteration of habitat
		Alteration of reproductive & developmental potential of populations
	Exotic species introduction	Reduction of available habitat
		Loss of biodiversity
		Alter ecosystem function
	Contamination introduction	Alteration of habitat
	Waste water	Alteration of habitat
	Debris, garbage & loss of cargo	Alteration of habitat
	Light	Harassment of species (seabirds)
	Noise	Harassments of species (marine mammals)
	Vessel strikes	Removal of individuals (marine mammals)
Anchoring	Alteration of habitat	

Oil Spill

Oil tankers transit through BC waters carrying crude oil from the terminus of the Trans Alaskan Pipeline System (TAPS) in Valdez, AK to ports along the US west coast. The pipeline pumps over 600,000 barrels of crude oil a day from oil fields in northern Alaska to the Valdez Marine Terminal where it is loaded onto tankers varying in size from 50,000 to 250,000 DWT (Alyeska Pipeline 2010).

In order to reduce the risk of an oil spill along the coast, a voluntary Tanker Exclusion Zone (TEZ) has been established 100 miles offshore of Haida Gwaii (Canadian Coast Guard 1998; Canessa et al. 2003). The boundary line was designated to ensure that a disabled tanker will not drift ashore prior to the arrival of salvage tugs. The SK-B MPA is west of the TEZ boundary and is therefore susceptible to oil tanker, as well as cargo tanker traffic; groundings on the shallow Bowie seamount and collisions of ocean-going vessels are a risk to the area and could alter habitat. The shallowest portion of the Bowie seamount is only 24m deep, therefore tankers that draft up to 14m can ground in 10m swells.

Transport Canada (2010) conducts aerial pollution patrols over Canada's major shipping routes in the Pacific Ocean through its National Aerial Surveillance Program (NASP). Information collected through these surveys is used by Transport Canada to enforce legislation applicable to illegal discharges from ships. Additional data is collected through Environment Canada's Integrated Satellite Tracking of Pollution (ISTOP) surveillance program. ISTOP uses Radarsat imagery to identify surface anomalies due to an oil spill. This satellite imagery is compared with NASP aerial photos in order to ground-truth results.

The impacts of oil on marine organisms are varied depending on the concentration of oil, oil type, duration of contact with oil, sensitivity of organisms, and geographical location of the spill (Gin et al. 2001). Tankers along BC coast transport crude oil; a complex mixture hydrocarbons including polycyclic aromatic hydrocarbons (PAH's) and nonhydrocarbon compounds that contain heavy metals. Offshore oil spills are very poorly studied, especially with regard to the effects of oil slicks and dissolved oil (Teal and Howarth 1984). A spill in the waters in and around the SK-B MPA would cover the ocean surface with a layer of oil, emulsified oil concentrations would be present in the water column and particulate oil concentrations would enter seabed sediments. The SK-B MPA is subject to strong winds that generate high seas, as well as seasonal Haida Eddies (Canessa et al. 2003). The oceanographic conditions around the SK-B MPA would likely disperse an oil spill and keep the oil in suspension, thereby impacting organisms in the water column.

An oil spill would cause a loss of biodiversity for all trophic levels of marine organisms. On the sea surface, marine mammals and birds would be exposed to floating oil and toxic fumes that would make it difficult to breathe and could cause asphyxiation (National Research Council 2003). Moreover, oiling of fur or feathers will cause loss of insulating capacity and can lead to death from hypothermia, smothering, drowning, and ingestion of toxic hydrocarbons (Peterson et al. 2003). Fish and other pelagic species will have different levels of sensitivity to oil, depending on their life stage and the ability to swim away from affected areas. In general, eggs and larvae are more sensitive than juvenile stages which, in turn, are more sensitive than adults (Sloan 1999). Sessile organisms, including biogenic structures will be unable to avoid oil as it settles on the seafloor, causing suffocation and reductions in population densities (National Research Council 2003).

There have been limited studies examining the long-term effects of oil spills on offshore communities. However, chemicals that affect mortality, population levels, biological interactions, recruitment, growth rates, through either acute or chronic sub-lethal toxicity, or habitat alteration, or both, are likely to affect soft-bottom benthos in the deep sea similarly to continental shelf organisms (National Research Council 2003). These impacts will extend to all trophic levels of the seamount ecosystem, from benthic invertebrates who continue to uptake dissolved oil from sea bed sediments, to predator populations through contaminated prey. Chronic toxicity of petroleum hydrocarbons after an oil spill has been associated with alterations in reproductive and developmental potential of populations of marine organisms, resulting in possible changes in population structure and dynamics (National Research Council 2003).

Aquatic Invasive Species

In 2006 the Ballast Water and Management Regulations of the Canada Shipping Act implemented a 50 nautical mile buffer zone around the submarine peak of Bowie seamount excluding ballast water exchange to reduce the risk of an invasive species establishing at SK-B MPA (Figure 4). The buffer distance was generated by modelling dispersal rates based on

seasonal currents and bathymetry features along coastal British Columbia. However, because there were no current measurements available for the seamount region, either directly from current meters or indirectly via drifters, the standard buffer distance used for coast regions was recommended for the Bowie seamount (Levings C.D. and Foreman 2004).

Invasive alien species are those harmful species (plants, animals, or micro-organisms) introduced by human actions outside their natural distribution where their introduction or spread threatens the environment, the economy, or society, including human health (Government of Canada 2004b). Human activities, such as the transport of ballast water by ocean-going vessels have created pathways for transmission of invasive species from other parts of the world to the BC coast. These vessels unintentionally transport invasive species that attach themselves to ship hulls or that survive in the ballast water that is taken on in foreign ports (Government of Canada 2004a). Ballast water is used to maintain stability and balance of vessels while travelling and during loading/unloading operations at port. Ships that transit through the SK-B MPA area en route to ports throughout the Pacific will exchange ballast water at various points along their journey. This exchange can introduce novel species to the area; once non-native species have established in a new region, expansion of range is possible, as are ecosystem-level consequences. Successful invaders are able to easily adapt to different environmental conditions and compete with native species for food and habitat. Invasive species can be detrimental to native populations, reduce or destroy habitat, cause biodiversity loss and alter ecosystem function. Effects on ecosystem structure and function from alien invasive species that have become established along the BC coast are documented in Levings et al. (2002). It is not known if any invasive species are present within the SK-B MPA due to a lack of data.

2.2.3 Tourism

Members of the general public have an interest in experiencing the natural beauty and high biodiversity of the SK-B MPA. Tourism interest is extremely limited, but there have been documented incidents of recreational fishing and diving (Canessa et al. 2003). The remote location and poor weather conditions in the area limit the tourism potential; however, the actual level of activity is unknown.

Recreational fishers are interested in the area because of the opportunity to catch large halibut, sablefish and rockfish. The stressors due to fishing activity and vessel traffic associated with tourism are described above in the fishing section (2.2.1) and the vessel traffic section (2.2.2).

Divers are attracted to the site because of the abundant marine life and submarine features. Below water, divers may have a wide range of known effects, including the harvest of natural resources, direct physical damage to habitat and indirect impacts, such as harassment of species with underwater lights (Lynch et al. 2004).

Table 3. Pathways of effects for tourism activities

Activity	Stressor	Effect
Tourism	Underwater light	Harassment of species (benthic)
	Physical disturbance	Harassment of species (benthic)
		Alteration of habitat

2.2.4 Scientific Research and Monitoring

Scientific research in the SK-B MPA has been sporadic. Research has focused on geology, ecology, oceanography, and fisheries research to investigate the potential of rockfish and sablefish fisheries. Past surveys provide preliminary information on the species richness and biodiversity of the area but is not complete enough to be regarded as a baseline study; Canessa et al. (2003) provides a summary of past research activities.

Previous data collection methods at Bowie have included measurements of the physical and chemical characteristics along the seabed, capturing video footage from a submersible vehicle, exploratory fishing (trawl, hook and line, trap and jig) and hydroacoustic surveys. While the data obtained from this work is informative, it should be recognized that the stressors associated with physical biological sample collection has the potential to effect to the flora and fauna of the seamount community similar to those outlined above in the fishing section (2.2.1) and the vessel traffic section (2.2.2). Scientific research and monitoring activities from non-biological sample collection activities (e.g. physical and chemical measurement of the seabed characteristic and video assessments) also can produce stressors that may disturb organisms and/or habitat structures such as sediment re-suspension through accidental contact by submersible vehicles or the use of propulsion thrusters.

Table 4. Pathways of effects for scientific research and monitoring activities

Activity	Stressor	Effect
Scientific research & monitoring	Anchoring equipment	Loss of biodiversity
		Indirect effects on biodiversity from the destruction of biogenic species that create complex habitat
	Light exposure from submersible vessels and underwater observation equipment	Harassment of species (benthic)
	Bottom contact from a submersible	Harassments of species (benthic)
Alteration of habitat		

2.2.5 Environmental Forcers

SK-B MPA does not exist in isolation and is influenced by large scale environmental forcers that affect the northeastern Pacific Ocean. Environmental forcers are potential or existing environmental conditions that have a significant influence on the environmental quality of the region, but cannot be managed solely through changes in human use of the MPA. These environmental forcers may include climate change and cyclic weather patterns.

Changes to global and regional climate

Changes have occurred in several aspects of the atmosphere and surface that alter the global energy budget of the Earth (Solomon et al. 2007). The United Nations Intergovernmental Panel

on Climate Change (IPCC) and the national science academies of eleven nations, including Canada, have recognized that the Earth's atmosphere is warming and that human activities that release greenhouse gases are an important cause (BC Ministry of Environment 2006). Although several of the major greenhouse gases occur naturally, increases in their atmospheric concentrations over the last 250 years are due largely to human activities (Solomon et al. 2007). The increase in greenhouse gases warms the atmosphere and affects the temperature of air, land, and water, as well as patterns of precipitation, evaporation, wind, and ocean currents. Climate change impacts on the ocean include sea surface temperature-induced shifts in the geographic distribution of marine biota and compositional changes in biodiversity, particularly at higher latitudes (Gitay et al. 2002). It has not been determined whether or not climate change will also amplify the effects of existing ocean-atmospheric cyclic weather patterns, such as El Niño Southern Oscillation and the Pacific Decadal Oscillation (Folland et al. 2001; McPhadden et al. 2006).

The result of climate change on the SK-B MPA ecosystem and species is unknown. Changes in oceanic temperature and circulation patterns cause changes in production of the phytoplankton that form the base of the oceanic food chain (BC Ministry of Environment 2006). These changes may cascade through the food chain and impact higher trophic levels at the SK-B MPA.

Cyclic weather patterns

Cyclic oceanographic patterns that impact the northeastern Pacific include the El Niño–Southern Oscillation cycle and Pacific Decadal Oscillation. These oscillations produce fluctuations in climate and oceanographic conditions. The trends or regimes can be characterized by stable means in physical data series (e.g. sea surface temperature) or multiyear periods of linked recruitment patterns in fish populations (Beamish et al. 1999). Changes due to regime shifts can include changes to prey composition, availability and seasonality and can impact several trophic levels of the food web. These changes reflect the resilience of the ecosystem and are not necessarily a sign of detrimental impacts.

The El Niño–Southern Oscillation (ENSO) cycle is the strongest natural variation of Earth's climate on year-to-year time scales, affecting physical, biological, chemical, and geological processes in the oceans, in the atmosphere and on land (McPhadden et al. 2006). The ENSO cycle consists of alternating cycles of cold, productive ocean conditions (La Niña) and warm, less productive ocean conditions (El Niño), both of which have been observed and documented for decades.

During El Niño years some migratory species that prefer warmer water, such as Humboldt squid (*Dosidicus gigas*) and Ocean Sunfish (*Mola mola*), are observed farther north than usual (DFO 2006). El Niño years have produced strong mid-latitude low pressure systems in the region of the Gulf of Alaska which tend to create stronger offshore storms than normal (Environment Canada 2010). In addition, years with very strong El Niño events appear to produce strong Haida eddies (Miller et al. 2005).

La Niña often produces climate impacts that are roughly opposite to those of El Niño (McPhadden et al. 2006). During La Niña years there is increased productivity of the ocean caused by upwelling of colder, nutrient rich water along the continental slope.

The Pacific Decadal Oscillation (PDO) describes decadal-scale pattern of variability based on mean monthly sea surface temperature anomalies in the North Pacific basin (Mantua et al.

1997; DFO 2006). The PDO, like ENSO will produce oceanographic conditions with high productivity, though not on a global scale. The PDO can produce alternating positive and negative phases that have lasted 20–30 years and have resulted in regional changes to prey composition and availability along the Pacific coast (Hollowed et al. 2001; Chavez et al. 2009).

2.3 ECOLOGICAL RISK ANALYSIS

Completing the pathways of effects analysis for all the human activities that take place within the MPA will identify effects that need to be evaluated using an ecological risk analysis framework (ERAF). The ERAF is a starting point to ask scientifically plausible questions about the nature and extent of the effects due to human activities. Many different types of ecological risk analysis frameworks exist to address different ecosystems and human activities. DFO has developed an ecological risk analysis framework for habitat assessment that can be used to understand the impacts of activities within an MPA. This risk analysis framework is intended to provide a structured approach to decision-making that takes into account the concepts of risk, uncertainty and precaution (DFO 2010b).

To assess risk from a specific stressor, the scale of negative effects as identified in the PoE, must be considered in context with the sensitivity of the biodiversity, habitat or ecosystem form or function that is being impacted. The scale of negative effect may be described as the extent or direct or indirect footprint of the stressor, the duration or amount of time that effects from the stressor will persist in the environment, and intensity of the stressor. The sensitivity of the ecosystem components (biodiversity, habitat or ecosystem form or function) can be described as the expected degree of change due to the stressor and ability of the ecosystem component to recover. A risk assessment matrix (Figure 5) incorporates these two factors in order to characterize the residual effects as either low risk, medium risk, high risk and significant negative effects (DFO 2010b). The residual effects are those effects to the ecosystem that can not be mitigated. The rationale used to locate the residual effects on the matrix forms the basis for decision-making (Boutillier et al. 2010). The risk assessment matrix can also be used to acknowledge uncertainty associated with predicting the scale of negative effects on the ecosystem. Uncertainty can be represented visually on the risk assessment matrix by plotting a circle or oval of various sizing around the point plotted; a small circle would represent a low level of uncertainty whereas a large circle would represent a high level of uncertainty (Figure 6). An oval can be plotted in situations where there is a high level of uncertainty for one descriptor and a low level of uncertainty for other descriptors.

Completion of both the pathways of effects and a risk assessment will produce a large volume of information to describe the stressors and effects for each activity. Plotting the results on a risk assessment matrix for a single stressor may not provide enough direction to prioritize a monitoring plan. It may be necessary to determine the frequency or likelihood of occurrence for each activity, and their associated effects, in order to judge the severity of impact and prioritize monitoring efforts. An activity with a high level of risk but a low probability of occurrence should not necessarily be given the same priority as an activity with a low or medium level of risk but a high probability of occurrence. It is also important to consider cumulative effects due to similar stressors from several different activities when ranking the severity of effects. There may be synergistic effects whereby two or more effects in combination express a greater impact than the sum of the individual impacts.

2.4 REFINEMENT OF CONSERVATION OBJECTIVES

If conservation objectives established for a particular MPA are not measurable, then the identification of the stressors, their effects and the resulting risk they pose may help inform the development of measurable objectives. Conservation objectives, thus redefined, are often referred as operational objectives. Conservation objectives should use language that directly corresponds to the language in policies, regulations, and legislation that already exists (DFO 2007).

The need for clear and specific operational objectives is supported by a rich body of scientific literature on the selection of indicators and development of monitoring protocols (Noss 1999; Dale and Beyeler 2001; Failing and Gregory 2003; Niemi and McDonald 2004; DFO 2008; Niemeijer and de Groot 2008). When developing a cost-effective, statistically sound, and scientifically defensible monitoring program, all decisions related to indicator selection, sampling design and optimal allocation of research dollars should be informed by specific operational objectives. Ultimately, the lack of clearly specified objectives can lead to inconsistent and scientifically indefensible management actions, and the inability to assess management success (Failing and Gregory 2003).

The need to unpack high level objectives for the SK-B MPA was recognized in the 2008 Bowie Seamount Science Monitoring Workshop (Kucera 2008). The current conservation objective for the SK-B MPA, *'to conserve and protect biodiversity and biological productivity'*, can not be measured until the specific attributes of biodiversity and biological productivity that are to be managed are defined (Failing and Gregory 2003). It will also be necessary to define the desired target state, along with a timeframe and an acceptable probability of achieving the state (assuming the current state does not meet the targeted state). The involvement of other branches within DFO (Fisheries and Aquaculture Management, Science, etc.) will be essential to ensure operational objectives have a mechanism to support decisions regarding the human activities within the MPA.

Given that the high level conservation objective has not been unpacked into operational objectives, the authors' ability to provide scientifically defensible advice on key indicators and monitoring protocols is severely limited. However, in the absence of the anticipated operational objectives, work can begin on steps 1 and 2 of the five step stressor based indicator identification framework described in section 3.1. Completion of the pathways of effects and risk assessments may help inform the refinement of the high level conservation objectives into operational objectives.

3 MONITORING ACTIVITIES

3.1 CURRENT STATE OF MONITORING ACTIVITIES

Several different types of monitoring are needed for a Marine Protected Area monitoring program. Activity monitoring can be used to determine the nature and extent of impact from human activities in the area. Compliance monitoring can ensure that regulations and legislation around human activities are being followed. Trend monitoring can be used to track changes in the ecosystem through time, and effectiveness monitoring can evaluate ability of management actions to meet conservation objective.

Currently a comprehensive monitoring program for the SK-B MPA does not exist, however some monitoring of human activities and ecosystem trends does take place by a number of different agencies.

The seamount sablefish fishery that takes place at Bowie seamount is monitored through several fishery management programs; fishing logbooks, at-sea observation through either at-sea observers or electronic monitoring (EM), port-sampling, and dockside monitoring (DFO 2010a). All harvesters are required to keep at-sea catch records through the use of both fishing logbooks and EM to record vessel details, line/trap specifications, soak time, fishing location and retained and released catch by species. During the months of April and September fishers at the SK-B MPA are required to take one at-sea observer on-board to opportunistically record additional data such as length frequencies, sex ratios, and collect otoliths for age compositions. Electronic video monitoring takes place during all other trips with 10% of the video reviewed for accuracy of catch documentation by an independent consultant. Port-samplers in Prince Rupert and Vancouver collect biological data from commercial landings whenever feasible, and third-party dock-side monitoring verifies the catch as it is offloaded from the fishing vessel.

DFO participates in several programs that track the status of oceanographic conditions in the North Pacific. These include the free-drifting profiling floats for the Argo project that provide information on water temperature and salinity profiles, as well as satellite imagery from SeaWiFS and MODIS satellites that monitor phytoplankton and nitrate levels. In addition, sampling by the Continuous Plankton Recorder (CPR) for the Sir Alister Hardy Foundation for Ocean Science provides data on the seasonal cycle of total mesozooplankton biomass throughout the Pacific. All of the above information is currently summarized in the annual State of the Oceans Report (<http://www.pac.dfo-mpo.gc.ca/science/psarc-ceesp/osrs/index-eng.htm>). However, it should be noted that this summary provides a snap-shot for conditions over the previous year and is not a synthesis of a multi-year dataset. The above work is designed to document the state of the North Pacific Ocean and may present results at too coarse a scale for the SK-B MPA monitoring.

Other federal departments also monitor human activities within the area. Transport Canada monitors ballast water exchange of ocean-going vessels through the Canadian Ballast Water Program, and pollution due to oil spills through the National Aerial Surveillance Program (NASP). Environment Canada also monitors oil spills and other ocean surface anomalies through the Integrated Satellite Tracking of Pollution (ISTOP) program which uses satellite imagery.

Previous data collection efforts within the SK-B MPA have focused on fisheries research studies, geological studies, oceanographic and ecological studies to understand the area's physical components, species richness and oceanographic conditions at seamounts and is summarized in Canessa et al. (2003). An evaluation of current data holdings and monitoring protocols needs to be completed before any of the above datasets and associated methodologies are incorporated into a comprehensive monitoring program.

3.2 SELECTION OF APPROPRIATE AND MEANINGFUL INDICATORS AS RELATED TO CONSERVATION OBJECTIVES

The selection of indicators for the SK-B MPA is not possible until operational objectives are developed. The management plan for the SK-B MPA is currently being drafted, and development of operational objectives is anticipated through this process.

Indicators for a monitoring program should inform and support decision-making necessary for the management of an Ocean's Act MPA. To meet this need, the indicators should be used to answer the basic question; Are the conservation objectives being met? This question should be expanded to a set of scientifically based questions and testable hypotheses that relate to the specific conservation objectives for the MPA, and the human activities that impact the MPA ecosystem.

The selection of indicators for any MPA will depend on the nature of the conservation objectives. Some MPAs have straight-forward conservation objectives that relate to a specific species or habitat function, for example the protection of the Gilbert Bay cod population and its habitat (DFO 2010c). These MPAs may be well suited to relatively simple and easily defined indicators and the straightforward wording of the conservation objective may actually articulate the indicator. Other MPAs, such as the SK-B MPA have broader conservation objectives that describe the maintenance of biodiversity or productivity of an ecosystem, and are better suited to indicators that monitor complex systems or ecosystem-level characteristics. Broader conservation objectives will be challenging when determining indicators that provide meaningful data, particularly if the conservation objectives are so broad that they describe aspirations rather than specific operational objectives. Unpacking the broad conservation objectives into finer scale conservation objectives based on stressor based framework which; identifies the human activities that can be managed; understands the stressors associated with the activity; and quantify resulting effects against which that take place within the MPA will provide the most relevant information to MPA managers and allow for the sustainable management of these activities and the conservation of biodiversity, habitat and ecosystem form and function. Ideally the suite of indicators should represent key information about structure, function, and composition of the ecological systems (Dale and Beyeler 2001), and should be linked in a logical manner to the conservation objectives. Indicators that cannot be linked to a specific operational objective should not be proposed for inclusion in a monitoring program. By the same token, all operational objectives should be linked to at least one key indicator so that progress on meeting all operational objectives can be evaluated.

If indicators are to be used in a structured decision support context, their selection must be guided even more closely by suitable criteria (Rice and Rochet 2005). These criteria will assess the quality of the information provided by a candidate indicator. Rice and Rochet (2005) have proposed the following set of nine criteria for evaluating candidate indicators; concreteness, theoretical basis, public awareness, cost, measurement, historic data, sensitivity, responsiveness, and specificity. It is essential that the indicators selected describe a concrete property of the ecosystem that can be measured (either directly or in-directly). The candidate indicators should also be sensitive and responsive to change, and have specificity to a particular management action. Other criteria to consider in the screening process include the existence of historical data, public awareness, and theoretical basis for use of the particular indicator. Cost is also a consideration when prioritizing indicators for monitoring.

3.3 APPROACHES AND WORKPLANS FOR MONITORING

A methodology to understand the ecological footprint of each human activity is described below and a workplan for specific data requirements and analysis are summarized. In some instances protocols for data collection and historical data sets may already exist for some indicators; in other cases protocols may need to be developed and baseline surveys completed. Some of this work will require additional data collection, including vessel time and staff to complete the field studies, and subsequent data analysis. Operational objectives and monitoring priorities will be

necessary to prioritize this work. Data management will need to be incorporated into all workplans.

3.3.1 Monitoring Fishing Activities

Fish Populations

The existing sources of fishery data (logbooks, at-sea observers, electronic video monitoring, port samplers, dockside verification) should be reviewed to determine the fishing pressure and population structure of target and non-target species within the SK-B MPA. Sampling effort by at-sea observers is dependent on available time and work-load; accurate documentation of catch is their first priority and takes precedent over biological sampling. Data collection that is not part of current sablefish licence requirements would require additional resources, including vessel time and staff to complete the work, and subsequent data analysis.

Table 5. Workplan for monitoring fish populations

Work needed	Potential existing datasets and protocols
Determine the feasibility to carry out sustainable fishing practices as defined in the policies of the Sustainable Fisheries Framework	Review existing sources of fishery data (logbooks, at-sea observers, electronic video monitoring, port samplers, dockside verification) to determine fishing pressure on target and non-target species within the SK-B MPA

Benthic Impacts

An impact assessment that follows an ecological risk analysis framework is necessary to quantify the amount of seafloor disturbance due to fishing activities. A review of fishery logbook and observer data will track occurrences of by-catch of biogenic structures (corals and sponges). However, documented encounters must be considered a minimum of actual encounter activity due to the inability to detect disturbances where corals or sponges are not landed, and inaccuracies in logbook recording. Undetected encounters may be caused by traps crushing structures but not being retained by the trap, and dragging traps along the seabed during retrieval of the string or during a storm. Previous submersible data could be reviewed to characterize the benthic habitat and species richness of visited areas; although all of this submersible work has been within Zone 1 at depths much shallower than the area impacted by the commercial fishery. Predictive modeling may be used to interpolate the species distribution in unsurveyed areas (Finney 2010).

Table 6. Workplan for monitoring benthic impacts

Work needed	Potential existing datasets and protocols
Impact assessment of fishing activities to quantify amount of seafloor disturbance	Fishery logbook data on gear configurations (e.g. length of lines and number of traps)
Determine amount of encounters between fishing gear and biogenic structures (corals and sponges)	Fishery logbook data on coral and sponge encounters
Characterize the habitat within fished area (Zone 2), either through predictive modelling to interpolate habitat type in areas not surveyed by submersibles, or through additional survey work (submersibles or substrate collection grabs)	Historic submersible survey data within SK-B MPA (Yamanaka 2005); use protocol developed by Finney (2010) to predict potential coral and sponge distribution within Zone 2

3.3.2 Monitoring Vessel Traffic

Monitoring of vessel activity could be achieved through the use of passive acoustic monitoring. This would allow MPA managers to track the frequency of vessel visits to the area and qualify the potential risk from groundings, collisions, oil spills and aquatic invasive species to the area as low, medium or high risk.

Knowledge of the seamount biodiversity and biological productivity is necessary to understand the potential impacts of vessel traffic to the area.

Oceanographic studies may also be necessary to determine if the existing ballast water exchange buffer of 50 nautical miles from the Bowie seamount pinnacle provides appropriate protection for the entire MPA from aquatic organisms that are not native to the area and may be transported through ballast water.

Table 7. Workplan for monitoring vessel traffic

Work needed	Potential existing datasets and protocols
Quantify of the amount of vessel traffic in SK-B MPA	Build on previous studies by Ford et al. (2010) and conduct passive acoustic surveys at the SK-B MPA
Expand baseline knowledge to understand impacts contaminants, oil spill or aquatic invasive species may have on structure and function of seamount ecosystem	Build on previous studies that have collected baseline information on the seamount ecosystem, summarized in Canessa et al. (2003)
Determine if existing ballast water exchange buffer of 50 nautical miles from the Bowie seamount pinnacle is appropriate	Use protocol developed by Levings and Foreman (2004) and relevant oceanographic and current data to determine appropriate water exchange buffer for Bowie seamount

3.3.3 Monitoring Scientific Research

An impact assessment for all proposed research activities is necessary in order to determine the ecological footprint of proposed research activities. Currently a post-cruise reporting system does not exist for the SK-B MPA.

Table 8. Workplan for monitoring scientific research

Work needed	Potential existing datasets and protocols
Quantify the nature and extent of research activities in SK-B MPA; amount of research activity and the area of seafloor that is impacted	No existing datasets

3.3.4 Ecosystem Reference State

Although the conservation objective for this MPA is to protect and conserve the biodiversity and biological productivity of the area, the level of biodiversity and natural variability is unknown. The 2009 Bowie Seamount Science Workshop (Kucera 2008) also identified the need to build on previous studies and expand the knowledge base of the seamount ecosystem.

Oceanographic trends in the waters west of Haida Gwaii could be characterized using information contained in the annual State of the Ocean report for the Pacific region. Previous studies on the seamount ecosystem could be used to develop indices to monitor trends in biological productivity.

Table 9. Workplan for monitoring ecosystem reference state

Work needed	Potential existing datasets and protocols
Review State of the Ocean reports to determine what information can be used to characterize oceanographic trends in the waters west of Haida Gwaii	Annual State of the Ocean reporting for Pacific Region http://www.pac.dfo-mpo.gc.ca/science/psarc-ceesp/osrs/index-eng.htm
Develop indices to document biodiversity trends in the waters west of Haida Gwaii	Build on previous studies that have collected baseline information on the seamount ecosystem, summarized in Canessa et al. (2003)

4 DISCUSSION

Ultimately DFO is responsible for the coordination of monitoring in the MPA. However, a collaborative effort involving a variety of organizations and research groups will be necessary to successfully monitor this remote seamount. Collaboration may need to include other DFO branches (i.e. Fisheries and Aquaculture Management, Oceans and Habitat Enhancement, Science, Conservation and Protection etc.) and other federal departments (Environment Canada, Transport Canada) as well as other partners (academic researchers, Council of Haida Nation), in order to share resources and achieve similar goals.

Planning for long-term monitoring activities will be crucial for the development of long-term data sets and the ultimate success of a monitoring program. Data gathered may require vessels or aircrafts of opportunity, fixed station monitoring, or remote sensing. When possible, data collection should be coordinated to support multiple objectives and monitoring programs that extend beyond the SK-B MPA boundaries, such as monitoring the recovery of species at risk. For example, several species designated as under the Species at Risk Act (SARA) have been documented throughout the North Pacific. MPAs may provide critical habitat and monitoring

sites for species specific field studies. These research projects may support objectives outlined in both recovery plans for species at risk and MPA monitoring programs.

Although collaborations are critical for monitoring this MPA, a dedicated sampling program may be necessary to ensure all proposed monitoring activities are completed. Research and monitoring activities at this MPA are only feasible from large vessels that are costly to run, and potential research may be limited to government agencies or university scientists. Opportunities for scientific monitoring by external (non-government) researchers will be dependent upon external funding sources and research interest in the area. Research networks such as Seamounts Online (<http://seamounts.sdsc.edu/>) may provide linkages with other researchers. Seamounts Online facilitates research on seamount ecology worldwide by maintaining a database of species observations at seamounts around the globe. This network allows researchers to access data and post new findings to share with other researchers. Currently there are no records in the database for the Bowie, Hodgkins or Davidson seamounts.

To determine the nature and effects that human activities have on the achievement of the broader conservation objective, a comprehensive reporting and data management system is needed that captures existing and proposed activities at SK-B MPA. Currently reporting of some activities in the area takes place using logbooks. Development of a data management system is an integral component to a monitoring program, as it will ensure data integrity and access. Data management will be necessary to compile historic information, information gathered for completing risk assessments, as well as current and future monitoring activities.

Several knowledge gaps exist that will need to be addressed in order to develop a monitoring program. There are information gaps regarding the frequency of human activities in the MPA, as well as uncertainties regarding the nature and extent of the stressors and their effects that result from these activities. The ability to complete the steps in the Stressor Based Indicator Identification Framework, including the refinement of the conservation objective, will be dependent on the data available.

There are sources of uncertainty regarding the ecosystem structure and function that will continue to exist, regardless of how extensive and thorough a monitoring program becomes. Regime shifts due to large global processes such as the Pacific decadal oscillation (PDO), El Niño and climate change may have unanticipated results on the MPA ecosystem. These large scale stressors or ecosystem drivers are not within the scope of management, but will need to be taken into consideration and may require indicators and monitoring. Cumulative impacts also need to be acknowledged when assessing the effects of human activities, developing management measures and prioritizing monitoring efforts. These are difficult to identify and hence have the potential of being overlooked or underestimated.

Although the conservation objective for the SK-B MPA is to protect and conserve the biodiversity and biological productivity of the area, the level of biodiversity is unknown at this MPA. Without understanding the biodiversity of the area it will be difficult to assess the achievement of the high level conservation objective and understand the ecosystems resilience to stressors.

5 CONCLUSIONS AND RECOMMENDATIONS

The identification of appropriate indicators to assess whether a MPA is achieving the established conservation objectives is a key component of overall management planning and implementation. The identification of indicators that are relevant and prioritized can only be successfully achieved when conservation objectives are measurable, and for the SK-B MPA, this is currently hampered by the lack of specific operational objectives.

In the absence of operational objectives, it is important to direct monitoring efforts to an evaluation of human activities in the MPA. This document proposes a five-step framework for the identification of indicators that is based on an evaluation of activities, and identifies the human activities that would be considered human induced ecosystem stressors which would have effects on the ecosystem components of the broad conservation objective including biodiversity, habitat and ecosystem form and function. A preliminary PoE assessment was conducted for human activities currently occurring at the SK-B MPA, to identify stressors and effects that impact on ecosystem components above. A more thorough evaluation of the stressors to this MPA needs to be completed before a risk assessment can be undertaken. Once the risk assessment is complete it will provide guidance priorities for the development of measurable conservation objectives. Once these operational conservation objectives are set then it will be easier to set potential indicators that include the criteria: concreteness, theoretical basis, public awareness, cost, measurement, historic data, sensitivity, responsiveness, and specificity measurable to the conservation objectives. Effective monitoring of an MPA will also require an understanding of the ecosystem processes and natural variability that take place within the MPA.

Recommendations:

1. Follow prescribed Stressor Based Indicator Identification Framework as described in this document to assess risks to the MPA and select appropriate indicators for monitoring.
2. Build on previous studies that are summarized in Canessa et al. (2003) and collect baseline data to evaluate the effects of the identified stressors for the SK-B MPA.
3. To determine the nature and effects that human activities have on the achievement of the broader conservation objective, a comprehensive reporting system is required that captures existing and proposed activities at SK-B MPA.

6 SOURCES OF INFORMATION

- Alyeska Pipeline. 2010. Alyeska Pipeline. Accessed on June 17th, 2010. <http://www.alyeska-pipe.com/Default.asp>
- Auster, P.J. and R.W. Langton. 1998. The effects of fishing on fish habitat. In L. Benaka, editor. Fish habitat: essential fish habitat (EFH) and rehabilitation. American Fisheries Society, Bethesda, Maryland.
- BC Ministry of Environment. 2006. Alive and inseparable - British Columbia's coastal environment: 2006. xii + 322
- Beamish, R.J., D.J. Noakes, G.A. McFarlane, L. Klyashtorin, V.V. Ivanov and V. Kurashov. 1999. The regime concept and natural trends in the production of Pacific salmon. Can. J. Fish. Aquat. Sci. 56: 516-526.
- Boutillier, J., E. Kenchington and J. Rice. 2010. A review of the biological characteristics and ecological functions served by corals, sponges and hydrothermal vents, in the context of applying an ecosystem approach to fisheries. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/048.
- Canadian Coast Guard. 1998. Canadian Coast Guard. Accessed on June 8th, 2010. <http://www.ccg-qcc.gc.ca/e0003909>
- Canessa, R., K. Conley and B. Smiley. 2003. Bowie Seamount Pilot Marine Protected Area: an ecosystem overview. Can. Tech. Rep. Fish. Aquat. Sci. 2461. xi + 85p.
- Chavez, F.P., J. Ryan, S.E. Lluch-Cota and C.N. Miguel. 2009. From anchovies to sardines and back: multidecadal change in the Pacific Ocean. Science. 299: 217-221.
- Crawford, W.R. 2002. Physical characteristics of Haida Eddies. Journal of Oceanography. 58: 703 - 713.
- Dale, V.H. and S.C. Beyeler. 2001. Challenges in the development and use of ecological indicators. Ecological Indicators. 1 (1): 3-10.
- DFO. 2006. State of the Ocean 2005. DFO Sci. Status Report. 2006/001.
- DFO. 2007. Guidance document on identifying conservation priorities and phrasing conservation objectives for Large Ocean Management Areas. 2007/010.
- DFO. 2008. Further guidance on the formulation, prioritization, and use of conservation objectives in an ecosystem approach to integrated management of human activities in aquatic ecosystems. Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/029.
- DFO. 2010a. Pacific region integrated fisheries management plan, Groundfish, February 21, 2010 to February 20, 2011. 189p
- DFO. 2010b. Practitioners guide to the risk management framework for DFO Habitat Management staff. 25p

-
- DFO. 2010c. Review of the Gilbert Bay Marine Protected Area monitoring indicators, protocols and strategies, and an assessment of the Gilbert Bay cod population. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/27:
- Environment Canada. 2010. Climate change - global effects of El Niño Accessed on Jan. 6th. <http://www.ec.gc.ca/adsc-cmda/default.asp?lang=En&n=CBFCFFE3-1>
- Failing, L. and R. Gregory. 2003. Ten common mistakes in designing biodiversity indicators for forest policy. *Journal of Environmental Management*. 68 (2): 121-132.
- Finney, J.L. 2010. Overlap of predicted cold-water coral habitat and bottom-contact fisheries in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/067.
- Folland, C.K., T.R. Karl, J.R. Christy, R.A. Clarke, G.V. Gruza, J. Jouzel, M.E. Mann, J. Oerlemans, M.J. Salinger and S.-W. Wang. 2001. Observed climate variability and change. In J.T. Houghton, Ding, Y., Griggs, D.J., M. Nouer, Linden, P.J.v.d., Dai, X., Maskell, K. and Johnson, C.A., editor. *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge UK and New York, NY, USA.
- Ford, J.K.B., B. Koot, S. Vagle, N. Hall-Patch and G. Kamitakahara. 2010. Passive acoustic monitoring of large whales in offshore waters of British Columbia. *Can. Tech. Rep. of Fish. and Aquat. Sci.* (2898): vi + 30p.
- Gin, K.Y.H., M. Kamrul Huda, W. Kiat Lim and P. Tkalich. 2001. An Oil Spill-Food Chain Interaction Model for Coastal Waters. *Marine Pollution Bulletin*. 42 (7): 590-597.
- Gitay, H., A. Suráñez, R.T. Watson and D.J. Dokken. 2002. Climate change and biodiversity. Technical Paper of the Intergovernmental Panel on Climate Change. 86.
- Government of Canada. 2004a. Canadian action plan to address the threat of aquatic invasive species. Canadian Council of Fisheries and Aquaculture Ministers. 26p
- Government of Canada. 2004b. An invasive alien species strategy for Canada. 40p
- Hall, M.A., D.L. Alverson and K.I. Metuzals. 2000. By-Catch: Problems and Solutions. *Marine Pollution Bulletin*. 41 (1-6): 204-219.
- Hollowed, A.B., S.R. Hare and W.S. Wooster. 2001. Pacific Basin climate variability and patterns of Northeast Pacific marine fish production. *Progress In Oceanography*. 49 (1-4): 257-282.
- Jennings, S. 2005. Indicators to support an ecosystem approach to fisheries. *Fish and Fisheries*. 6 (3): 212-232.
- Jennings, S., M.J. Kaiser, A.J.S. J.H.S. Blaxter and P.A. Tyler. 1998. The Effects of Fishing on Marine Ecosystems. In editor. *Advances in Marine Biology*. Academic Press,
- Johnson, K.A. 2002. A review of national and international literature on the effects of fishing on benthic habitats. NOAA Technical Memorandum. NMFS-F/SPO-57: iv+72p.

-
- Kenchington, T. 2010. Environmental Monitoring of the Gully Marine Protected Area: A Recommendation DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/75:
- Kucera, H. 2008. Bowie Seamount science monitoring workshop report. *unpublished*.
- Levings, C., D. Kieser, G.S. Jamieson and S. Dudas. 2002 Marine and estuarine alien species in the Strait of Georgia, British Columbia. *Journal/Alien Invaders in Canada's waters, wetlands and forests*. 111-132.
- Levings, C.D. and M.G.G. Foreman. 2004. Ecological and oceanographic criteria for alternate ballast water exchange zones in the Pacific region. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/118. iv + 37p
- Lynch, T.P., E. Wilkinson, L. Melling, R. Hamilton, A. Macready and S. Feary. 2004. Conflict and Impacts of Divers and Anglers in a Marine Park. *Environmental Management*. 33 (2): 196-211.
- Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace and R.C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bulletine of the American Meteorological Society*. 78 (6): 1069 - 1079.
- McPhadden, M.J., S.E. Zebiak and M.H. Glantz. 2006. ENSO as an integrating concept in Earth Science. *Science*. 314: 1740-1747.
- Miller, L.A., M. Robert and W.R. Crawford. 2005. The large, westward-propagating Haida Eddies of the Pacific eastern boundary. *Deep Sea Research Part II: Topical Studies in Oceanography*. 52 (7-8): 845-851.
- National Research Council. 2003. Oil in the sea III: inputs, fates, and effects. National Academy Press. Washington, D.C.
- Niemeijer, D. and R.S. de Groot. 2008. A conceptual framework for selecting environmental indicator sets. *Ecological Indicators*. 8 (1): 14-25.
- Niemi, G.J. and M.E. McDonald. 2004. Application of Ecological Indicators. *Annual Review of Ecology, Evolution, and Systematics*. 35: 89-111.
- Noss, R.F. 1999. Assessing and monitoring forest biodiversity: A suggested framework and indicators. *Forest Ecology and Management*. 115 (2-3): 135-146.
- Peterson, C.H., S.D. Rice, J.W. Short, D. Esler, J.L. Bodkin, B.E. Ballachey and D.B. Irons. 2003. Long-term ecosystem response to the Exxon Valdez oil spill. *Science*. 302:
- Rice, J. and M. Rochet. 2005. A framework for selecting a suite of indicators for fisheries management. *ICES Journal of Marine Science*. 62: 516-527.
- Sloan, N.A. 1999. Oil impacts on cold-water marine resources: A review relevant to Parks Canada's evolving marine mandate. *Occasional Paper No. 11*.

-
- Solomon, S., D. Qin, M. Manning, R.B. Alley, T. Berntsen, N.L. Bindoff, Z. Chen, A. Chidthaisong, J.M. Gregory, G.C. Hegerl, M. Heimann, B. Hewitson, B.J. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T.F. Stocker, P. Whetton, R.A. Wood and D. Wratt. 2007. Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.
- Teal, J.M. and R.W. Howarth. 1984. Oil spill studies: A review of ecological effects. *Environmental Management*. 8 (1): 27-44.
- Transport Canada. 2010. National Aerial Surveillance Program. Accessed on September 15th, 2010. <http://www.tc.gc.ca/eng/mediaroom/backgrounders-b04-m126e-1342.htm>
- Wyeth, M.R., A.R. Kronlund and M. Elfert. 2006. Summary of the 2004 British Columbia Sablefish (*Anoplopoma fimbria*) research and assessment survey. *Can. Tech. Rep. of Fish. and Aquat. Sci.* 2660.
- Yamanaka, K.L. 2005. Data report for the cruise onboard the *CCGS John P. Tully* and the *F/V Double Decker* to Bowie Seamount and Queen Charlotte Islands July 31st to August 14th 2000. . *Can. Data. Rep. Fish. Aquat. Sci.* 1163. vii + 46p

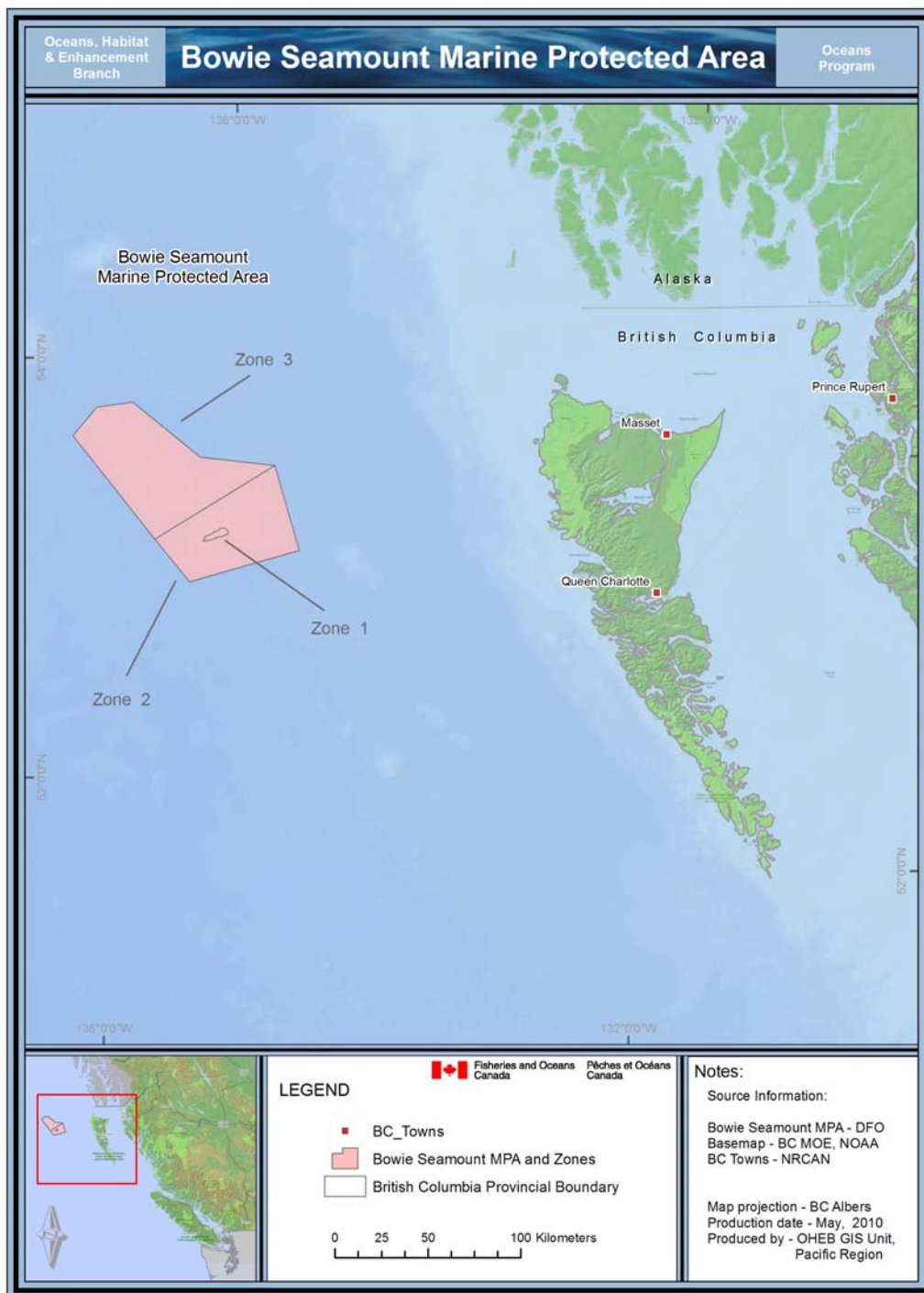


Figure 1. Location of Sgaan Kinghlas Bowie Seamount Marine Protected Area

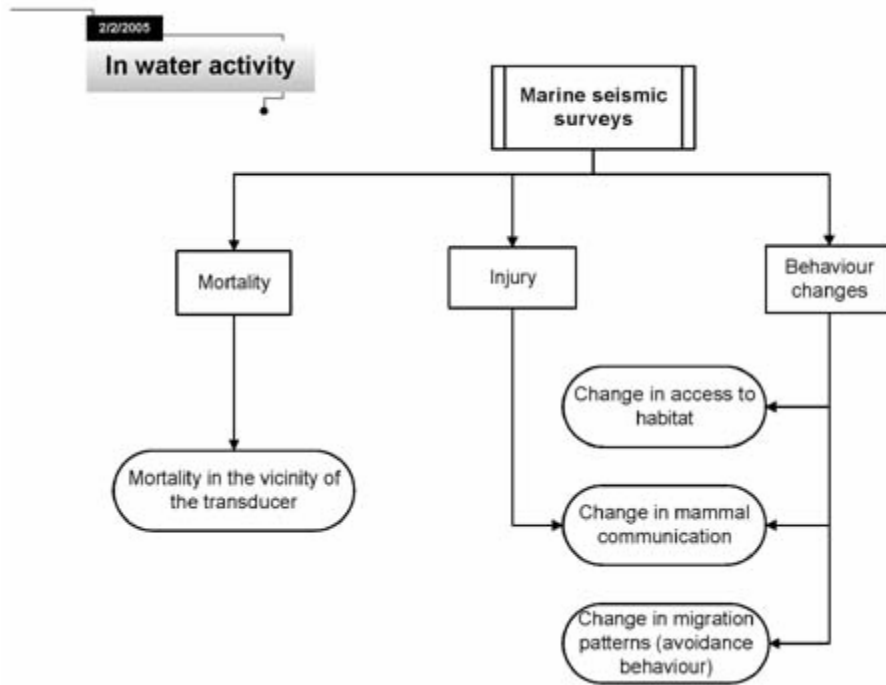


Figure 2. Pathways of effects for marine seismic surveys

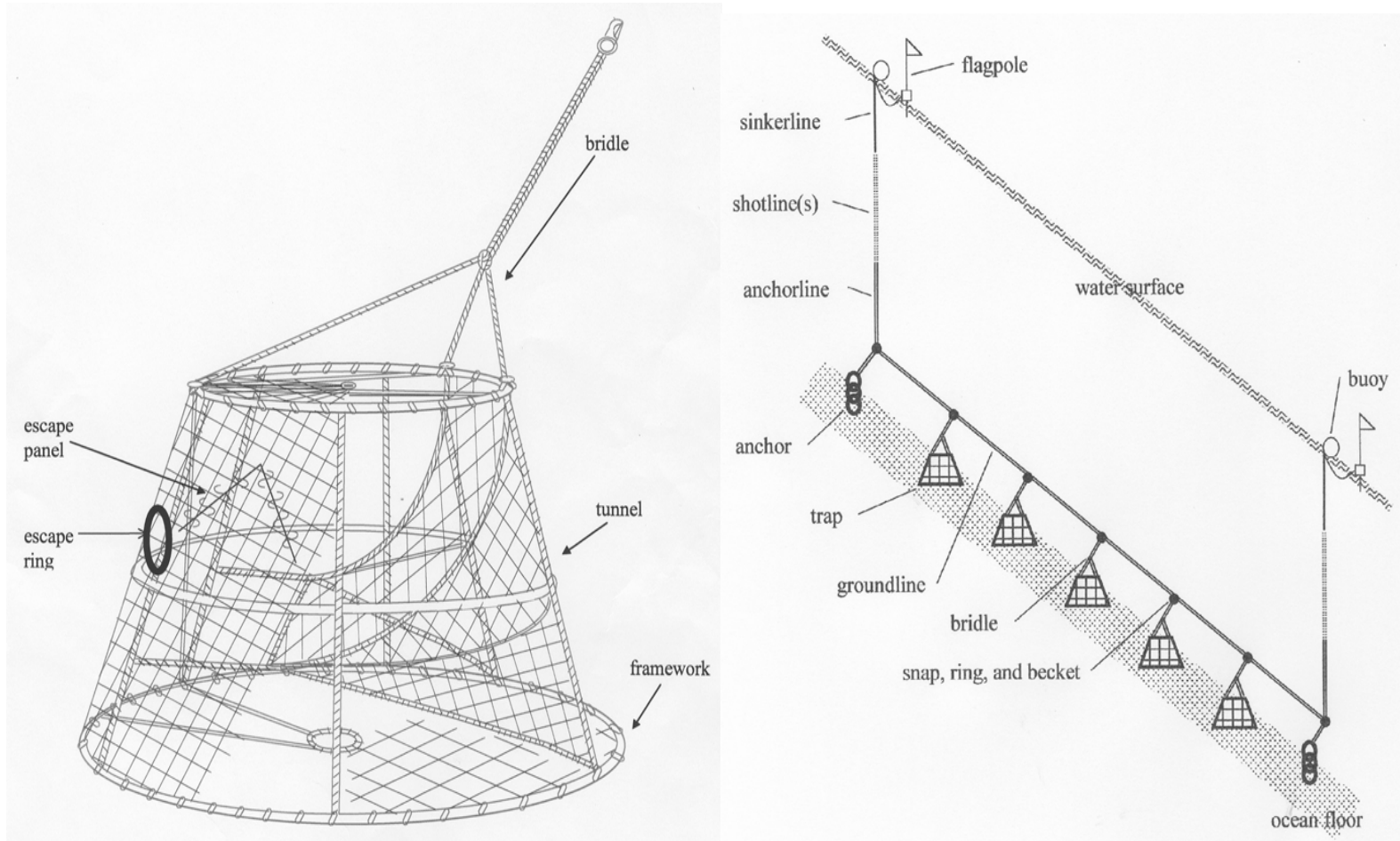


Figure 3. Diagrams of typical fishing gear used for the sablefish trap fishery. The left panel shows a modified Korean trap of the kind used for survey fishing. The right panel shows a diagrammatic representation of the components of a set, or string, of trap gear (Wyeth et al. 2006)

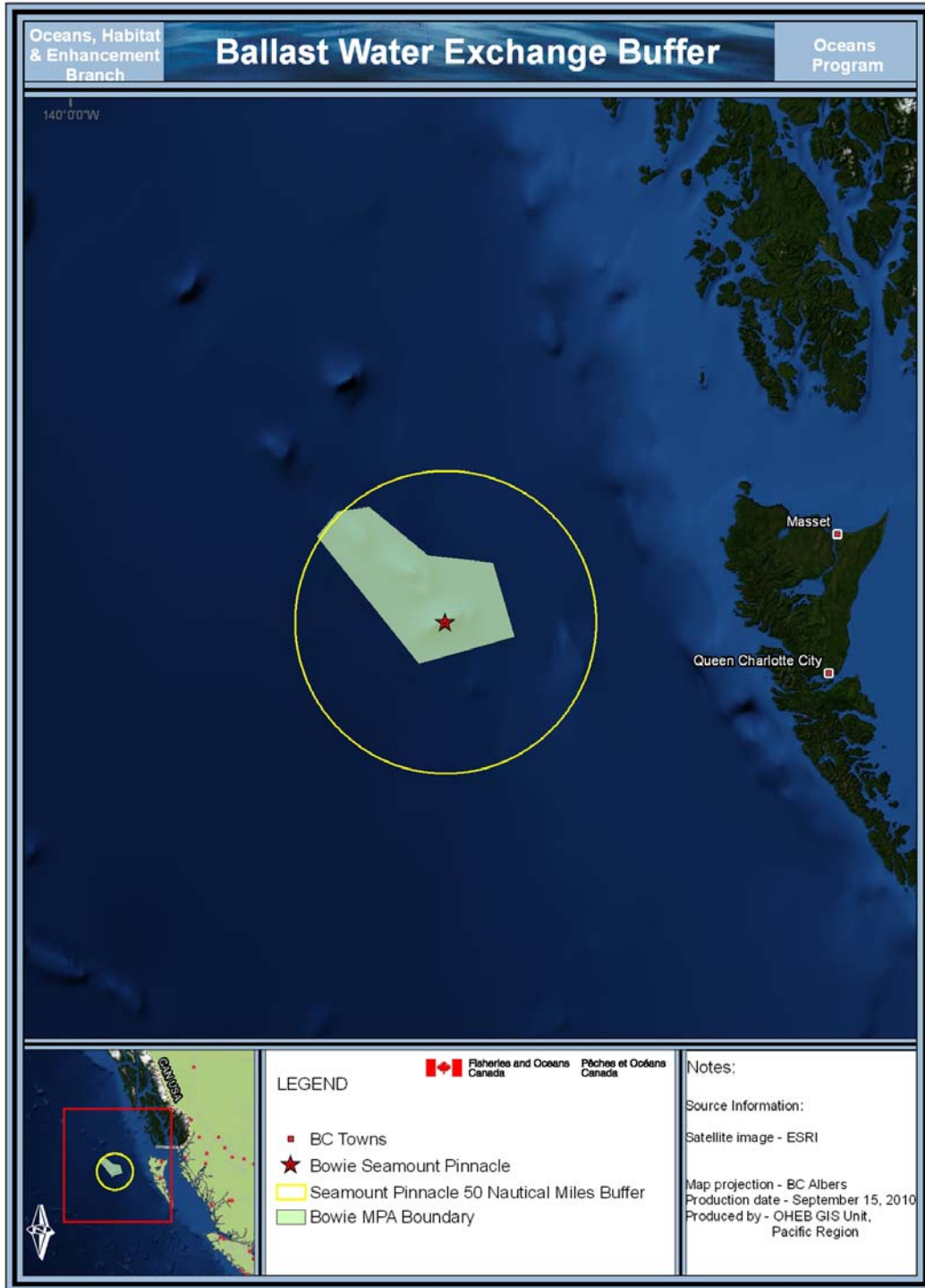


Figure 4. Sgaan Kinghlas Bowie Seamount Marine Protected Area ballast water exchange buffer

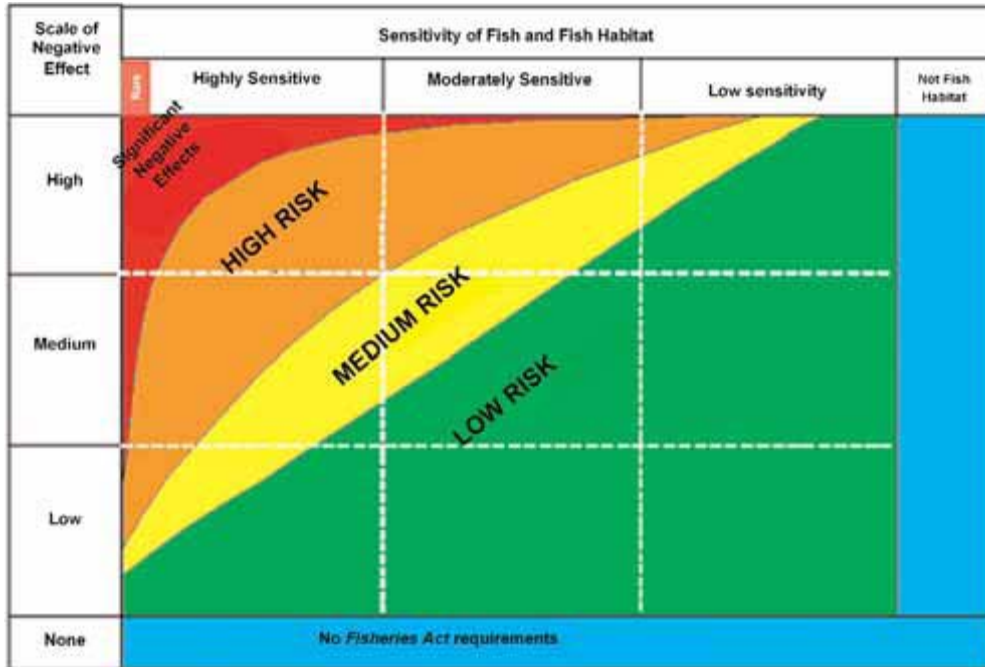


Figure 5. Risk assessment matrix used to illustrate various categories of risk (DFO 2010b)

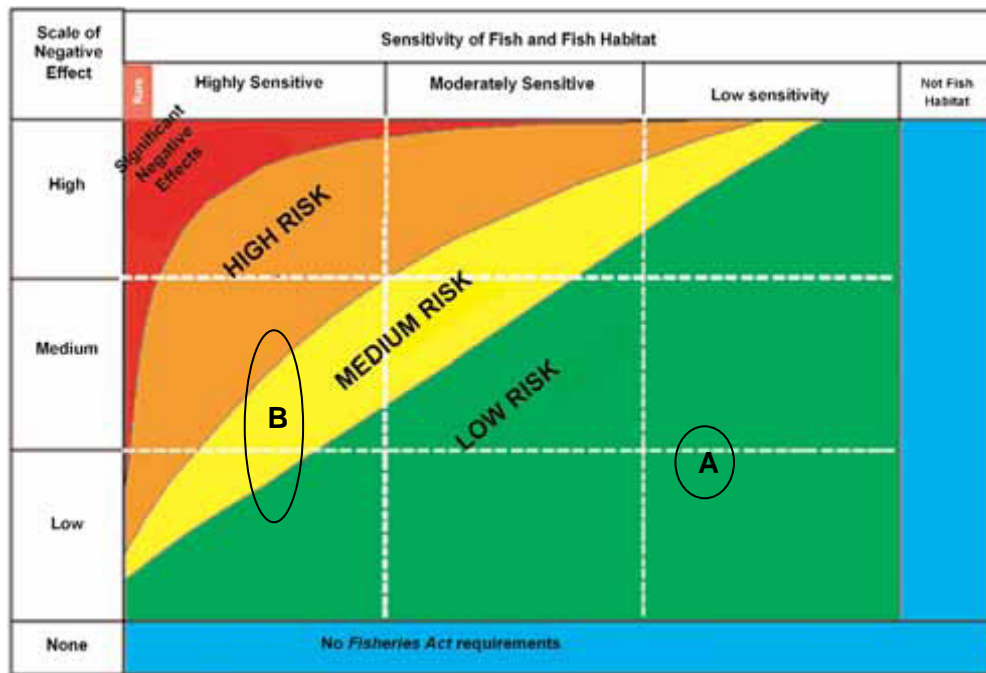


Figure 6. Risk assessment matrix used to illustrate uncertainty. (A) Low risk project with little uncertainty associated with the risk assessment. (B) A high degree of uncertainty associated with predicting scale of negative effect has led to an overlap of risk categories (DFO 2010b).