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Ecological Risk Assessment for the Effects of Human Activities at the SGaan Kinghlas-Bowie Seamount Marine Protected Area

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

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ABSTRACT

This project applied the Level 2 Risk Assessment framework proposed by O et al. (2015) to the SGaan Kinghlas-Bowie Seamount Marine Protected Area (SK-B MPA) to determine the relative risk to the SK-B MPA ecosystem from anthropogenic activities. We identified a total of 16 significant ecosystem components (SECs) for the SK-B MPA ecosystem based on the criteria and considerations identified in O et al. (2015). Only 14 SECs (10 species SECs and four habitat SECs) underwent a Level 2 Risk Assessment. Two community property SECs were identified, but there was not enough information available to comprehensively apply the Level 2 assessment to these SECs. The risk assessment determined the overlap between selected SECs and human activities using an interaction matrix and highlighted potential negative effects. Interactions that were determined to have negligible or positive effects were filtered out at this stage. All SEC-stressor combinations were scored for exposure and consequence to calculate the relative risk to SECs in the ecosystem. Prior to the risk calculations, the scores were reviewed by subject matter experts (SMEs). The results of the risk analysis indicate that stressors related to *oil spills*, *seismic surveys*, *fishing*, and *aquatic invasive species* pose the greatest risk to the SK-B MPA ecosystem. The Bamboo Coral species SEC, *Isidella tentaculum*, the Gorgonian Coral habitat SEC, and the Sponge habitat SEC have the highest cumulative risk score within the MPA. For the fish SECs, Rougheye Rockfish has the highest cumulative risk score. Most of the other SECs were similarly ranked on a relative scale and our results show that species and habitats that are predominantly found in Zone 1 of the SK-B MPA are at lower risk because they are protected from the stressors associated with the Sablefish trap fishery that is only permitted in Zone 2 of the MPA. Species and habitats that are predominantly found in Zone 1 include Macroalgae, Crustose Coralline Algae, and the coral species SEC, *Primnoa sp*. The high uncertainty surrounding certain stressors such as those related to *seismic surveys*, *oils spills*, the *aquatic invasive species* increase the median risk score and highlight gaps in our understanding of the exposure and consequence of these activities within the MPA boundary. This result shows the need for monitoring in order to understand and quantify the exposure of SECs to these activities within the MPA area. The relative risk scores and ranked stressors can be used for the prioritization of monitoring and management efforts in the SK-B MPA.

Évaluation des risques écologiques liés aux effets des activités humaines sur la zone de protection marine du mont sous-marin Bowie SGaan Kinghlas-Bowie

RÉSUMÉ

Pour ce projet, on a appliqué le cadre d'évaluation du risque de niveau 2 proposé par O *et al*. (2015) à la zone de protection marine du champ hydrothermal Endeavour (ZPM CHE) afin de déterminer le risque relatif que posent les activités anthropiques pour l'écosystème de la ZPM-CHE. La phase d'établissement de la portée a défini 11 composantes importantes de l'écosystème (CIE) qui représentent adéquatement la ZPM-CHE (six CIE relatives aux espèces, quatre CIE relatives à l'habitat, et une CIE relative aux communautés) ainsi que les activités anthropiques et les agents de stress connexes dans la ZPM CHE. L'évaluation des risques a permis de déterminer l'interaction entre les CIE choisies et les agents de stress, et elle a classé par ordre de priorité les CIE et les agents de stress sur une échelle relative dans la ZPM CHE en se basant sur l'estimation du risque cumulatif. Cette détermination et hiérarchisation des CIE et des agents de stress est essentielle pour la sélection des indicateurs et, au bout du compte, pour l'élaboration de plans de surveillance. Les CIE qui présentent les estimations de cotes de risque cumulatives les plus élevées ont été *Ridgeia piscesae* (flux élevé), *Ridgeia piscesae* (flux faible), *(Paralvinella sulfincola)* et la communauté benthique des gisements de myes. Les *débris (décharge)*, la *perturbation du substrat (écrasement) [échantillonnage]*, la *perturbation du substrat (écrasement) [opérations avec submersibles]* et les *espèces aquatiques envahissantes [opérations avec submersibles]* sont les agents de stress qui ont reçu les estimations de cote de puissance (risque cumulatif par agent de stress) les plus élevées. Les incertitudes relevées par l'évaluation des risques aideront à tenir les gestionnaires des océans au courant des lacunes de connaissances et à cerner les priorités en matière de surveillance. Les incertitudes les plus élevées étaient associées aux agents de stress potentiels suivants : les *débris [décharge], les espèces aquatiques envahissantes [opérations avec submersibles],* et *les hydrocarbures [déversements d'hydrocarbures].* Certains critères décrits par O et al. (2015) pour l'évaluation du risque de niveau 2 n'étaient pas applicables ou se sont révélés difficiles à appliquer sans quelques modifications afin de pouvoir estimer le risque. Dans la plupart des cas, cette approche a été une réussite, et, dans l'ensemble, l'évaluation du risque de niveau 2 a donné de bons résultats.

1. INTRODUCTION

The development of systematic, science-based ecological risk-assessment frameworks for ecosystem-based management (EBM) holds significant value for Fisheries and Oceans Canada (DFO) Oceans Management. Such frameworks may be used to determine the linkages between specific anthropogenic activities, their associated stressors, and ecologically significant ecosystem components (SECs) deemed important for the health and survival of an ecosystem. This information is crucial for the selection of indicators and in turn, the development of monitoring plans that will feed into an integrated management (IM) approach to ecological monitoring.

An ecological risk-assessment framework (ERAF) was developed by the Pacific Region (O et al. 2015) to evaluate the single and cumulative threats from multiple anthropogenic activities and their associated stressors to SECs. This framework considers ecological SECs on a species, habitat, and community level. The key elements of this framework consist of an initial scoping phase followed by the risk assessment. Scoping includes the identification of SECs and the identification of anthropogenic activities and stressors that have the potential to affect these SECs using Pathway of Effects (PoE) Models. The risk assessment consists of evaluating the risk of harm to each SEC from the identified activities and associated stressors using criteria and scoring methodology described in the ERAF (O et al. 2015) with modifications recommended by a February 2014 CSAS review (DFO 2015). The ERAF consists of three levels of risk assessment: Level 1 - qualitative; Level 2 - semi-quantitative; and, Level 3 - fully quantitative. Selection of risk assessment level is dependent on available information of SECs and activities in the specified area.

This study applied a Level 2 risk assessment framework to the SGaan Kinghlas-Bowie Seamount Marine Protected Area (SK-B MPA) in DFO’s Pacific Region. This MPA was selected for evaluation as it represents a geographically defined area in the marine environment where anthropogenic activities are limited and monitored. In applying the ERAF to the SK-B MPA, this study specifically aims to: identify ecological SECs that appropriately represent the ecosystem at the SK-B MPA; identify anthropogenic activities and stressors that have the potential to negatively impact these SECs; and, prioritize stressors and SECs on a relative scale within the SK-B MPA.

Ultimately, the information gained from this study will increase our understanding of human impacts on the SK-B MPA, and how we may reduce those impacts through the monitoring and management of human activities. The detailed process of the ERAF will also reveal knowledge gaps in our understanding of the SGaan Kinghlas-Bowie Seamount ecosystem, and the lack of quantitative data on many of the human activities in the area.

1.1 SGAAN KINGHLAS-BOWIE SEAMOUNT MARINE PROTECTED AREA

The SGaan Kinghlas-Bowie Seamount Marine Protected Area is located 180 km west of Haida Gwaii and consists of the shallowest submarine volcano in Canadian waters (Figure 1). The summit of the Bowie Seamount is within the photic zone creating a unique ecosystem at the seamount that contains both deep-water species and coastal species. The SK-B MPA was officially designated an MPA in 2008 with a conservation objective to:

> *“Conserve and protect the unique biodiversity and biological productivity of the area’s marine ecosystem, which includes the Bowie, Hodgkins, and Davidson Seamounts and the surrounding waters, seabed and subsoil”*

The MPA comprises the Bowie, Hodgkins, and Davidson (also called Peirce Seamount and Pierce Seamount) Seamounts of the Kodiak-Bowie seamount chain and covers a total area of approximately 6,131 km^2.The MPA consists of a single zone and one external boundary as described in the Bowie Seamount MPA regulations (SOR/2008-124). For the purpose of fisheries management inside the MPA, three zones are defined in the Pacific Region Groundfish Integrated Fisheries Management Plan (IFMP; DFO 2016):

- Zone 1 - the fragile and productive photic zone defined by 457 m bathymetric contour. Zone 1 is considered sensitive and is afforded a higher level of protection. Area: 44 km^2.
- Zone 2 - Bowie Seamount structure and surrounding waters, seabed and subsoil, excluding the sensitive upper portion identified as Zone 1. Area: 2,538 km^2.
- Zone 3 - Hodgkins Seamount and Davidson structures, the surrounding waters, seabed, and subsoil. Area: 3,549 km^2 (there is little known about Zone 3).

Bowie Seamount rises from a depth of 3,000 m to within 25 m of the surface (see Appendix A). It is young in geological terms and its base is believed to have formed less than one million years ago and the summit shows evidence of volcanic activity as recently as 18,000 years ago (Dower and Fee 1999). The substrate is made of basalt, a common volcanic rock low in silica content. The seamount is about 55 km long and 24 km wide and its flat-topped summit is made of weakly consolidated tephra. The summit consists of two distinct terraces at depths of 220-250 m and 65-100 m. The shallower terrace is dotted with steep-sided pinnacles, the largest rising to within 25 m of the surface.

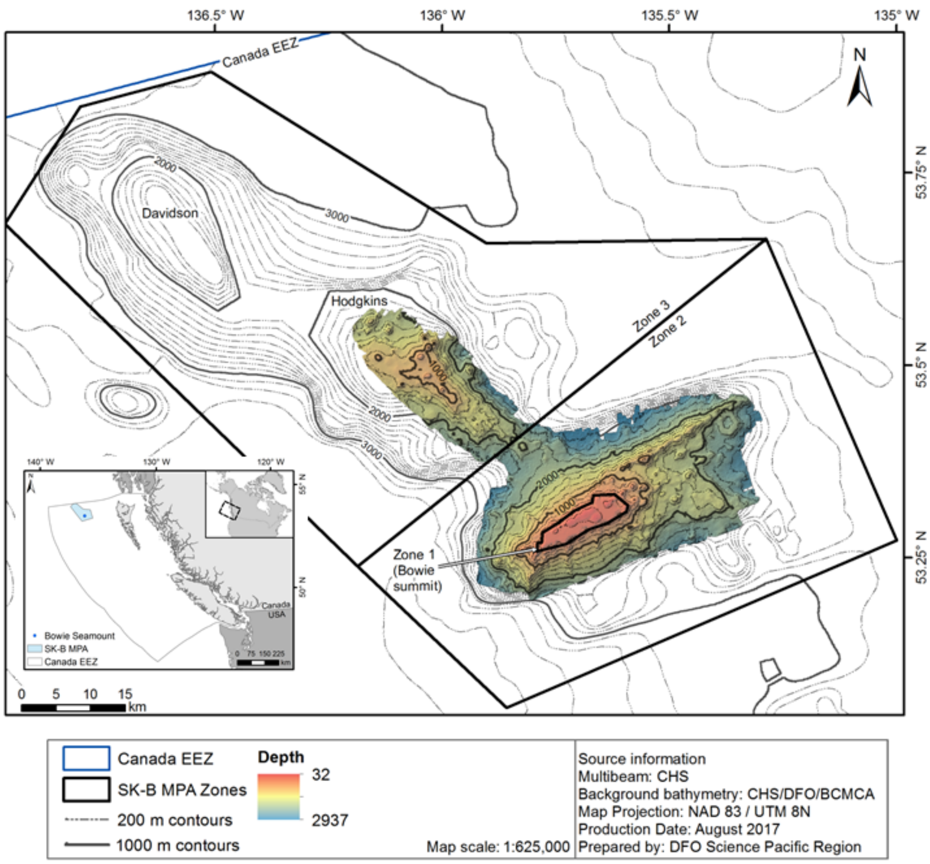


Figure 1: SGaan Kinghlas-Bowie Seamount Marine Protected Area with the fishing zones displayed. Source: K. Gale

1.1.1 Productivity at the SK-B MPA

Bowie Seamount, like other seamounts, supports a rich biological community in an otherwise unproductive region of the ocean. No specific scientific research has been conducted on the types of water flow phenomena that occur at or near Bowie, Hodgkins, and Davidson Seamounts. However, Cobb Seamount shares many characteristics with Bowie and has been studied extensively. There is evidence of a closed eddy and a Taylor cone over Cobb Seamount and assuming similar flow phenomena occur at Bowie then there is a high probability of an area of cold nutrient rich water in the upper euphotic zone where a high level of mixing occurs. In addition to localized eddies, Bowie is subject to regional eddies known as “Haida eddies”, that carry coastal waters rich in fish, plankton and nutrients such as nitrate and iron out to the SK-B MPA area. Finally, due to water clarity at the seamount, light can penetrate to depths of 40 m or more allowing for many algal species at Bowie to reach greater depths than they do in coastal waters (Canessa et al. 2003).

Seamounts often support a rich diversity of fishes, and the Bowie Seamount is no exception. There are three main hypotheses on how the large aggregations of benthopelagic fishes observed at seamounts are supported trophodynamically (summarized in Porteiro and Sutton 2007). The first hypothesis is that the high biomass of fish is a result of locally enhanced primary production and subsequent bottom-up transfer of this energy to higher trophic levels in the seamount food chain (Boehlert and Genin 1987). Upwelling and Taylor cone formation can enhance nutrients in epipelagic waters and drive increased primary productivity recorded over certain well-studied seamounts (e.g., Genin and Boehlert 1985). However, for this hypothesis to be supported the nutrient rich water would have to be retained around the seamount for a period long enough for production to work its way through the food chain (a week to a month), and Porteiro and Sutton (2007) suggest this retention is unlikely at many seamounts. The second hypothesis is the “feed-rest” hypothesis (Genin 2004) where fish aggregations are sustained at a seamount by the enhanced horizontal flux of pelagic prey organisms (via the strong currents on the upper slopes and summits of seamounts) past the seamount (Dower and Mackas 1996). This behavior is summarized as fish rest motionless in shelters and crevices during non-feeding intervals and when conditions are appropriate they emerge from shelter, feed quickly and then retreat to rest. Data to support this hypothesis include the dominance of open-water migrating micronekton in the diets of certain fish resident at seamounts (e.g., Seki and Somerton 1994). The third “topographic blockage” hypothesis (Genin 2004), and one that is likely important at Bowie (J. Boutillier, DFO Science, Pacific Biological Station, pers. comm.), is that seamount aggregations are maintained through predation on vertical migrants that are intercepted and trapped during the migration process (Isaacs and Schwatzlose 1965; Genin et al. 1988; Genin et al. 1994). In other words, zooplankton migrate to the photic zone at night to feed on phytoplankton, the current then carries them over the summit of the seamount and they are trapped on the seamount terraces during their descent, providing a concentration of forage species for visual predators such as fish during the day. There is evidence that the food supplied to seamount communities via topographic trapping is as much as 40 times greater than the local primary productivity (Isaacs and Scwartzlose 1965). If this hypothesis is true, then the physical structure of Bowie Seamount, including the two distinct terraces at depths of 220-250 m and 65-100 m, and the several steep sided pinnacles are key features maintaining the productivity of the SK-B MPA ecosystem (See Appendix A for more details of important physical habitats at the SK-B).

2. METHODS

The ERAF (O et al. 2015) is comprised of two key phases: scoping and risk assessment. A scoping phase and semi-quantitative risk assessment were applied to the SK-B MPA following the methods outlined by O et al. (2015), but with the inclusion of a revised risk scoring method recommended through a February 2014 CSAS regional peer review process (DFO 2015). All revisions to the original ERAF method (O et al. 2015) are detailed here, including any modifications to the methods considering the unique nature of the SK-B MPA.

2.1 SCOPING

The scoping phase encompasses the review and identification of key features or properties of the system (i.e., SECs) including species, habitats, and community/ecosystem properties (see *2.1.1. Identification of Significant Ecosystem Components*). Scoping also includes identifying the activities and associated stressors that have the potential to affect the SECs using Pathway of Effects (PoE) models and/or a stressor-SEC interaction matrix (see *2.1.2. Identification of Activities and Associated Stressors Using Pathway of Effects Models*).

2.1.1 Identification of Significant Ecosystem Components

A significant ecosystem component (SEC) in the context of this study is defined as an environmental element that has ecological importance to an ecosystem. The use of ecologically significant ecosystem components will inform DFO's implementation of ecosystem-based management (EBM). Although all species, habitats, and communities have some degree of ecological significance, it is important to identify and focus on those components with greater relative significance, and those components impacted by stressors that are manageable at an MPA scale.

In order to identify appropriate SECs, the MPA ecosystem was organized into three component groups: species, habitats, and community/ecosystem properties. All known species, habitats, and community properties at the SK-B MPA were identified from the literature, under the criteria outlined by O et al. (2015). Criteria are summarized in Table 1 and presented in full in Appendix B. However, it is important to note that we are selecting SECs based on the best available knowledge at the time of this study, and given the lack of extensive biological research undertaken at the SK-B MPA, we are working with an incomplete list of ecological components. Furthermore, while selecting SECs for the SK-B MPA, we wanted to ensure we were capturing the uniqueness of the seamount ecosystem. The presence of deep-water species at shallower depths (e.g., Squat Lobsters, Prowfish) and the presence of shallow species at deeper depths (e.g., Macroalgae, Crustose Coralline Algae) are often used when describing the "uniqueness" of the SK-B MPA (e.g., Dower and Fee 1999; Canessa et al. 2003; McDaniel et al. 2003). It is an ecosystem where deep-water and coastal species co-occur and we wanted to ensure that this characteristic was reflected in our SEC list for this ecosystem.

2.1.1.1 Selecting Species SECs

O et al. (2015) defined criteria to identify species with greater relative ecological significance due to their role in the ecosystem (see Table 1 for full list; Appendix B for full definitions). These criteria include: nutrient importer/exporter; specialized or keystone role in the food web; habitat creating species; rare, unique, or endemic species; sensitive species; and, depleted (listed) species (Table 1; Appendix B).

2.1.1.2 Selecting Habitat SECs

While a bioregional classification system would ideally be used to identify rare or unique habitat SECs, this information was unavailable at the MPA scale or for the Pacific Region in general at the time of this study. In the absence of this information, O et al. (2015) suggested considerations for selecting habitat SECs (see Table 1 for full list; Appendix B for full definitions).

2.1.1.3 Selecting Ecosystem/Community SECs

Considerations suggested by O et al. (2015) for selecting ecosystem and community property components include those listed in Table 1; Appendix B.

Table 1: Criteria outlined by O et al. (2015) used to select species, habitat, and community SECs. See Appendix B for full descriptions of considerations.

SEC type	SEC considerations
Species	• Nutrient importer/exporter • Specialised or keystone role in the food web • Habitat creating species • Rare, unique, or endemic species • Sensitive species • Depleted (listed) species
Habitat	• Biogenic habitat types • Sensitive habitats • Habitats critical for sensitive species • Threatened or depleted species • Habitats critical for supporting rare, unique or endemic species • Habitats supporting critical life stages • Habitats providing critical ecosystem functions or services
Ecosystem / community	• Ecologically significant community properties • Functional groups that play a critical role in ecosystem functioning • Ecological processes critical for ecosystem functioning • Sensitive functional groups

2.1.2 Identification of Activities and Associated Stressors Using Pathways of Effects Models

The second step in the scoping phase is the identification of activities and the associated stressors that may impact the SK-B MPA using Pathways of Effects (PoE) Models. A PoE model is a representation of cause-and-effect relationships between human activities and their associated stressors, and their impacts to the ecosystem. DFO Oceans Management provided activities that occur within the SK-B MPA and our analysis included only known legal activities within the MPA. Based on this list of activities, PoE models were developed using peer-reviewed literature to describe the mechanisms by which these activities affect the environment, identifying the stressors associated with each activity and the potential impact on the environment. For a full list of activity categories and all activities, see Table 2. A list of the PoE models developed for these activities and the date the models were last modified is provided in Appendix D. We note that a distinction was made between the ‘current snapshot’ and ‘potential’ activities. Current snapshot represents stressors that are known to occur with some predictability at the SK-B MPA and are scored on their current levels (for example, fishing, the number of submersible dives, or sampling events). Potential stressors include those that occur infrequently and/or unpredictably or may not have occurred yet, but when they do occur, the extent of the exposure if uncertain (these include stressors associated with *oil spill, discharge,* and *aquatic invasive species*).

Table 2: SK-B MPA activity categories and activities provided by DFO Oceans Management.

Activity Category	Activity
Vessels	Vessel grounding
	Discharge
	Movement underway
	Oil spill
Research	Equipment abandonment
	Equipment installation
	Sampling
	Scuba diving
	Submersible operations
Seismic surveys	Seismic testing/air guns
Fishing	Trap/pot fishing

2.2 LEVEL 2 SEMI-QUANTITATIVE RISK ASSESSMENT

Risk assessment is an analytical approach for estimating risk, which in this case, is defined as the likelihood that a SEC will experience adverse consequences due to exposure to one or more identified stressors (O et al. 2015). Relative risk ($\boldsymbol{Risk_{SC}}$) to a SEC describes the chance that a SEC will experience a decline due to an activity in terms of higher or lower exposure ($\boldsymbol{Exposure_{SC}}$) and consequence ($\boldsymbol{Consequence_{sc}}$) scores. Cumulative risk ($\boldsymbol{CRisk_{C}}$) sums the relative risk of a SEC to more than one stressor, and can be used to determine overall risk to a given SEC (under the assumption that cumulative risk is additive).

The following assessment aims to analyse two types of risk: relative risk to a SEC from each of the different stressors that affect it within the MPA; and, cumulative risk to a SEC from the stressors that affect it within the SK-B MPA.

2.2.1 SEC-Stressor Matrix

The first step in a Level 2 risk assessment is to identify potential interactions between the identified stressors and selected SECs with an interaction matrix. A binary system was used to score interactions as either (1) interaction, or (0) no interaction based on the biological expertise of the authors. These interactions are later explored in detail by consulting primary literature and subject matter expert (SME) reviews of scoring decisions (see *2.2.2 Computation of Risk* for detailed descriptions of scoring methods). It should be noted that the ERAF scoring rubric only takes into account negative SEC-stressor interactions (i.e., where the stressor has a detrimental impact on the health/integrity of the SEC), and does not include any positive interaction (i.e., where interaction would result in an increase in the overall health/integrity of a SEC). While the framework may be used to score both direct and indirect impacts of a stressor on a SEC, only direct impacts were scored for this first iteration of a risk assessment on the SK-B MPA. Examples of indirect impacts include increased predation due to disturbances, increased competition for food sources as the result of disturbances, etc. This focus on direct impacts creates a baseline unto which future risk assessments may further develop. Additionally, only the impacts of stressors on adult life-stages of the SECs were scored for this application of the Level 2 ERAF for two reasons: (1) there is very limited information available on the juvenile life stages of many of the SK-B MPA SECs, which would result in high uncertainty scores; and, (2) the inclusion of juveniles may skew the weightings of certain stressors that are otherwise benign to the adult organism, focusing on the effect of stressors on the sensitive juveniles (pelagic juvenile forms of benthic invertebrates), rather than on the existing ecosystem. This could cause little or no differentiation in scoring between SECs and/or stressors.

2.2.2 Computation of Risk

2.2.2.1 Calculating relative risk (***$Risk_{SC}$***) to a SEC (***C***) from a stressor (***S***)

The relative risk (***$Risk_{SC}$***) to SEC (***C***) from a single stressor (***S***) is defined by the equation:

$$Risk_{SC} = Exposure_{SC} \times Consequence_{SC} \qquad \text{(Equation 1)}$$

Where:

$Exposure_{SC}$ is the estimated magnitude of interaction between the stressor and SEC; and

$Consequence_{SC}$ is the potential for long-term harm to the SEC as a result of interaction with the stressor and its estimated metrics that represent the capacity of the SEC to resist/recover from exposure to the stressor.

2.2.2.2 Calculating terms of risk of exposure of SEC (***C***) to stressor (***S***) (***$Exposure_{SC}$***):

$Exposure_{SC}$ is defined by the equation:

$$Exposure_{SC} = \left(\sqrt[3]{Area_{sc} \times Depth_{sc} \times Temporal_{sc}}\right) x \left(\sqrt[2]{i\,(amount)_{sc} \times i\,(frequency)_{sc}}\right) \qquad \text{(Equation 2)}$$

Where:

$Area_{SC}$ is the percentage of area of overlap between a stressor and SEC;

$Depth_{SC}$ is the percentage of depth overlap between a stressor and SEC;

$Temporal_{SC}$ is the percentage of temporal overlap between a stressor and SEC;

$i\ (amount)_{SC}$ is the measure of the intensity (level or effort/density) of the activity/stressor; and

$i\ (frequency)_{SC}$ is the frequency at which the stressor occurs.

$Exposure_{SC}$ is calculated using the geometric mean (defined as the n^{th} root of the product of n numbers) of the spatial overlap (i.e., ***$Area_{SC}$***, ***$Depth_{SC}$***) and temporal overlap (***$Temporal_{SC}$***), multiplied by the geometric mean of the intensity variables (i.e., ***$i\ (amount)_{SC}$***, ***$i\ (frequency)_{SC}$***). The geometric mean was selected over the arithmetic mean so that the spatial/temporal exposure (three terms) does not outweigh the intensity (with only two terms). The use of the geometric mean ensured that ***$Exposure_{SC}$*** (five terms) and ***$Consequence_{SC}$*** (two terms) would be on the same scale (1-16 and 1-18, respectively) for the risk calculations. The qualitative scoring rubric is shown in Table 3 and Table 4.

*Table 3: Qualitative scoring bins for sub-terms of **$Exposure_{SC}$** (**$Area_{SC}$**, **$Depth_{SC}$**, and **$Temporal_{SC}$**).*

Very Low (0.1-1%)	Low (1-20%)	Medium (20-50%)	High (>50%)
1	2	3	4

*Table 4: Qualitative scoring bins for sub-terms of **$Exposure_{SC}$** (**$i\ (amount)_{SC}$** and **$i\ (frequency)_{SC}$**).*

Intensity $(amount)_{SC}$	Very Low (0.1-1%)	Low (1-20%)	Medium (20-50%)	High (>50%)
Intensity $(frequency)_{SC}$	Occurs rarely (1 in 100-year period)	Occurs infrequently (e.g. once every 5-50-year period)	Occurs occasionally but not regularly (e.g. occurs more than 1 years but not every year within a 5-year period)	Occurs frequently (e.g. every year)
Bin	1	2	3	4

2.2.2.3 Calculating $\boldsymbol{Consequence_{SC}}$ of a single stressor

$\boldsymbol{Consequence_{SC}}$ is calculated by scoring the impact of the stressor (***S***) on the SEC (***C***), ($\boldsymbol{Resilience_{C}}$) and the ability of that SEC to recover from the impact using categories based on life history traits ($\boldsymbol{Recovery_{C}}$).

$\boldsymbol{Consequence_{SC}}$ is defined by the equation and ranges between 1-18:

$$Consequence_{SC} = Resilience_{C} \times Recovery_{C} \qquad \text{(Equation 3)}$$

Where:

$\boldsymbol{Resilience_{C}}$ is the percent change of SEC in response to stressor (acute and chronic); and,

$\boldsymbol{Recovery_{C}}$ is the time for SEC to return to pre-stress level once the stressor is removed.

2.2.2.4 Calculating $\boldsymbol{Resilience_{C}}$

$\boldsymbol{Resilience_{C}}$ is defined by the equation:

$$Resilience_{C} = AcuteChange_{C} + ChronicChange_{C} \qquad \text{(Equation 4)}$$

Where:

$\boldsymbol{AcuteChange_{C}}$ is the *percent* change in the population-wide mortality rate of a species SEC when exposed to a given stressor, the loss of area and productive capacity of habitat SEC, and the percentage of species impacted for community/ecosystem SEC;

$\boldsymbol{ChronicChange_{C}}$ is the percent change in the long-term fitness (including condition and genetic diversity) of a species SEC, the percent change in structural integrity, condition, or loss of productive capacity of habitat SEC, or the percentage of functional groups impacted for community/ecosystem SEC. Each factor was assigned a score of 0-3 using a qualitative binned system (Table 5).

Table 5: Qualitative scoring bins for sub-terms of $\boldsymbol{Resilience_{C}}$ *(adapted from O et al. 2015).*

Undetectable population effect	Low (<10% change)	Medium (10-30% change)	High (>30% change)
0	1	2	3

2.2.2.5 Calculating $\boldsymbol{Recovery_{C}}$

$\boldsymbol{Recovery_{C}}$ is defined by the equation:

$$Recovery_{C} = \text{Mean of } n \text{ Recovery factors} \qquad \text{(Equation 5)}$$

Recovery factors were averaged to determine the $\boldsymbol{Recovery_{c}}$ variable of the $\boldsymbol{Consequence_{sc}}$ equation (*Equation 3*). The recovery factors for each SEC (species, habitat, and community) are listed in Appendix C. Not all recovery factors for species, habitats, and communities listed by O et al. (2015) were applicable to all SECs (for example, many of the species recovery factors are fish-specific). $\boldsymbol{Recovery_{c}}$ was calculated using only those factors that could be scored (n) on a scale from 1-3. That is, factors with no available information were not scored, and were not included in the mean. Scoring of recovery factors was based on peer-reviewed information.

2.2.2.6 Computation of Cumulative Risk (***$CRisk_c$***) to SEC from multiple stressors

Estimation of ***$CRisk_c$*** across SECs enables evaluation of the relative risk (***$Risk_{sc}$***) to SECs within the area assessed. This was calculated by summing the risk scores of all stressors that impact a SEC.

$CRisk_C$ is defined by the equation:

$$\boldsymbol{CRisk}_C = \sum_{S=1}^{n} (Risk_{SC}) \quad \text{(Equation 6)}$$

where ***S*** is the stressor interacting with the SEC (***C***).

2.2.2.7 Computation of cumulative risk (***$Potency_s$***) by stressor

The ***$Potency_s$*** of each stressor was calculated by summing the median ***$Risk_{sc}$*** scores of stressors for each SEC that the stressor interacts with.

$Potency_S$ is defined by the equation:

$$\boldsymbol{Potency}_s = \sum_{C=1}^{n} (Risk_{SC}) \quad \text{(Equation 7)}$$

where ***C*** is the SEC that the stressor (***S***) impacts.

2.2.2.8 Uncertainty scoring and incorporation

An uncertainty score between 1-5 was assigned for each risk variable analysed during scoring, where 1 represents low uncertainty and 5 represents high uncertainty (Table 6). These variables included up to sixteen uncertainty scores per SEC: ***$Exposure_{SC}$*** (***$Area\ overlap_{SC}$, $Depth\ overlap_{SC}$, $Temporal\ overlap_{SC}$, $Intensity_{SC}$(amount), $Intensity_{SC}$(frequency)***), ***$Resilience_C$*** (***$AcuteChange_C$***, ***$ChronicChange_C$***), and ***$Recovery_C$*** (up to nine factors related to the SEC life history).

Table 6: Definitions of uncertainty scoring bins, based on categories outlined in Therriault and Herborg (2008) and Therriault et al. (2011).

Score	Literature	Definition
1	Extensive	Extensive scientific information; peer-reviewed information; data specific to the location; supported by long-term datasets
2	Substantial	Substantial scientific information; non-peer-reviewed information; data specific to the region
3	Moderate	Moderate level of information; data from comparable regions from the area of interest
4	Limited	Limited information; expert opinion based on observational information or circumstantial evidence
5	Little to None	Little or no information; expert opinion based on general knowledge

Two types of uncertainty are inherent in the risk scoring: (1) the amount of literature available about the SEC-stressor interaction; and, (2) scientific consensus about the consequences of the SEC-stressor interaction. In some cases, there is a wealth of scientific information but no agreement about the consequence. This second type of uncertainty is not represented in Table 6; however, it is implicitly considered when scoring uncertainty because the uncertainty score was increased by one (uncertainty score + 1) when there was no scientific consensus.

The uncertainty associated with each scored variable was incorporated into the risk score using the method outlined by Murray et al. (2016). Each risk variable was assigned as the mean of a normal distribution (Figure 2) with standard deviation set according to the level of uncertainty assigned, i.e., the width of the sample distribution is based on the perception of uncertainty in the variable score. An uncertainty of 1 was assigned a standard deviation of 0.2, while uncertainty of 5 was assigned a standard deviation of 1 (Table 7). The normal distribution was bounded by the minimum and maximum possible scores for each $\boldsymbol{Risk_{sc}}$ variable to ensure scores could not exceed the score range for that variable. The score of each $\boldsymbol{Risk_{sc}}$ variable was then randomly sampled from this distribution with 10,000 replicates to produce an array for each variable. The final $\boldsymbol{Risk_{sc}}$ score for each SEC-stressor relationship was a product of the $\boldsymbol{Exposure_{sc}}$ and $\boldsymbol{Consequence_{sc}}$ variable arrays (*Equations 1,2,* and *3,* respectively), where the first score generated from each variable array is multiplied across all $\boldsymbol{Risk_{sc}}$ variables, followed by the second, and so forth for all 10,000 replicates, resulting in a final risk array of 10,000 scores. The median and 10th and 90th percentiles from this final array are reported as the final $\boldsymbol{Risk_{sc}}$ score for each SEC-stressor interaction. Percentiles were used instead of standard deviation or standard error because the resulting distribution of risk scores was non-normal. The statistical platform R was used to generate and run the code for the uncertainty scoring (R Core Team 2014). See Appendix E for full R code.

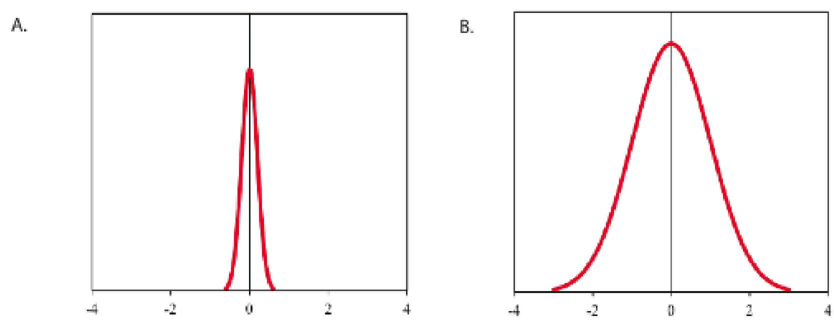


Figure 2: Normal distribution with a standard deviation of (A) 0.2 and (B) 1.0 (from Clarke Murray et al. 2016).

Table 7: Standard deviation levels assigned for each uncertainty score when calculating the distribution of each subcomponent.

Uncertainty Score	Standard Deviation
1	0.2
2	0.4
3	0.6
4	0.8
5	1.0

2.2.2.9 Review process

Subject matter experts (SMEs) were consulted to review each scored SEC/stressor interaction and associated uncertainty score. This process required the SMEs to review the scores, and then provide feedback in a workshop-style session where suggested changes were discussed. All suggested changes were incorporated into the final scores presented in Appendix H. Subject matter experts for the SK-B MPA included Robyn Forrest, Allen (Rob) Kronlund, Lynne Yamanaka (fish SECs) and Jason Dunham, Anya Dunham, and Denis Rutherford (invertebrate and habitat SECs). Meetings took place in August and September of 2014 at the Pacific Biological Station, Nanaimo, BC. Since there are potentially several thousand scoring decisions covering a wide variety of SECs and stressors, implementing a review of these scoring decisions by SMEs is an important quality assurance procedure and is recommended for future ERAF applications.

3. RESULTS

3.1 SCOPING PHASE

3.1.1 Identification of Significant Ecosystem Components

A list of 188 species known to occur in the SK-B MPA was compiled from available literature and reports. The list includes 19 algae, 85 invertebrates, 54 bony fish, six sharks or rays, 16 birds, and seven marine mammal species reported to occur in and around the SK-B MPA (see Appendix F for full species list). Using the criteria described in O et al. (2015) (Table 1; Appendix B), we selected a total of 16 SECs, including 10 species SECs, four habitat SECs, and two community SECs (Table 8). We considered two issues that were not captured in the criteria outlined by O et al. (2015) when selecting SECs. First, we confined our SEC list to components that could be managed at the MPA scale (excluding highly transient species like marine mammals and birds). Second, to ensure that the unique nature of the seamount ecosystem (overlapping coastal and deep-water species) was captured in the SEC list, we considered species and/or biogenic habitats that were found at unusual depths given what is expected from their distributions elsewhere. However, it should be noted that these species lists were compiled primarily for Bowie Seamount, as we have little knowledge of the Hodgkins and Davidson Seamounts. The scoping and selection results are discussed in detail according to the SEC type below.

3.1.1.1 Species SECs

Following O et al. (2015), we selected ten species SECs (Table 8). The interpretation of certain species SEC criteria from O et al. (2015) was straightforward (i.e., habitat creating species, rare species, sensitive species, and listed species). However, the nutrient importer/exporter and specialized or keystone role in the food web criteria relied upon the interpretation of the criteria in the context of the current state of knowledge at the SK-B MPA.

O et al. (2015) defined nutrient importer/exporter as “species that play a crucial role in maintaining ecosystem structure and function through the transfer of energy or nutrients that would otherwise be limiting to an ecosystem” (see Appendix B.1. for descriptions of species SEC considerations). As little research has been conducted at the SK-B MPA, we found it difficult to select distinct species that fulfilled this role. Most available studies on the feeding ecology at seamounts conclude that imported pelagic food supplies (e.g., zooplankton) support the large fish aggregations on seamounts (see *0. Productivity at the SK-B MPA*). Therefore, vertically migrating zooplankton, as well as the horizontal transfer of open-water micronekton, via upwelling, currents and eddies are likely crucial nutrient imports supporting the productivity of the SK-B MPA. However, zooplankton are not a good candidate as a SEC because the diversity, density, and distribution of zooplankton at the SK-B MPA is most likely independent of human activities that occur within the MPA boundary, and their survival is not linked to the seamount itself. Instead, zooplankton should be considered in any future state of the ecosystem indicator selection and monitoring).

Transient species such as seabirds, marine mammals, and pelagic sharks use seamounts for feeding, migration stopovers, and to facilitate oceanic navigation (Litvinov 2007; Kaschner 2007; Thompson 2007). Transient visitors, particularly top predators, to the SK-B MPA may play a key role in nutrient or energy exports; however, there is little available data on the use of Bowie Seamount by transient or migratory species. The Bowie Seamount area has been identified as a Canadian Wildlife Service (CWS) Area of Interest for Migratory Birds and Bowie Seamount itself is a CWS confirmed Area of Importance to marine and coastal birds. Two species of conservation interest, Black-footed Albatross (*Phoebastria nigripes*) and Ancient Murrelet

(*Synthliboramphus antiquus*), both listed under the Species at Risk Act (SARA) are known to occur in the Bowie area (Canessa et al. 2003).

The use of the SK-B MPA by transient species is important to monitor because of the conservation objective of “protecting the unique biodiversity and biological productivity” of the MPA. However, it is difficult to determine if transient species play a “crucial role in maintaining ecosystem structure and function through the transfer of energy or nutrients” without supporting data on the timing, abundance, and feeding rates of these species inside the MPA boundary. For the purposes of the SEC selection procedure and subsequent risk assessment, transient species of conservation relevance that are impacted by stressors not manageable at the MPA scale are not considered as SECs for risk assessment but should be considered for state of the ecosystem monitoring.

In contrast to transient species, migratory species such as Sablefish (*Anoplopoma fimbria*) are considered a significant nutrient importer/exporter at the SK-B MPA and are included in this assessment. Sablefish is a demersal fish endemic to the North Pacific Ocean and a key predator associated with the Bowie Seamount Area (Beamish and Neville 2003; Beamish et al. 2005). During their life cycle, this species shows two migratory patterns; movement from the continental slope across the abyssal plains to seamounts and later returning to the continental slope, and migration along the continental slope from the Bering Sea to Southern California (Moser et al. 1994; Kimura et al. 1998). Although there has been some debate over whether Sablefish at Bowie are a distinct population from the coast (Beamish and Neville 2003; Whitaker and McFarlane 1997; Kimura et al. 1998; Kabata et al. 1988), recent DFO tagging data show that Sablefish move regularly between the coast and the seamount and that there is no distinct seamount population.

Although Sablefish may not be a year-round resident at the SK-B MPA, the presence of a Sablefish population in the MPA is consistent. Landing data show that Sablefish are caught every year at the seamount. Sablefish regularly moving on and off the seamount could be considered an important nutrient exporter of the Bowie ecosystem because of their high trophic status in the food chain and their relatively high abundance. Furthermore, because of the presence of a Sablefish fishery at the seamount, the impact of this activity is manageable at the MPA scale justifying the selection of Sablefish as a SEC. Other important groups of species important to the transfer of nutrients and energy on Bowie Seamount include primary producers (phytoplankton, macroalgae), detritvores (Squat Lobsters, crabs, seastars), sediment re-workers (sea cucumbers), and benthic filter/suspension feeders (bivalves and barnacles).

The second criterion that depended upon interpretation in the context of Bowie Seamount was the “specialized or keystone role in the food web” criterion. O et al. (2015) defined this criterion as species that have “a highly-specialized relationship with another species or guild; an important food web relationship where an impact to it would cause vertical or horizontal change in food web or a species that supports a temporally or spatially explicit event important for other species”. Our current knowledge of the trophic dynamics of the SK-B MPA relies on data from other seamounts and coastal systems. As a result, we relaxed the definition of a keystone species while selecting species that fit the specialized or keystone role criterion and instead considered species that most likely played an important trophic role as either a top predator or key prey species. In addition, because Bowie Seamount, like other seamount ecosystems, is a very fish-dominated system, we also wanted to ensure ecologically distinct groups of fish were well covered in our species SEC list.

The fish community at the SK-B MPA is dominated by rockfish (25 species), including seven listed species. The most abundant rockfish species in the MPA are Rougheye, Yelloweye, and

Widow Rockfish (Canessa et al. 2003; McDaniel et al. 2003; Yamanaka 2005). The complete age range has been observed in the Widow Rockfish population at Bowie Seamount, which may mean that it is a self-sustaining population and because of the high numbers of juvenile Widow Rockfish, they are likely an important prey fish for other species of rockfish, Halibut, and Sablefish (L. Yamanaka, DFO Science, Pacific Biological Station, Nanaimo, B.C., pers. comm.). The fish assemblage at Bowie Seamount appears to lack a small-pelagic fish community, and the coastal population by comparison, has a larger proportion of older slow growing demersal fish species (Beamish and Neville 2003). The dominant fish species tend to be top predators such as Sablefish, Pacific Halibut, and rockfish (Beamish and Neville 2003; Beamish et al. 2005). Beamish and Neville (2003) developed an ecosystem model using Ecopath to represent trophic relationships at the Bowie Seamount. They found that in the absence of any small-pelagic fish community, the loss of Rougheye Rockfish, both a key predator and prey in their model, reduced the Sablefish and Halibut populations to unsustainable levels. Although a prey switch from rockfish to crab may occur, Beamish and Neville (2003) speculate that Sablefish and Halibut would likely leave the ecosystem if the rockfish population significantly declined. Finally, the trophic model also showed that a reduction in Halibut abundance increased the production of Sablefish, rockfish, and crab in the ecosystem because these species are key in the Halibut diet. The Ecopath model, developed by Beamish and Neville (2003), provides the only estimate of trophic dynamics at Bowie Seamount and although this model can only estimate the cause-effect relationships in a somewhat simplified food web, it clearly shows how population fluctuations of one species can impact other key species. The Ecopath model also highlights the important trophic relationships between Halibut, Sablefish and the dominant rockfish species, Rougheye Rockfish, at the Bowie Seamount.

As stated, rockfish are a key component of the Bowie ecosystem but rather than complete the risk assessment on all 25 species that are present in the MPA, we have selected representative rockfish species from: each rockfish community assemblage (inshore, shelf, and slope); species that are of high conservation concern (threatened or endangered); and, species that are known to be highly abundant at the MPA. In addition to rockfish species, the other top predators selected as species SECs are Pacific Halibut and Sablefish. A final species SEC that was selected was the highly abundant Squat Lobster. McDaniel et al. (2003) note that crabs were not common during their dive survey of the seamount. Given the importance of crabs in the diets of several fish species (including Rougheye Rockfish, Sablefish, and Halibut, as demonstrated by the Ecopath model), it is reasonable to suggest that Squat Lobster could be an important prey species in the absence of crabs. This species is known to be very abundant at the SK-B MPA and because of this abundance, likely plays a key role in nutrient cycling as a detritivore and a key prey species (J. Boutillier, DFO Science, Pacific Biological Station, Nanaimo, B.C., pers. comm.). Additionally, Squat Lobster have been observed in very high numbers at depths shallower than expected at Bowie Seamount (Auster et al. 2005). As Squat Lobsters are known to be quite resilient to certain stressors, such as oxygen deficiency (Matabos et al. 2012), a decrease in benthic species diversity where only this species remains may be an indication of a rapid environmental change.

Two Gorgonian coral species were also selected as species SECs. White Primnoa sp. (referred to in this document as Primnoa) is highly prevalent at the seamount and is found predominantly in the no fishing zone at the SK-B MPA (above 457 m) (J. Boutillier, DFO Science, Pacific Biological Station, Nanaimo, B.C., pers. comm.). White Primnoa sp. is known to occur in Alaska but has not been identified elsewhere within BC waters. There are no reports anywhere else of the large concentrations as seen at the SK-B MPA, making the high prevalence unique to the SK-B MPA (J. Boutillier, DFO Science, Pacific Biological Station, Nanaimo, B.C., pers. comm.). The other coral species SEC selected is a Bamboo Coral that occurs outside of Zone 1. It inhabits greater depths than Primnoa and is a newly described species named *Isidella* *tentaculum* (Etnoyer 2008; referred to in this document as Isidella). This species is not endemic to the SK-B MPA but like Primnoa there is very little information about these animals in BC waters (J. Boutillier, DFO Science, Pacific Biological Station, Nanaimo, B.C., pers. comm*.).* Isidella ranges in depths from 720 m to 1,050 m and is known from Northeast Pacific seamount peaks, continental slopes, and shelf canyons. This species is a large (up to 132 cm high), abundant, and a conspicuous habitat former (Etoyner 2008). The taxonomy of the Isidella group is not yet well understood and aging of this family of corals has shown that they can live hundreds, if not thousands, of years (Andrews et al. 2005a, 2005b). These species were also chosen because they fit several of the species criteria including rare, unique, sensitive, and habitat creating species. A comparison of these two ecologically similar species will highlight the differential risk of species that occur in different management zones with the MPA. All selected species SECs are shown in Table 8.

3.1.1.2 Habitat SECs

Four habitat SECs were selected: Macoralgae, Crustose Coralline Algae, Demosponges, and Gorgonian Corals (Table 8). The habitat creating species criterion and habitat components as SECs are closely related. Species that are considered habitat creating species are species that create habitat on the seafloor and habitat for infauna and aerate substrates. Considerations for selecting relevant habitat components as SECs are described in Appendix B.2. In addition to the four habitat SECS, we highlight the importance of the physical habitat of the seamount (the tephra and loose cobble; Appendix A) but we have not included these habitats in the Level 2 risk assessment.

3.1.1.3 Community SECs

Community and ecosystem properties are aspects of the ecosystem that capture community composition and ecosystem structure (O et al. 2015). Considerations for selecting relevant community components as SECs include communities or species assemblages are described in Appendix B.3.

Key communities that likely play a crucial role in ecosystem processes and function at Bowie Seamount include zooplankton, rockfish, and nutrient cyclers (primary producers and the benthic invertebrate assemblage). Many of these communities were well represented within the species SEC category: at least one rockfish species per habitat type was selected (inshore, shelf, and slope); primary producers are represented by Macroalgae (kelps); the benthic invertebrate assemblage includes sessile Corals and Sponges; and, highly mobile species are represented by Squat Lobster. Zooplankton, as previously discussed, are recommended for state of the ecosystem monitoring. Although these community properties were selected as SECs, we were unable to complete the Level 2 Risk Assessment on them.

In order to properly score community SECs as outlined in O et al. (2015), more information is needed about the underlying ecosystem processes that occur at the SK-B MPA. More specifically, we need a better understanding of oceanographic processes at the seamount, as they are important drivers of the ecosystem properties and community structure, particularly within the zooplankton community. Also, the community properties scoring scheme requires scoring relative to a baseline; there is little to no baseline biological data at the SK-B MPA for these comparisons. For example, we need to know how species richness changes before and after a specific stressor occurs. Even for comparable areas (such as other seamounts), it is difficult to find studies that measure ecological impacts at the community level as most studies are habitat- or species-specific. A further complication is that the SK-B ecosystem consists of both coastal and deep-water species and there are few community level studies of comparable ecosystem assemblages available for analysis. A more complete discussion of how to incorporate community and/or ecosystem properties, and the information needed to do so, is provided in section *4. Discussion*.

Versions of selected SEC lists for the SK-B MPA ecological risk assessment were reviewed by SMEs including Dr. Rebecca Martone (Ecosystem Health Program Lead, Center for Ocean Solutions, Stanford University, Stanford, CA) and Jim Boutillier (DFO Science, Pacific Biological Station, Nanaimo, B.C.) before the list was finalized (Table 8).

Table 8: Summary list of SECs selected for the SK-B MPA. See also Appendix H for more descriptive justifications for inclusion in SEC list.

SEC	Category	Justification
Prowfish	Species SEC	• Only genus and species in family (unique evolutionary lineage) • Large numbers of Prowfish at Bowie Seamount are unique given it is a rare fish • Unusually common in open water and at surface at the SK-B (McDaniel et al. 2003) whereas considered a benthic species elsewhere.
Sablefish	Species SEC	• Top predator at Bowie • Regularly moves on and off seamount and may play important role as nutrient exporter
Pacific Halibut	Species SEC	• Top predator at Bowie
Bocaccio	Species SEC	• Shelf rockfish species • COSEWIC: Threatened • IUCN Redlist: Critically endangered • The SK-B MPA is a potential refuge for this species
Yelloweye Rockfish	Species SEC	• Inshore rockfish species • COSEWIC: special concern • Abundant at Bowie
Rougheye/ Blackspotted Rockfish complex	Species SEC	• Slope rockfish species • COSEWIC special concern (both types) • SARA Status: Schedule 1, Special Concern • Dominant fish species at Bowie
Widow Rockfish	Species SEC	• Shelf rockfish species • All age classes and highly abundant at seamount (large schools of many thousands observed at 25 m depth) • Due to abundance, likely an important prey species • May be a resident SK-B population
Squat Lobster	Species SEC	• Detritivore (important in decomposition and nutrient cycling) • Abundant at shallower depths at SK-B than rest of its range • Because of its abundance likely plays a key role as a prey species and nutrient cycler • Link between benthic and pelagic communities
Isidella	Species SEC	• Very rare in BC waters • Unique family of corals • Provides habitat for several associated species • Sensitive to disturbance
Primnoa	Species SEC	• Potentially endemic to SK-B (has only been described to genus) • Highly abundant at SK-B, not seen in such concentrations elsewhere • Provides habitat for several associated species • Sensitive to disturbance
Sponges	Biogenic	• Sensitive to disturbances, slow to recover

SEC	Category	Justification
(Demosponges)	habitat SEC	• Provides three-dimensional structure and food source for many associated species.
Deep water Gorgonian Corals	Biogenic habitat SEC	• Sensitive to disturbances, slow to recover • Provide a three dimensional and complex structure. • Corals are associated with numerous species that utilize corals for food, settlement, protection etc.
Macroalgae	Biogenic habitat SEC	• Vegetation provides habitat for numerous invertebrates and fish species (particularly juvenile rockfish including sensitive and listed species) • *Desmarestia sp.* (flattened acid and stringy acid kelp) represent the dominant large algae at Bowie. • Present only in restricted shallowest areas at pinnacle and reach much deeper depths at seamount than on coast (SK-B likely represent new depth records for several algal species – McDaniel et al. 2003).
Crustose Coralline Algae	Biogenic habitat SEC	• Vulnerable to ocean acidification • Critical role in binding reef materials into sturdy structure • 2D structure for larval settlement • Associated with numerous other algal and invertebrate species • Reaches much deeper depths at seamount than on coast
Benthic Invertebrate Assemblage	Community SEC	• Divided into sub-assemblages based on mobility: sessile, low-mobility, high mobility • Nutrient cyclers – key role in decomposition, aeration of sediments, consumption of detritus. • Vulnerable to similar threats
Rockfish Species Assemblage	Community SEC	• Divided into sub-assemblages based on ecotype: Inshore, Shelf, and Slope species • Rockfish are the dominant fish group and an integral component of trophic structure at Bowie (few or no typical forage fish species present at Bowie) • Group sensitive and slow to recover from population declines (Nine COSEWIC or IUCN listed species are present at Bowie) • Shelf species in particular are an important link between benthic and pelagic systems

3.1.2 Activities and Stressors occurring in the SK-B MPA

There have been many potential economic and research interests at the Bowie Seamount and surrounding area including fisheries, ocean mining, offshore hydrocarbon development, and recreational uses (reviewed in Canessa et al. 2003). Since establishing the MPA in 2008, human activities in and around the area have become more regulated. DFO Oceans Management provided a list of anthropogenic activities currently occurring at the SK-B MPA, including those related to vessel traffic, seismic surveys, trap/pot fishing, and scientific research. PoE models of each activity were used to identify associated stressors with the potential to interact with the SECs. A full list of activities and associated stressors identified from the PoE models is presented in Table 9, and a summary of the available information on activities included in this assessment is presented in this section.

Table 9: SK-B MPA activities and associated stressors

Activity category	Activity	Associated Stressor
Vessels	Movement underway	Noise disturbance
		Substrate disturbance (waves)
	Oil spill	Oils
	Discharge	Debris
		Introduction of aquatic invasive species
		Oils/contaminants
		Nutrients
	Vessel grounding	Substrate disturbance (crushing)
		Substrate disturbance (sediment resuspension)
Scientific research	Equipment abandonment	Contamination
	Equipment installation	Substrate disturbance (crushing)
		Substrate disturbance (sediment resuspension)
		Light disturbance
		Noise disturbance
	Sampling	Substrate disturbance (crushing)
		Substrate disturbance (sediment resuspension)
		Removal of organisms
	Scuba diving	Light disturbance
		Noise disturbance
		Substrate disturbance (crushing)
		Substrate disturbance (sediment resuspension)
	Submersible operations	Introduction of aquatic invasive species
		Light disturbance
		Noise disturbance
		Substrate disturbance (crushing)
		Substrate disturbance (sediment resuspension)
Fishing	Trap fishing	Introduction of aquatic invasive species
		Entrapment/entanglement
		Removal of biological material
		Substrate disturbance (crushing)
		Substrate disturbance (sediment resuspension)
Seismic surveys	Seismic testing/air guns	Sound generation

3.1.2.1 Vessel Traffic

Many ships travel near the SK-B MPA but vessel traffic within the boundaries of the MPA is mainly a result of fishing and research vessels. The number of vessels traveling in the SK-B MPA area has not been directly quantified but according to one study, an estimated 2,527 vessels travelled along the BC coast between 1998 and 1999 and since 1970, the tonnage from west coast vessel traffic has quadrupled contributing to an increase in the number of vessels in the area (reviewed in Canessa et al. 2003). Acoustic monitoring is currently ongoing at the seamount and the assessment of vessel activity is an objective of this monitoring (DFO Ocean Sciences Division) However, the data collected from acoustic monitoring have not yet been analyzed and therefore are unavailable for use in this risk assessment.

Sablefish fishing vessels are the only vessels that visit the MPA on a regular basis. A lottery system was used prior to 2014 to choose one vessel per month (April – September) permitted to fish within the MPA for the entire month to meet their fishing vessel catch limit (75,000 lbs of Sablefish, 5,000 lbs of Rougheye Rockfish, and 1,000 lbs of other rockfish, Sole and Flounders;

DFO 2013). However, the boats do not consistently go on their scheduled month (due to weather and/or logistics) and in general, they do not meet their allowable catch (D. Freethy, DFO Ecosystems and Fisheries Management, Nanaimo, B.C., pers. comm., and see section below on fishing). Therefore, the seamount was often not visited by a fishing vessel every month during the six-month timeframe. In 2014, new regulations were implemented in which fishing on the seamount was permitted for only three months of the year (May – August) with the same vessel limits and lottery system to choose the vessels (DFO 2014A).

Activities associated with vessel traffic at or near the SK-B MPA include: *vessel grounding*; *discharge* (of *debris*, *nutrients*, *aquatic invasive species*, and *oils/contaminants*); movement underway (creating *noise disturbance)*; and *oil spills*. Each are discussed below.

Vessel groundings: Investigations into vessel casualties between December 1994 and August 1999 found that there were five vessel casualties within 200 km of the SK-B MPA (Canessa et al. 2003). There have been no vessel grounding incidents in the SK-B MPA vicinity since 1999 (J. Hillier, DFO Ecosystems and Fisheries Management, Nanaimo, B.C., pers. comm.). Vessel groundings of an oil tanker typically with draft of 14 m is possible on the shallow seamount summit, especially under high wave conditions; however, tanker companies have stated that their vessels typically stay at least 18 km away from the SK-B seamount as this is their most efficient route. Similarly, cargo ships will also give the SK-B MPA a wide-birth as Bowie Seamount could be a navigation hazard to them.

Discharge: Discharge from vessels includes *aquatic invasive species*, *debris*, *oil/contaminants*, *nutrients,* and any other foreign materials/chemicals that can be expelled from a vessel via ballast or other means. The Ballast Water and Management Regulations in the *Canadian Shipping Act* were amended in 2006 to implement a 50 Nm buffer zone around the submarine peak of Bowie seamount in which ballast water exchange is no longer permitted. This buffer zone will reduce the direct impacts of stressors in ballast at the SK-B MPA; however, currents can still bring in vessel discharge from surrounding areas. There are no data quantifying the concentration or frequency of vessel discharges released at or near the SK-B MPA. However, because the concentration of vessels using or travelling through the SK-B MPA is assumed to be relatively low, the stressors associated with discharge from vessel traffic are most likely also low. In addition, because of its open water location, any discharge that does occur in the area will be dispersed more widely than in coastal bays and harbours.

Noise disturbance [movement underway]: Anthropogenic ocean noise is considered a chronic stressor for a variety of marine organisms including mammals, fish, and cephalopods. Noise from shipping is pervasive throughout the marine environment especially at low frequencies (<300 Hz) and is therefore a key concern regarding chronic noise exposure on the marine environment (Erbe et al. 2012; Merchant et al. 2012). Noise from cargo ships and oil tankers passing at distance and Sablefish fishing vessels could negatively impact organisms at the seamount. For example, detrimental effects of sound on fish populations include disturbance and deterrence, fitness consequences (reduced growth and reproduction), predator-prey interactions (interference and community effects), and communication and masking effects (reviewed in Slabbekorn et al. 2010). In comparison to areas closer to the coast and/or shipping routes, ambient noise levels in the open water (like the SK-B MPA area) are low (Erbe et al. 2012); however, the impacts of even low levels of noise on marine organisms are not well understood.

Oil Spills: Oils spilled into marine environments are comprised of a complex suite of several thousand hydrocarbon and synthetic substances, including radionuclides, mineral salts, trace elements and heavy metals. The environmental impacts of an oil spill can be catastrophic and result in direct mortality of many marine organisms, in addition to sub-lethal effects that can persist for years after the spill. There have been no reports of an oil spill of any size near the SK-B MPA (J. Hillier, DFO Ecosystems and Fisheries Management, Nanaimo, B.C., pers. comm.) However, the summit of the seamount is 18 – 36 km outside of the voluntary tanker exclusion zone, therefore the MPA is subject to oil tanker traffic and associated risks (Canessa et al. 2003).

3.1.2.2 Scientific Research

Extensive oceanographic and biological research has been conducted on other seamounts in the Northeast Pacific Ocean (e.g., Cobb Seamount), but Bowie Seamount has received less attention. The seamount is a relatively new research location and although interest to perform research exists, there are several obstacles impeding research activity. These obstacles include the remote location of the seamount, limited availability of suitable vessels, difficulty performing research in open waters, harsh wave and weather conditions, and research funding (reviewed in Canessa et al. 2003). Between 2008 and 2014, there have been four research trips to the SK-B MPA (J. Hillier, DFO Ecoystems and Fisheries Management, Nanaimo, B.C., pers. comm.). There is potential for increased research activity and there are several activities associated with research that can have a negative impact on the environment including e*quipment installation*, *equipment abandonment*, *sampling*, *scuba diving* and *submersible operations*. Currently, research activities are considered low frequency stressors because in general, they occur less than once a year. The intensity of the activity solely depends on the type of stressor.

Equipment installation can stress marine organisms in the following ways: *substrate disturbance (crushing), light disturbance*, and *noise disturbance*. Four hydrophones have been installed on Bowie Seamount between 2010 and 2013 (D. Freethy, DFO Ecosystems and Fisheries Management, Nanaimo, B.C., pers. comm, DFO.) These are low stressor installations (small footprint) and not expected to result in high risks. However, if the frequency and or density of equipment installations were to change, impacts could also change.

Equipment abandonment impacts include *oil/contaminant* seepage and *introduction of foreign material*. Anchors for hydrophones for acoustic monitoring are the only known equipment that has been abandoned at the SK-B MPA. The anchors consist of a steel train wheel, approximately 0.5 m of steel chain and a 1 m segment of poly rope. It is assumed that there is no negative impact of these materials on the benthic community, and that they will provide a hard structure for animals to settle on as seen in artificial reefs. Eventually the steel will rust away and the poly rope will disintegrate. Four of these anchors have been abandoned at the seamount between 2010 - 2013 (D. Freethy, J. Hillier, DFO Ecosystems and Fisheries Management, Nanaimo, B.C., pers. comm, DFO).

Research sampling impacts the environment through the *removal of organisms* and *substrate disturbance (sediment resuspension)* and *substrate disturbance (crushing)* (when sampling benthic organisms). Recent biological sampling of benthic invertebrates at the SK-B MPA removed only five animals per species.

Scuba divers can impact marine organisms via *substrate disturbance (crushing), substrate disturbance (sediment resuspension)*, *light disturbance*, and *noise disturbance*. The first known recreational dive occurred on Bowie Seamount in 2002 and there have also been research dives in 2003 but no scuba diving has occurred at the seamount since MPA designation.

Submersible operations can negatively impact the marine environment through *light disturbance*, *noise disturbance*, *introduction of aquatic invasive species, substrate disturbance (crushing),* and *substrate disturbance (sediment resuspension)* from the thrusters. Between 2008 and 2014 remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) have been deployed at Bowie once in 2011 by DFO scientists.

3.1.2.3 Seismic Surveys/Air Guns

Scientists use seismic surveys to map the seafloor and look for geological features. The offshore oil and gas industry also uses seismic surveys to help determine the location of oil and gas deposits beneath the seafloor. The sounds generated by air guns during seismic surveys can impact marine organisms with physiological, behavioural, and even fatal consequences (McCauley et al. 2000). Most of the recorded impacts to marine life come from studies on marine mammals and fish but lower taxonomic groups are also negatively impacted (e.g., Hirst and Rodhouse 2000). Two seismic surveys are known to have recently occurred off the North coast of British Columbia, but none in the vicinity of the SK-B MPA (info provided via J. Hillier, DFO, Ecosystems and Fisheries Management, Nanaimo, B.C.). In general, there was little information available on the exposure of air gun blasts to the SK-B MPA ecosystem.

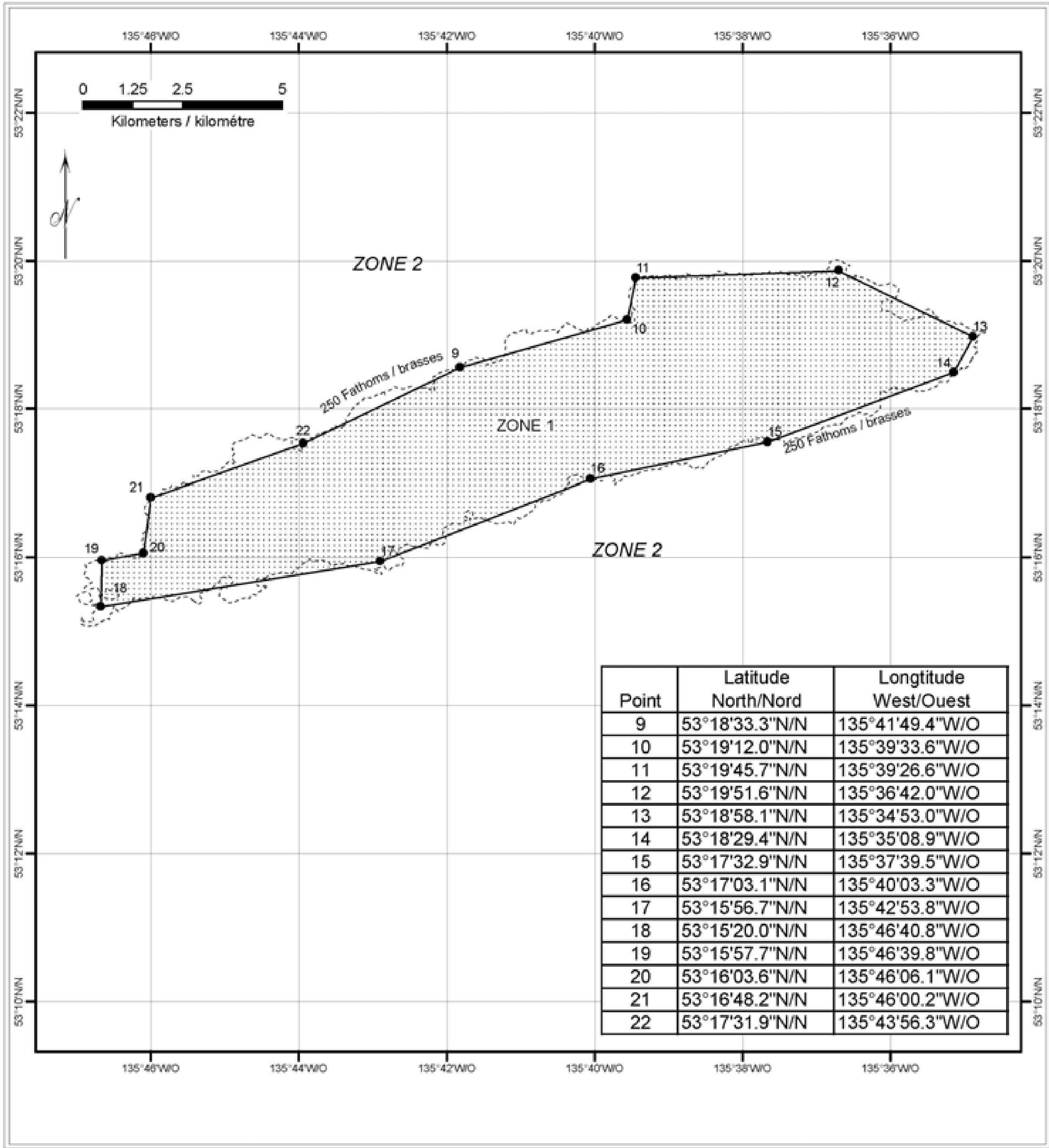
3.1.2.4 Sablefish Trap Fishing

Sablefish have been actively fished at the seamount since 1982 (Canessa et al. 2003). The fishery has the potential to expose the marine environment to several stressors including vessel traffic, bycatch, ghost fishing (entrapment), direct harvest, and habitat degradation. However, upon creation of the MPA at the seamount in 2008, fishing regulations were implemented in order to reduce these impacts. Currently, only Sablefish trap fishing is allowed and is restricted to Zone 2 at the SK-B MPA. Zone 2 makes up 41% of the total MPA surface area (2,538 km^2/6,131 km^2) and fishing is mainly restricted to the area below the 250 fathom depth contour (457 m) to protect the more ecologically sensitive shallow zone (Zone 1). However, the points used to map the boundary between Zone 1 and Zone 2, do not follow the 250 depth contour precisely (see Figure 3) and therefore there are areas shallower than 250 fathoms that fall within Zone 2.

The Sablefish fishery was permitted at the SK-B MPA for six months annually from 2008 to 2013 (April – September) and beginning in 2014, the fishing period was shifted to May – August. A lottery system is used to choose one vessel per month to fish at Bowie Seamount. The monthly vessel catch limit is 34 metric tonnes (75,000 lbs) totaling to an annual catch of about 204 tonnes of Sablefish that could be removed from the system (DFO 2013; 2014A). However, this annual limit is rarely met. Many vessels chosen to fish do not fish during their allotted month due to the logistics and the risks associated with traveling to the remote location. The average number of Sablefish fishing trips (based on Trip ID) visiting the seamount between 1998 – 2008 was 4.4 per year; however, since 2008 when the area became a MPA and fishing regulations were implemented, the average number of trips to the seamount has decreased to 3.6 per year (2008 – 2012; Figure 3). Furthermore, when trips are made to the seamount, vessels often do not meet their allowable catch limit. For example, four vessels fished the seamount in 2012 and the total annual catch was 82 tonnes (~181,000 lbs). The average landing per vessel from the SK-B MPA in 2012 was 20.5 tonnes per month, well below the allowable limit of 34 tonnes per vessel per month. In addition, the average annual catch of Sablefish between 2008 and 2012 was 53 tonnes at the SK-B MPA, well under expectations if every vessel met the monthly catch limit every month (34 tonnes x 6 months = >204 tonnes per fishing season; Figure 5).

An analysis of recent fishing data showed that depths between 298 – 1372 m were actively fished between 2008 – 2012, with 90% of traps set between 457 – 1000 m (Figure 6). The depths that receive the highest fishing effort are between 550 – 649 m with more than 12,600 traps being set in that range over past four years. The depth range of the fishery that was used in the risk assessment $\textbf{\textit{Exposure}}_{sc}$ calculations for all SECs was 298 – 1372 m. The percent depth overlap was calculated by using the individual SEC depth range in comparison to fishery depth range. For example, Prowfish depth range is known to be approximately 0 – 800 m (Smith et al. 2004), so fishing and Prowfish overlap between 298 – 800 m and 63% (502/800) of the

Prowfish depth range is exposed to impacts of fishing (see Appendix H for ***Exposure$_{sc}$*** and ***Consequence$_{SC}$*** scores).



Point	Latitude North/Nord	Longtitude West/Ouest
9	53°18'33.3"N/N	135°41'49.4"W/O
10	53°19'12.0"N/N	135°39'33.6"W/O
11	53°19'45.7"N/N	135°39'26.6"W/O
12	53°19'51.6"N/N	135°36'42.0"W/O
13	53°18'58.1"N/N	135°34'53.0"W/O
14	53°18'29.4"N/N	135°35'08.9"W/O
15	53°17'32.9"N/N	135°37'39.5"W/O
16	53°17'03.1"N/N	135°40'03.3"W/O
17	53°15'56.7"N/N	135°42'53.8"W/O
18	53°15'20.0"N/N	135°46'40.8"W/O
19	53°15'57.7"N/N	135°46'39.8"W/O
20	53°16'03.6"N/N	135°46'06.1"W/O
21	53°16'48.2"N/N	135°46'00.2"W/O
22	53°17'31.9"N/N	135°43'56.3"W/O

Figure 3: Zone 1 and Zone 2 of the SK-B MPA showing 250 fathom depth contour in dotted line and Zone 2 MPA boundary in black line. Source: DFO 2013.

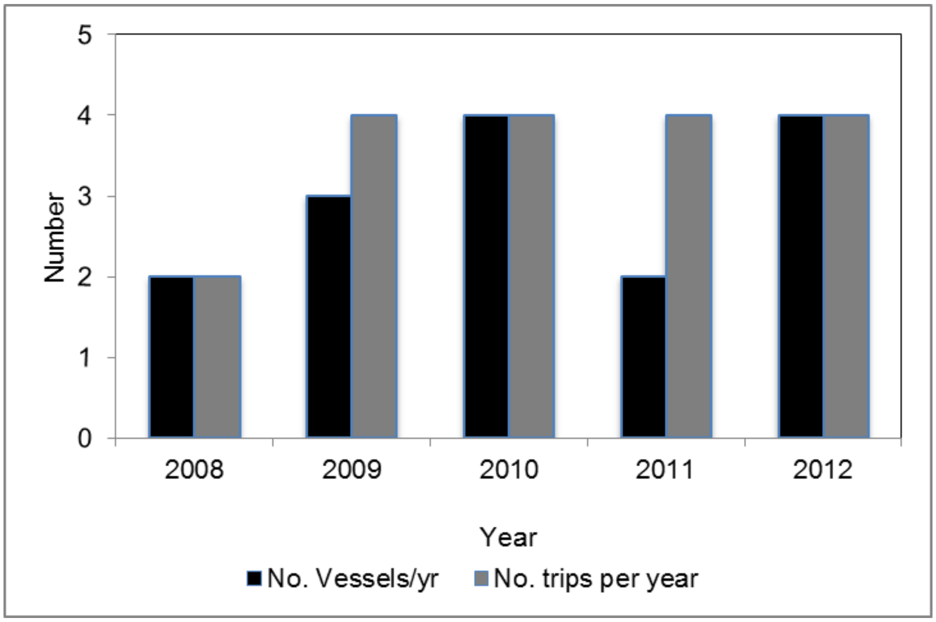


Figure 4: Number of trips (based on Trip ID) and vessels (based on vessel name) made by Sablefish trap fishing vessels per year to Bowie Seamount (2008-2012). Note that MPA designation and new fishing restrictions began in 2008. Source: Fisheries and Oceans Canada.

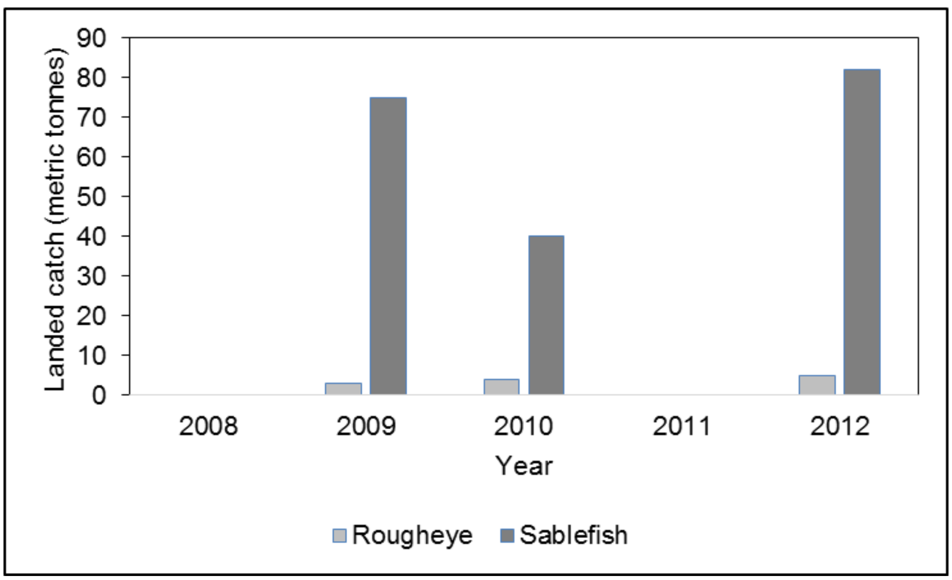


Figure 5: Sablefish and Rougheye Rockfish annual catch at Bowie Seamount. All Sablefish counts have been converted to kilograms using a value of 3 kg for legal-sized fish (> 55 cm fork length) and 1.5 for sublegal fish (< 55 cm fork length). The Rougheye Rockfish complex includes Sebastes aleutianus and S. melanostictus, Rougheye and Blackspotted Rockfish. Note that landed catch data for the years 2008 and 2011 cannot be shown due to Privacy rules ("3-vessel-rule"); only two vessels visited the seamount during these years. Source: Fisheries and Oceans Canada.*

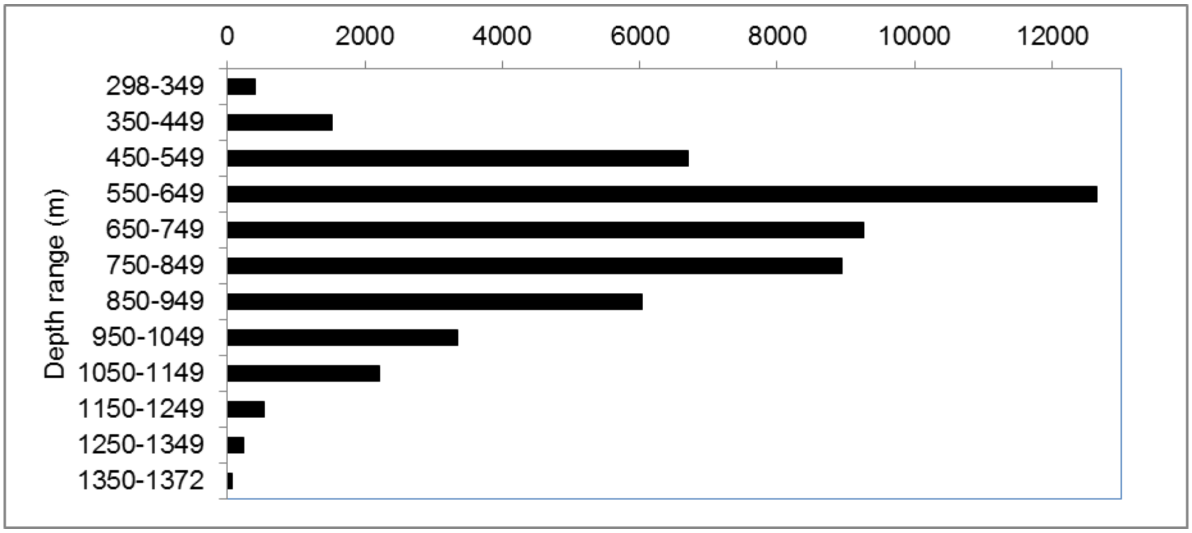


Figure 6: Cumulative number of traps set for Sablefish in the Bowie Seamount Area by depth (2008-2012). Depths used were depths with the highest catch ("best depth catch") on a given trip. Data were extracted and summarized from DFO's seamount database. Depths were binned to the nearest 100 m Source: Fisheries and Oceans Canada.

To get a general picture of the benthic footprint of the Sablefish trap fishery, we calculated the number of traps set per fishing season. The number of traps set at Bowie Seamount per fishing season between 2008 and 2012 ranges from 4,200 to 15,256. The average number of traps set per year is 10,381. In order to get a better understanding of the substrate disturbance involved with the current level of fishing in Zone 2, georeferenced data on where the sets are placed and the footprint of each trap are needed. We did not complete this analysis for the present study; however, there is a current CSAS request for science advice to address this issue.

The traps used in the Sablefish fishery are designed to reduce the catch of undersized Sablefish (fish <55 cm fork length must be released at sea) and to biodegrade if lost at sea. The traps must have a minimum of two escape openings (at least 8.9 cm in diameter) creating an unrestricted exit out of the trap (DFO 2013). Rougheye Rockfish are the most common non-target species caught at the SK-B MPA (Canessa et al. 2003; DFO 2013). Legally, fisherman can keep up to 2.2 metric tonnes (5,000 lbs) of Rougheye Rockfish and up to 0.45 tonnes (1,000 lbs) of other rockfish species, Soles and Flounders that are caught as bycatch in their Sablefish traps each month (DFO 2013). Therefore, up to 13.2 tonnes of Rougheye Rockfish can be removed from the SK-B MPA ecosystem every season by the Sablefish fishery. Any remaining rockfish must be discarded (with a 100% mortality rate for at sea release, DFO 2013). Landings of Sablefish and Rougheye Rockfish between 2008-2012 are shown in Figure 5. Average annual Sablefish landings over this period were 57.6 metric tonnes. Average annual Rougheye Rockfish landings for the same period were 3.3 metric tonnes – both well below allowable limits. The catch of non-target species is low in trap fisheries when compared to other fishing methods (Chuenpagdee et al. 2003). Based on weight (i.e., landed catch and released catch), the non-target catch rate (cumulative catch of non-target species/cumulative catch of Sablefish) from 2006-2012 for all non-target species is about 7% (DFO seamount database). Rockfish species, (Aurora, Rougheye, Redbanded, Rosethorn, Shortraker, Shortspine Thornyhead, and Longspine Thornyhead) make up 6% of the bycatch, with Rougheye Rockfish making up the majority (5%) of this catch. For a complete list of bycatch species from the SK-B MPA between 2006-2012 see Appendix J.

Since 2008, 141 Sablefish traps were reported lost between the minimum depth of 160 m and the maximum depth of 578 m at the SK-B MPA (Ground Fish Fisheries Operating System (GFFOS), DFO). When fishermen lose their traps, they are required to report a minimum and maximum depth of where traps were lost. Between 2008-2012, 98 traps were reported lost at maximum depths of less than 457 m (i.e., Zone 1 of MPA). Thirteen were reported lost at maximum depths between 548-578 m (Zone 2) and 30 trap losses did not include depth ranges or maximum depth range in their report. Sablefish traps are designed to reduce the impacts of “ghost fishing” since traps must have a sidewall with a section that has been secured by a single length of untreated natural fiber that biodegrades (“rot cord”) over time making the trap non-functional if lost (i.e., ghost fishing will not persist indefinitely because the trap will break down). The degradation rate of the rot cord depends upon the type of natural fiber. For example, hemp cord can degrade in under five weeks whereas cotton can take up to 15 weeks (Redekopp et al. 2006).

The information on the human activities at the SK-B MPA detailed above, was used to calculate the ***Exposure***$_{sc}$ variables in the risk equation (See Appendix H for SEC specific scores).

3.2 LEVEL 2 SEMI-QUANTITATIVE RISK ASSESSMENT

3.2.1 SEC-Stressor Interaction Matrix

The SEC-stressor interaction matrix is shown in Appendix G. Only activities and their associated stressors that are legal and known to occur at the SK-B MPA were included in the matrix.

The number of stressors that interact with a single SEC depends on the distribution, ecology, and life history of the SEC and the spatial and temporal overlap with the stressor. For example, deep-water fishes, such as Sablefish, Halibut, and Rougheye Rockfish do not overlap with stressors associated with *scuba diving*, but Yelloweye Rockfish, Bocaccio, Widow Rockfish and Prowfish occur in a depth range that can overlap with *scuba diving*. Whereas stressors associated with a *vessel grounding* event at the pinnacle will likely only impact benthic species found at shallow depths.

Completing the interaction matrix for 16 SECs and 33 stressors, resulted in 345 interactions (see Appendix G) that were put forward for the scoring phase of the risk assessment. However, not all interactions scored in the SEC-stressor interaction matrix were included in the final risk calculations. Some stressors have the potential to negatively impact SECs, but are not likely to impart a detectable change to population/habitat size or condition and therefore the ***Consequence***$_{SC}$ side of the equation was scored as zero. Additionally, due to the lack of baseline information on communities and functional groups at the SK-B MPA, the risk assessment was not applied to the community SECs (Rockfish Assemblage and Benthic Invertebrate Assemblage).

3.2.2 Computation of Risk

3.2.2.1 Risk of Exposure to a SEC from a Single Stressor

Risk of exposure to each SEC for each stressor was calculated from the available information collected about each activity. A description of each activity was presented in *3.1.2. Activities and Stressors Occurring at the SK-B MPA*.

3.2.2.2 Exposure$_{sc}$ Factors

Exposure scores were calculated from data collected on the human activities at the SK-B MPA as described in the scoping phase (see *3.1. Scoping Phase*). It should be noted that while calculating exposure of SECs to certain stressors, we distinguish between “current-snapshot” and “potential” ***Exposure***$_{sc}$, as defined in *2.1.2. Identification of Activities and Associated Stressors Using Pathways of Effects Models*. All scores and associated uncertainty for the ***Exposure***$_{sc}$ equation (i.e., *Area overlap*$_{sc}$, *Depth overlap*$_{sc}$, *Temporal overlap*$_{sc}$, *Intensity(amount)*$_{sc}$, and *Intensity(frequency)*$_{sc}$) are given in Appendix H.

3.2.2.3 Resilience$_c$ Factors

The ***Resilience***$_c$ factors ***AcuteChange***$_c$ and ***ChronicChange***$_c$ for each SEC-stressor interaction are presented in Appendix H along with justifications for each given score. To calculate ***Consequence***$_{sc}$, we used available information to choose a score of low, medium or high for each ***Resilience***$_c$ variable when exposed to the stressor.

At this stage in the scoring, several stressor-SEC interactions fell out of the risk assessment and were not included in the final count of stressors or final risk scores, as mentioned in *3.2.1 SEC-Stressor Interaction Matrix*. This reduction occurred when the stressor was scored as zero for both ***AcuteChange***$_c$ and ***ChronicChange***$_c$, and therefore had no impact on the SEC at the population level. Both *light disturbance* and *noise disturbance* for *equipment installation* and *submersible operations* were removed from the risk assessment for certain SECs (see Appendix H for details). An example of a species SEC where certain interactions were dropped from the risk calculation due to the ***Resilience***$_c$ going to zero is Squat Lobster. Although 24 potential stressors were identified in the interaction matrix and ***Exposure***$_{sc}$ was scored for all 24 stressors, once scoring was complete, only nine stressors remained. Given the abundance of Squat Lobsters at the SK-B MPA and what is known about their biology, certain stressors associated with *equipment abandonment* (4 stressors)*, equipment installation* (4 stressors), *nutrients [vessel discharge]* (1 stressor), *sampling* (3 stressors), *submersible operations* (3 stressors), and *trap fishing* (3 stressors), were removed from the risk calculations due to unlikely impacts at the population level. Another example of stressors falling out of the risk assessment is *removal of biological material [trap/pot fishing]* for several fish species. Although all fish species are potential bycatch in the Sablefish trap fishery, when we examined data on non-target catch, we found that Yelloweye Rockfish, Widow Rockfish, Bocaccio, and Prowfish have not been recorded as non-target bycatch in the Sablefish trap fishery at the SK-B MPA so there are no population impacts to these SECs from this stressor (see Appendix H for scores and Appendix J for list of non-target catch species).

We distinguish between scoring ***Resilience***$_c$ factors based on a ‘current snapshot’ and ‘potential’ stressors. While scoring of current snapshot stressors was straightforward, scoring of potential stressors required allocating scores based on the worst-case scenario. This difference means that *aquatic invasive species* was scored as establishment of an aquatic invasive species (rather than exposure to propagule), and *oil [oil spill]* was scored based on a large-scale tanker spill.

3.2.2.4 Recovery$_c$ Factors

There are a maximum of nine listed recovery factors to score for species SECs and seven for habitat SECs**.** ***Recovery***$_c$ factors scored for the analysis included life history traits such as: fecundity, natural mortality rate, age at maturity, life stage affected by stressor, population connectivity, and conservation status. All factors were scored with available information about the SECs biology based on the literature. Some species are better known that others and some ***Recovery***$_c$ factors are only applicable to certain taxa (e.g., the scoring bins for maximum age, maximum size, and von Bertalanffy growth coefficient are designed around fish). For a full list and definition of ***Recovery***$_c$ factors see Appendix C. The number of ***Recovery***$_c$ factors scored for each SEC ranged between six and nine (Table 10).

*Table 10: The number of **Recovery**$_c$ factors scored for each SEC.*

SEC type	SEC	Number of *Recovery*$_c$ factors scored
Species	*Isidella*	6
	Primnoa	6
	Squat Lobster	8
	Rougheye Rockfish	8
	Pacific Halibut	7
	Bocaccio	9
	Sablefish	7
	Yelloweye Rockfish	9
	Widow Rockfish	6
	Prowfish	6
Habitat	Sponges	6
	Corals	6
	Crustose Coralline Algae	6
	Macroalgae	6

3.2.2.5 Uncertainty

Similar to the SEC selection process, the identification and quantification of human activities in the SK-B MPA highlights gaps in the current state of knowledge surrounding the spatial (both areal and depth related) overlap between stressors and ecological components and the stressor intensity at the SK-B MPA. There were high uncertainty scores for the exposure of the SK-B MPA ecosystem to *oil [oil spills]* and *aquatic invasive species*. The high uncertainty surrounding these stressors is associated with the unpredictability of stressor occurrence and exposure to the stressor. For example, oil spills are not frequent but when they do occur, the impacts are highly dependent on the size of the spill, the type of oil, the proximity to the MPA and the ocean conditions after the spill. Similarly, the impacts of *aquatic invasive species* can be severe if the introduced species becomes established and outcompetes native species for resources, but the likelihood of an introduced species becoming established at the SK-B MPA is unknown. For these stressors, the potential exposure given a *oil spill* and *aquatic invasive species* establishment were scored, whereas for most other stressors that have some predictability, we scored them at their current rates. This issue is discussed further in *4. Discussion* (see also Appendix H for scoring justifications).

Others stressors had high uncertainty on the ***Consequence***$_{sc}$ side of the equation, for example the population impacts of engine noise from vessels and sound pressure of air guns used by *seismic surveys* has the potential to be high (particularly for *seismic surveys*) but there is little known about the impacts to fish and invertebrates. Most of the research on the impacts of sound (both in terms of intense air gun blasts and chronic exposure to low frequency engine noise) are on marine mammals. In addition, because sound from air gun blasts can travel long distances (Nieukirk et al. 2004) and even seismic surveys and engine noise that occur several hundred kilometers away from the SK-B MPA can be audible to species that hear and have the potential to be exposed to these stressors. Finally, the ERAF is set up to measure population changes, but with little information on current population sizes or abundance at the SK-B MPA, there was uncertainty associated with the ***Resilience***$_c$ scores (see Appendix H).

The Sablefish trap fishery had the lowest uncertainty scores in terms of ***Exposure***$_{sc}$ because there were data available to accurately calculate the areal, depth and temporal overlap of the fishing stressors with the SECs given known fishing regulations. However, uncertainty scores could be further reduced if a map of the biogenic habitat and the benthic footprint of the trap fishery were developed using a GIS framework.

It is important to point out that the higher the uncertainty scores for each variable in the ***Risk***$_{SC}$ equation, the higher the median ***Risk***$_{SC}$ score because the uncertainty is incorporated into the ***Risk***$_{SC}$ score calculation. Therefore, the results of the risk assessment also highlight which stressors need better quantification in terms of ***Exposure***$_{sc}$ and ***Consequence***$_{SC}$ to better understand their relative risk. In contrast, stressors associated with activities that we know more about (i.e., research activities and fishing) will have lower uncertainty values and therefore their ***Risk***$_{SC}$ scores will not be inflated in the same way as stressors with high uncertainty (discussed further in *4. Discussion*).

3.2.2.6 Relative Risk *(Risk$_{SC}$)*

Median relative ***Risk***$_{SC}$ scores and associated uncertainty were calculated for each of the 14 SECs (Figures 7-10), as were the median ***Consequence***$_{sc}$ and ***Exposure***$_{sc}$ scores (Figures 7-10). See Table 11 for the values of median risk, median ***Exposure***$_{sc}$ and median ***Consequence***$_{SC}$ of the top four stressors for each SEC. By examining the ***Exposure***$_{sc}$ and ***Consequence***$_{SC}$ columns of Table 11, the variable driving the ***Risk***$_{SC}$ score can be determined – either ***Exposure***$_{sc}$ or ***Consequence***$_{SC}$. For example, a stressor could result in a high median ***Risk***$_{SC}$ score with a very low ***Exposure***$_{sc}$ but a very high ***Consequence***$_{SC}$ and vice versa. A full list of all ***Risk***$_{SC}$ results is available in Appendix I.

The relative risk results for fish SECs (Figure 7 and Figure 8) show that the stressor with the highest median risk to fish is *seismic surveys* (labelled 7 in plots in Figures 7-8). The ***Exposure***$_{sc}$ and ***Consequence***$_{SC}$ plots show that this stressor has a high ***Consequence***$_{SC}$ to fish populations at the SK-B MPA (associated with the high uncertainty scores with respect to the population impacts of air guns on fish), and that compared to other stressors at the MPA, it also has moderate ***Exposure***$_{sc}$. This result is due to the fact that even though *seismic surveys* occur infrequently, when they do occur they produce high intensity sounds that can travel large distances underwater and will therefore have high spatial overlap even if the air guns are blasted outside the MPA. The stressor with the second highest median risk for all fish SECs, except Rougheye Rockfish, is *oil spill*. This score is driven more by the devastating consequences that are expected if a spill were to occur, rather than exposure to spills. Spills occur infrequently, and given that most of these species are demersal fish, they are less likely to have high spatial overlap with oil slicks that stay at the surface. The stressor with the second highest median risk score for Rougheye Rockfish is *removal of biological material [trap/pot fishing]* from the Sablefish Trap Fishery (i.e., landed catch). The Exposure-Consequence plot for this species shows that Rougheye Rockfish has the highest ***Exposure***$_{sc}$ value for this stressor (labelled 13) with a moderate ***Consequence***$_{SC}$ score. It is also apparent that there is high uncertainty in the ***Consequence***$_{SC}$ because there is little information about the size of the Rougheye Rockfish population at the SK-B MPA and therefore it was difficult to assess the percentage of the population removed via the fishery. *Removal of biological material [trap/pot fishing]* was ranked as the third highest risk stressor after *seismic surveys* and *oil spill* for Sablefish. Although Sablefish are the target of the fishery and the ***Exposure***$_{sc}$ to this stressor is high, the ***Consequence***$_{SC}$ was calculated as moderate given that Sablefish at the seamount are not a distinct population from the coast (see Appendix H). The ***Consequence***$_{SC}$ and the ***Exposure***$_{sc}$ calculations for both *oil spill* and *seismic surveys* have higher uncertainty values than the stressors associated with the Sablefish trap fishery, increasing their relative risk scores. *Noise disturbance [vessel movement underway]* was the third highest stressor after *seismic surveys* and *oil spills* for Yelloweye Rockfish and Bocaccio (Table 11) mainly driven by the exposure of these fish to engine noise, which is high for all fish SECs (Figures 7-8). Also, the impacts of low frequency chronic noise stress to fish species is not well understood increasing the uncertainty of the ***Consequence*** $_{SC}$ scores. Other stressors that ranked in the top four for fish SECs included *debris [vessel discharge]* and *aquatic invasive species*; however, since the median risk scores of these stressors are very similar and the error bars overlap, the risks imposed by these stressors are probably similar across SECs (see Table 11 for top four risk scores and Appendix I for all risk scores).

With the exception of the Squat Lobster, the invertebrate species SECs were most impacted by human activities that cause substrate disturbances in terms of both crushing and sediment resuspension, oil spills and aquatic invasive species (Figure 9). Isidella has the highest median risk score of all 14 SECs and is most at risk from stressors associated with the Sablefish trap fishery (*substrate disturbance (crushing)*, *substrate disturbance (sediment resuspension)*, *removal of biological material)* followed by *oil spills* (Table 11). Given the spatial and temporal overlap of Isidella with the trap fishery, its immobility and slow recovery time, both ***Exposure*** $_{sc}$ and ***Consequence*** $_{SC}$ variables are high for fishing stressors for this SEC. In contrast, Primnoa, which is ecologically similar to Isidella but found at shallower depths, is assumed to be only lightly impacted by the trap fishery because it is mainly restricted to Zone 1 of the SK-B MPA where fishing is restricted, but the impact is not quantifiable at this time. The highest risk stressors to Primnoa are *oil spills*, and *aquatic invasive species* associated with vessel discharge and submersible operations. In contrast to the more fragile coral species SECs, Squat Lobsters are robust to the current human activities at the SK-B MPA. It has the lowest median risk scores of any SEC and the highest-ranking stressors for this species are *seismic surveys* and *oil spills.* The higher median risk scores for these two stressors are associated with the higher uncertainty scores (Appendix H).

Stressors associated with the Sablefish trap fishery impart the greatest risk to Coral and Sponge habitats at the SK-B MPA (Figure 10). This finding is similar to the Isidella species SEC results given their ecological overlap. *Sediment disturbance (crushing) [trap/pot fishing]* from the Sablefish traps scraping the bottom upon retrieval poses the greatest threat to both habitat SECs. Other high risk stressors include *oil [oil spills], aquatic invasive species [submersible operations]* and *substrate disturbance (sediment resuspension) [trap/pot fishing].* Algae at the SK-B MPA are restricted to Zone 1 and are therefore at lower risk than Corals and Sponges from the impacts of the Sablefish trap fishery, due to low ***Exposure*** $_{sc}$. *Oil spill* is the highest risk to both algal habitats followed by stressors that may introduce *aquatic invasive species [submersible operations and vessel discharge]*. Crustose Coralline Algae has more stressors than Macroalgae (Kelps) because *substrate disturbance (sediment resuspension)* stressors are more likely to negatively impact Crustose Coralline Algae than Macroalgae given its encrusting and benthic structure (i.e., it is more prone to smothering – see Appendix H).

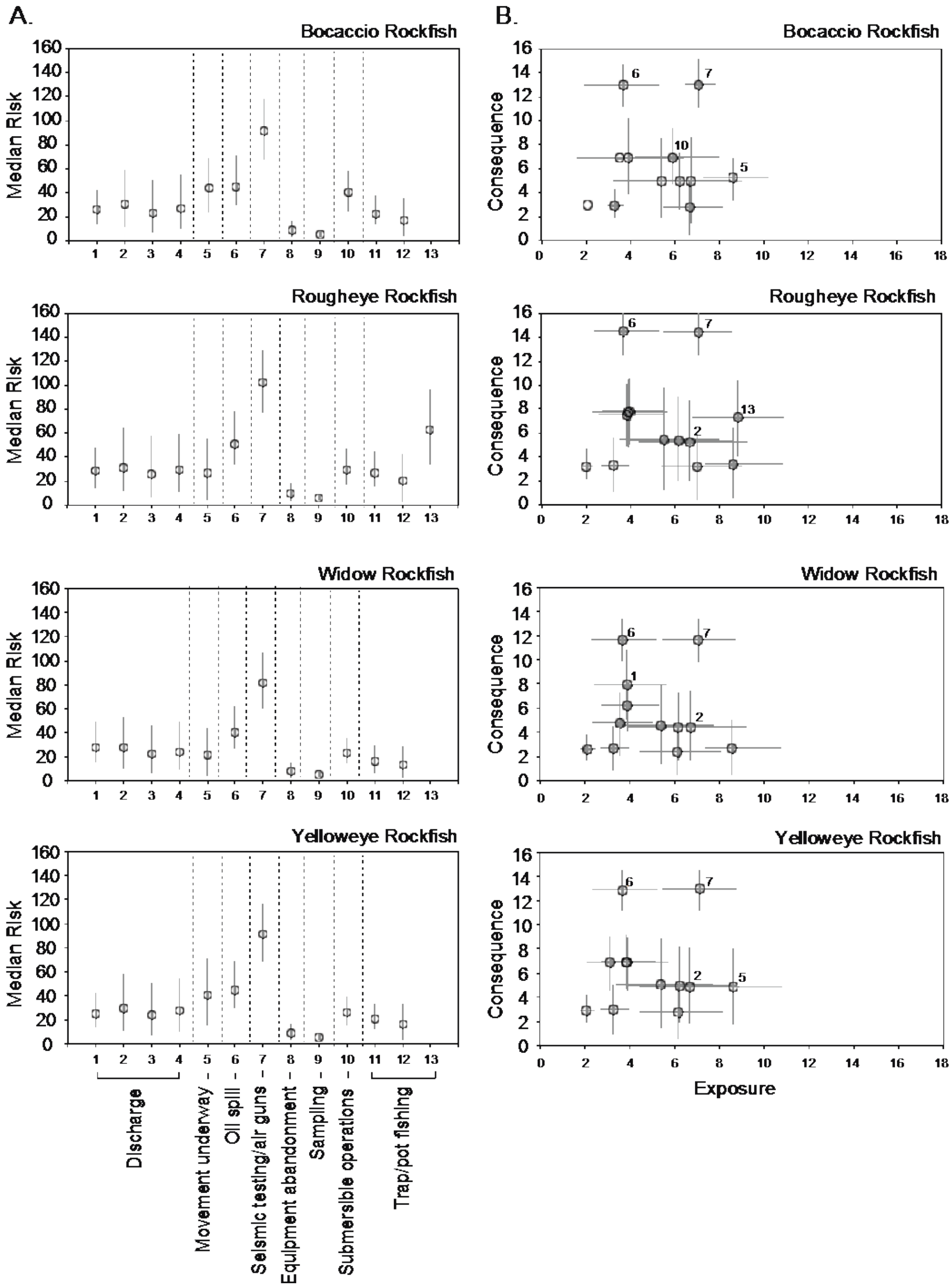


Figure 7: Median risk scores and Exposure-Consequence plots for rockfish species SECs: Bocaccio, Rougheye, Widow, and Yelloweye. Legend below.

***A.** Median risk scores for species SECs with stressors numbered as: (1) aquatic invasive species [discharge]; (2) debris [discharge]; (3) nutrients [discharge]; (4) oils/contaminants [discharge]; (5) noise disturbance [movement underway]; (6) oil [oil spill]; (7) sound generation [seismic testing/air guns]; (8) contamination [equipment installation]; (9) removal of organisms [sampling]; (10) aquatic invasive species [submersible operations]; (11) aquatic invasive species [trap/pot fishing]; (12) entrapment/entanglement [trap/pot fishing]; (13) removal of biological material [trap/pot fishing].*
***B.** **$Exposure_{sc}$/$Consequence_{SC}$** plots showing the four stressors with the highest risk scores labelled (numbering corresponds to that of A.), and the associated uncertainty represented 10/90% error bars.*

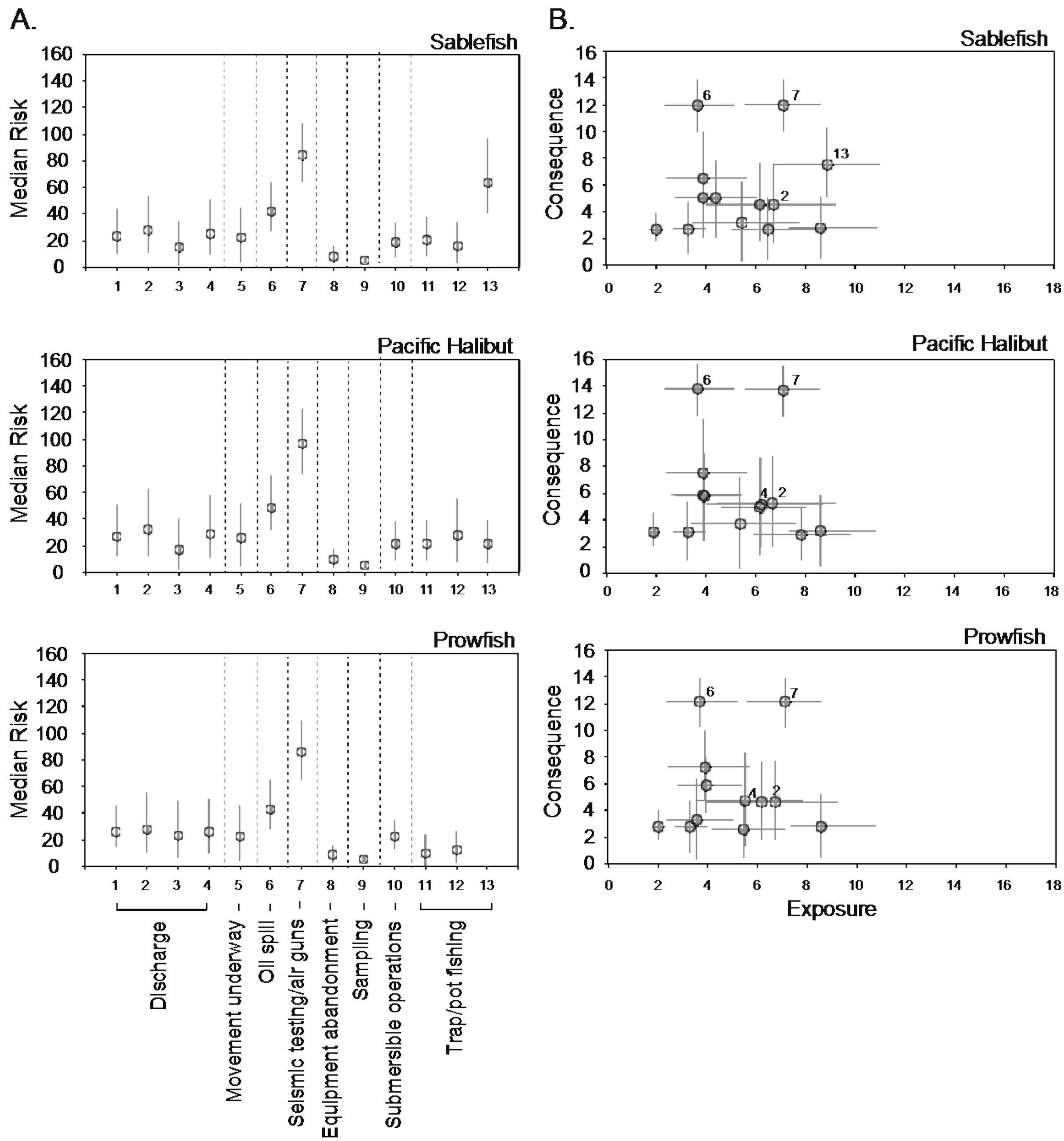


Figure 8: Median risk scores and Exposure-Consequence plots for Groundfish species SECs: Sablefish, Halibut, Prowfish. Legend below.

A. *Median risk scores species SECs with stressors numbered as: (1) aquatic invasive species [discharge]; (2) debris [discharge]; (3) nutrients [discharge]; (4) oils/contaminants [discharge]; (5) noise disturbance [movement underway]; (6) oil [oil spill]; (7) sound generation [seismic testing/air guns]; (8) contamination [equipment installation]; (9) removal of organisms [sampling]; (10) aquatic invasive species [submersible operations]; (11) aquatic invasive species [trap/pot fishing]; (12) entrapment/entanglement [trap/pot fishing]; (13) removal of biological material [trap/pot fishing].*

B. Exposure$_{sc}$/Consequence$_{SC}$ *plots showing the four stressors with the highest risk scores labelled (numbering corresponds to that of A.), and the associated uncertainty represented 10/90% error bars.*

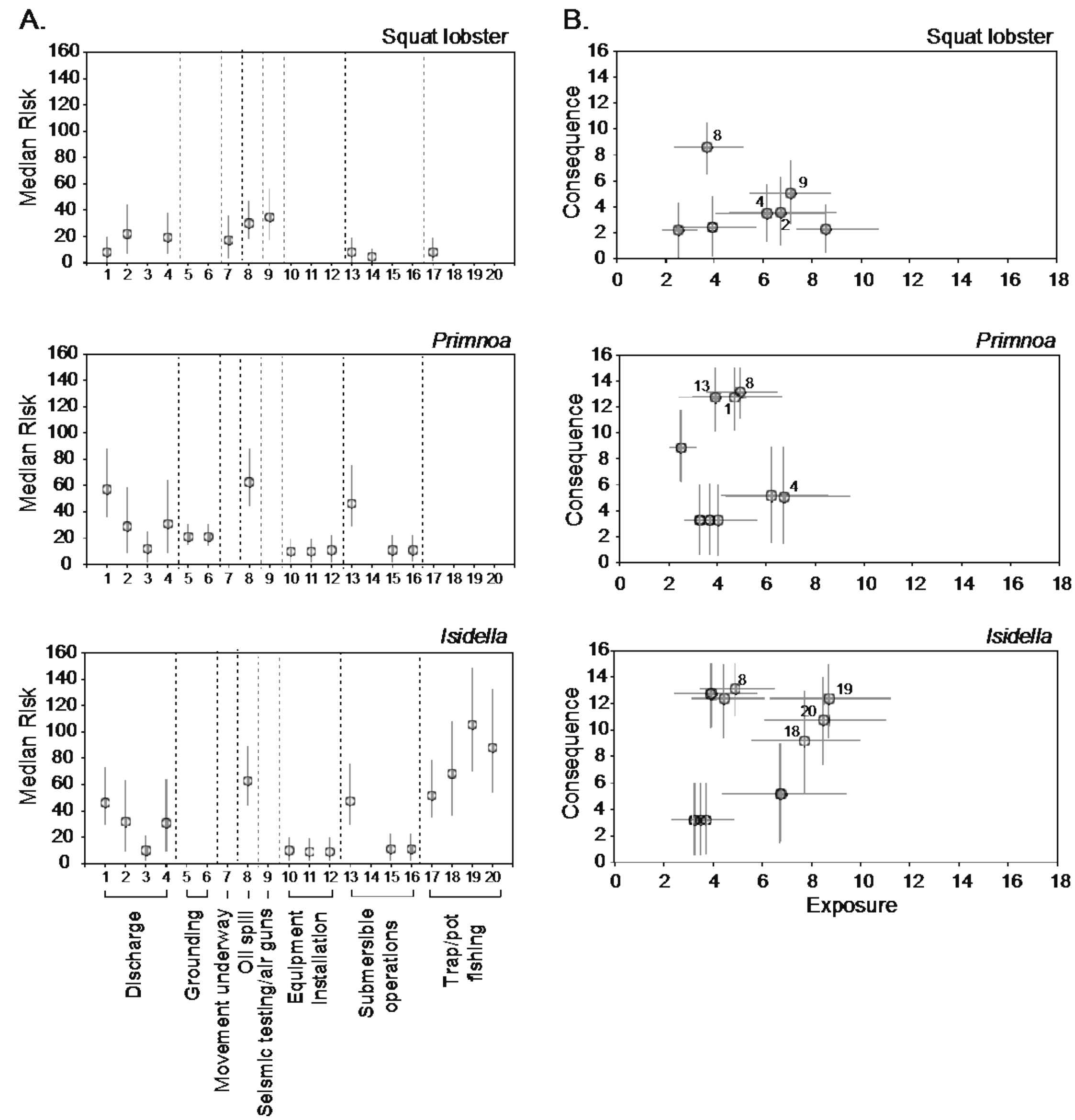


Figure 9: Median risk scores and Exposure-Consequence plots for invertebrate species SECs: Squat Lobster, Primnoa, and Isidella. Legend below.

A. *Median risk scores invertebrate species SECs with stressors numbered as: (1) aquatic invasive species [discharge]; (2) debris [discharge]; (3) nutrients [discharge]; (4) oils/contaminants [discharge]; (5) substrate disturbance (crushing) [vessel grounding]; (6) substrate disturbance (sediment resuspension) [vessel grounding]; (7) noise disturbance [movement underway]; (8) oil [oil spill]; (9) sound generation [seismic testing/air guns]; (10) contamination [equipment installation]; (11) substrate disturbance (crushing) [equipment installation]; (12) substrate disturbance (sediment resuspension) [equipment installation]; (13) aquatic invasive species [submersible operations]; (14) light disturbance [submersible operations]; (15) substrate disturbance (crushing) [submersible operations]; (16) substrate disturbance (sediment resuspension) [submersible operations]; (17) aquatic invasive species [trap/pot fishing]; (18) removal of biological material [trap/pot fishing]; (19) substrate disturbance (crushing) [trap/pot fishing]; and, (20) substrate disturbance (sediment resuspension) [trap/pot fishing].*

B. ***Exposure**$_{sc}$**/Consequence**$_{SC}$* *plots showing the stressors with the highest risk scores labelled (numbering corresponds to that of A.), and the associated uncertainty represented 10/90% error bars.*

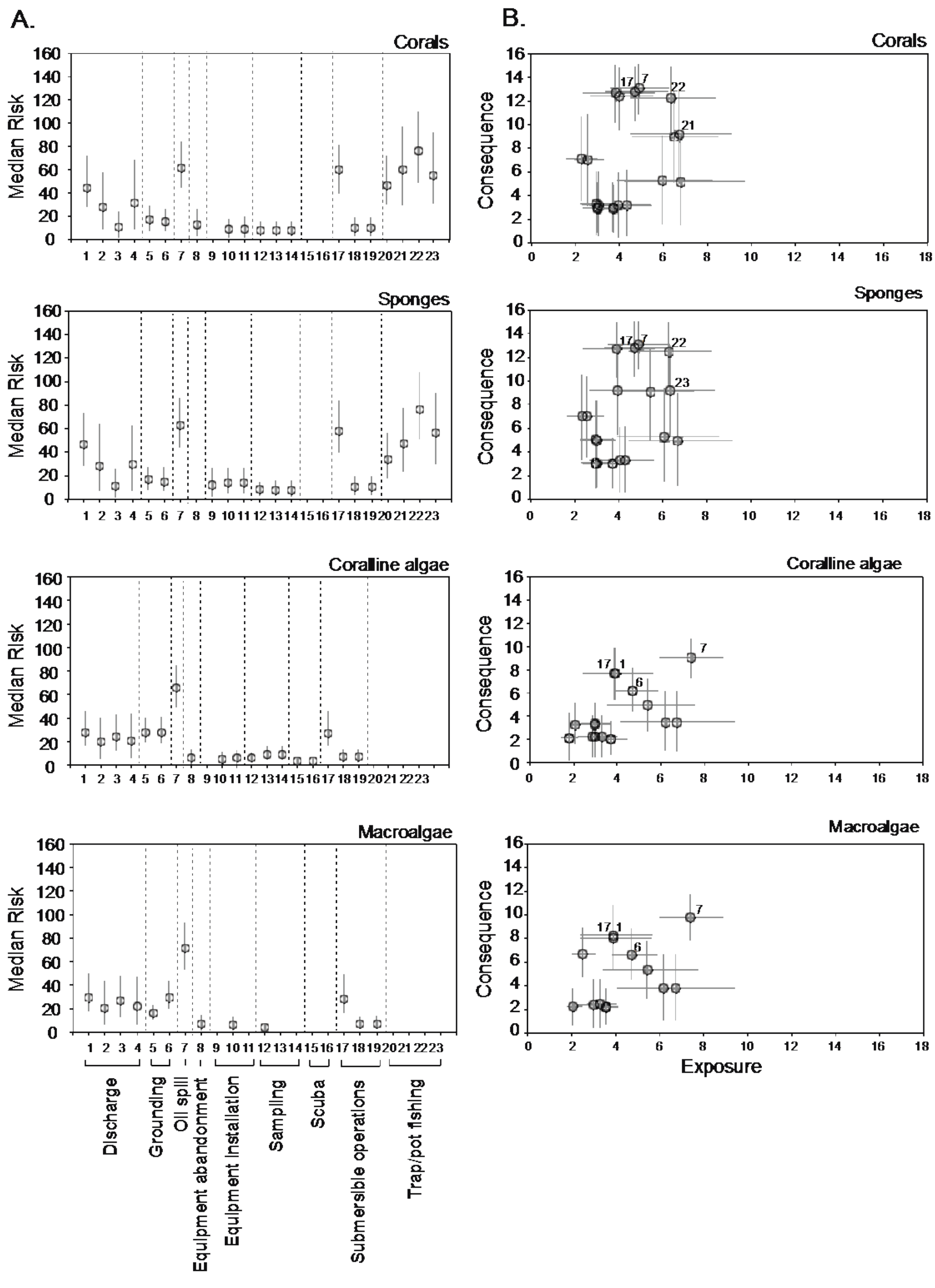


*Figure 10: Median risk scores and **Exposure$_{sc}$/Consequence$_{SC}$** plots for habitat SECs: Corals, Sponges, Crustose Coralline Algae, and Macroalgae. Legend below.*

***A.** Median risk scores invertebrate species SECs with stressors numbered as: (1) aquatic invasive species [discharge]; (2) debris [discharge]; (3) nutrients [discharge]; (4) oils/contaminants [discharge]; (5) substrate disturbance (crushing) [vessel grounding]; (6) substrate disturbance (sediment resuspension) [vessel grounding]; (7) oil [oil spill]; (8) contamination [equipment abandonment]; (9) contamination [equipment installation]; (10) substrate disturbance (crushing) [equipment installation]; (11) substrate*

disturbance (sediment resuspension) [equipment installation]; (12) removal of organisms [sampling]; (13) substrate disturbance (crushing) [sampling]; (14) substrate disturbance (sediment resuspension) [sampling]; (15) substrate disturbance (crushing) [scuba diving]; (16) substrate disturbance (sediment resuspension) [scuba diving]; (17) aquatic invasive species [submersible operations]; (18) substrate disturbance (crushing) [submersible operations]; (19) substrate disturbance (sediment resuspension) [submersible operations]; (20) aquatic invasive species [trap/pot fishing]; (21) removal of biological material [trap/pot fishing]; (22) substrate disturbance (crushing) [trap/pot fishing]; and, (23) substrate disturbance (sediment resuspension) [trap/pot fishing].
***B. Exposure$_{sc}$/Consequence$_{SC}$** plots showing the four stressors with the highest risk scores labelled (numbering corresponds to that of A.), and the associated uncertainty represented 10/90% error bars.*

*Table 11: The four stressors with the highest **Risk$_{SC}$** score for each SEC showing 10/90% quantiles, and the associated mean **Exposure$_{sc}$** and **Consequence$_{sc}$** scores.*

Activity	Stressor	*Risk$_{SC}$*	10% Quantile	90% Quantile	*Exposure$_{sc}$* Mean	*Consequence$_{sc}$* Mean
Bocaccio Rockfish						
Seismic testing/air guns	Sound generation	91.51	67.04	98.57	7.06	13.05
Oil spill	Oil	45.16	29.57	48.84	3.68	13.01
Movement underway	Noise disturbance	44.36	23.67	52.99	8.63	5.23
Submersible operations	Aquatic invasive species	40.56	24.13	46.49	5.93	6.96
Rougheye Rockfish						
Seismic testing/air guns	Sound generation	102.31	77.32	129.22	7.08	14.48
Trap/pot fishing	Removal of biological material	62.95	33.56	97.26	8.85	7.32
Oil spill	Oil	51.08	33.59	77.77	3.68	14.55
Discharge	Debris	31.59	11.78	65.05	6.65	5.25
Widow Rockfish						
Seismic surveys	Sound generation	81.68	60.25	106.78	7.09	11.69
Oil spill	Oil	40.86	26.51	62.34	3.68	11.68
Discharge	Aquatic invasive species	28.14	15.34	49.54	3.89	7.90
Discharge	Debris	27.47	10.04	53.39	6.72	4.46
Yelloweye Rockfish						
Seismic testing/air guns	Sound generation	91.43	68.31	117.11	7.11	12.96
Oil spill	Oil	45.35	29.54	68.83	3.68	12.95
Movement underway	Noise disturbance	40.00	14.82	70.99	8.60	4.86
Discharge	Debris	29.82	10.57	58.29	6.69	4.87
Sablefish						
Seismic testing/air guns	Sound generation	84.90	63.43	109.02	7.13	12.01
Trap/pot fishing	Removal of biological material	63.71	40.2	96.8	8.87	7.49
Oil spill	Oil	42.00	26.96	63.99	3.67	11.99
Discharge	Debris	27.40	10.29	54.04	6.71	4.51
Pacific Halibut						
Seismic testing/air guns	Sound generation	97.43	73.3	123.26	7.11	13.78
Oil spill	Oil	48.22	31.21	73.22	3.66	13.80
Discharge	Debris	32.10	11.75	63.11	6.69	5.27

Activity	Stressor	*Risk*$_{SC}$	10% Quantile	90% Quantile	*Exposure*$_{sc}$ Mean	*Consequence*$_{sc}$ Mean
Discharge	Oils/contaminants	29.04	10.46	58.3	6.21	5.20
Prowfish						
Seismic surveys	Sound generation	86.05	64.26	109.47	7.12	12.15
Oil spill	Oil	42.88	27.8	65.18	3.70	12.17
Discharge	Debris	27.95	10.29	55.76	6.71	4.61
Discharge	Aquatic invasive species	26.07	14.33	45.96	3.92	7.26
Squat Lobsters						
Seismic testing/air guns	Sound generation	34.43	17.62	56.09	7.11	5.05
Oil spill	Oil	30.20	18.18	47.49	3.69	8.61
Discharge	Debris	21.60	6.13	44.56	6.70	3.56
Discharge	Oils/contaminants	19.40	6.93	38.49	6.17	3.45
Primnoa						
Oil spill	Oil	62.83	44.07	87.87	4.93	13.13
Discharge	Aquatic invasive species	56.96	35.81	87.83	4.69	12.77
Submersible operations	Aquatic invasive species	46.42	28.76	75.96	3.92	12.73
Discharge	Oils/contaminants	30.64	8.51	64.39	6.71	5.10
Isidella						
Trap/pot fishing	Substrate disturbance (crushing)	105.66	69.88	148.81	8.71	12.38
Trap/pot fishing	Substrate disturbance (sediment resuspension)	88.43	53.98	132.32	8.48	10.75
Trap/pot fishing	Removal of biological material	68.46	36.61	108.64	7.72	9.22
Oil Spill	Oil	62.63	43.9	88.73	4.93	13.14
Corals (habitat)						
Trap/pot fishing	Substrate disturbance (crushing)	76.27	48.51	110.48	6.35	12.27
Oil spill	Oil	62.36	44.31	84.73	4.88	13.10
Submersible operations	Aquatic invasive species	60.06	39.31	82.33	4.73	12.77
Trap/pot fishing	Removal of biological material	59.71	29.27	97.1	6.71	9.19
Sponges (habitat)						
Trap/pot fishing	Substrate disturbance (crushing)	76.32	50.85	108.52	6.28	12.47
Oil Spill	Oil	62.64	44.27	86.3	4.92	13.09
Submersible operations	Aquatic invasive species	58.53	39.74	84.57	4.72	12.82
Trap/pot fishing	Substrate disturbance (sediment resuspension)	56.27	29.93	90.6	6.35	9.18
Crustose Coralline Algae (habitat)						
Oil spill	Oil	65.95	48.95	85.48	7.40	9.01
Vessel grounding	Substrate disturbance (resuspension)	28.22	18.95	41.28	4.73	6.21
Vessel grounding	Substrate disturbance (crushing)	27.93	19.12	40.83	4.72	6.19
Discharge	Aquatic invasive species	27.58	16.22	46.16	3.90	7.64
Macroalgae (habitat)						
Oil Spill	Oil	71.69	52.69	93.77	7.42	9.77
Vessel grounding	Substrate disturbance	29.95	19.64	44.18	4.73	6.59

Activity	Stressor	*$Risk_{SC}$*	10% Quantile	90% Quantile	*$Exposure_{sc}$* Mean	*$Consequence_{sc}$* Mean
	(resuspension)					
Discharge	Aquatic invasive species	29.70	17.51	50.46	3.89	8.30
Submersible operations	Aquatic invasive species	29.01	16.16	49.09	3.89	8.02

3.2.2.7 Cumulative Risk *($CRisk_{SC}$)*

Overall, three sessile invertebrate species SECs had the highest estimated cumulative risk scores at the SK-B MPA, with Isidella having the highest score (679) followed by two biogenic habitat SECs: Corals (677) and Sponges (661) (Table 12; Figure 11). Although Isidella is exposed to five fewer stressors than the Coral and Sponge habitat SECs (15 versus 20), mainly because its depth distribution protects it from stressors that occur near the surface or pinnacle of the seamount (*vessel grounding* and *discharge* stressors), it still has a higher cumulative risk score. The inclusion of Isidella (found generally below 700 m in Zone 2 where fishing is permitted), Primnoa (found generally in protected Zone 1) and Corals as a habitat SEC (depth range encompasses both Zone 1 and 2) shows the contrast in estimated ***$CRisk_c$*** between Corals predominantly found where fishing occurs and where fishing is prohibited. The estimated ***$CRisk_c$*** scores for Primnoa and Isidella are 386 and 679, respectively. The estimated ***$CRisk_c$*** to Corals as a habitat SEC is 677 and is driven by exposure to stressors associated with shallower depths (*vessel grounding*) and deeper depths (*trap* fishing). Crustose Coralline Algae has a higher estimated ***$CRisk_c$*** score (424) than Macroalgae (373) despite both being present only in Zone 1 of the MPA. This difference is attributed to the higher number of stressors for Crustose Coralline Algae (18 versus 13) due to the encrusting structure making ability of this SEC more prone to activities that cause sediment resuspension than Macroalgae, where sediments can be removed via passing currents.

Rougheye Rockfish (species SEC) had the highest estimated cumulative risk score of the fish (473) and has the fourth highest estimated ***$CRisk_c$*** score out of all 14 SECs (Table 12). All other fish scores estimated ranged between 432 for Sablefish and 363 for Yelloweye Rockfish. Fish SECs that are not reported as bycatch in the Sablefish trap fishery (Yelloweye, Boccacio, Widow and Prowfish) have lower estimated cumulative risk scores than fish that do get removed from the system via fishing (Rougheye, Sablefish, and Halibut); however, for all fish SECs the 10% and 90% quantiles overlap indicating that fish SECs are all at a comparable cumulative risk level. Squat Lobsters had the lowest estimated ***$CRisk_c$*** score of 162, well below the other SECs. This result is likely a result of this SEC having the lowest number of stressors (9) of all SECs, its mobility allowing it to behaviorally respond to benthic impacts in comparison to sessile invertebrates and its recovery factors as compared to slow recovery species.

*Table 12: Median cumulative risk (**$CRisk_c$**) scores for all SECs, showing 10/90% quantiles and the number of stressors contributing to the score*

SEC	*$Risk_{SC}$*	10% Quantile	90% Quantile	Stressor count
Isidella	679.43	579.91	782.75	15
Corals	677.41	586.69	770.65	20
Sponges	661.15	571.4	752.54	20
Rougheye Rockfish	473.56	397.92	553.87	13
Sablefish	432.31	361.37	506.14	13

SEC	$Risk_{SC}$	10% Quantile	90% Quantile	Stressor count
Pacific Halibut	428.40	356.04	505.14	13
Crustose Coralline Algae	424.63	365.52	485.16	18
Primnoa	386.47	319.57	458.27	13
Widow Rockfish	379.65	314.66	447.6	12
Prowfish	374.94	311.13	443.22	12
Macroalgae	373.68	314.41	435.97	13
Bocaccio	372.60	313.16	434.64	12
Yelloweye Rockfish	363.73	301.3	428.01	12
Squat Lobster	181.47	136.2	230.03	9

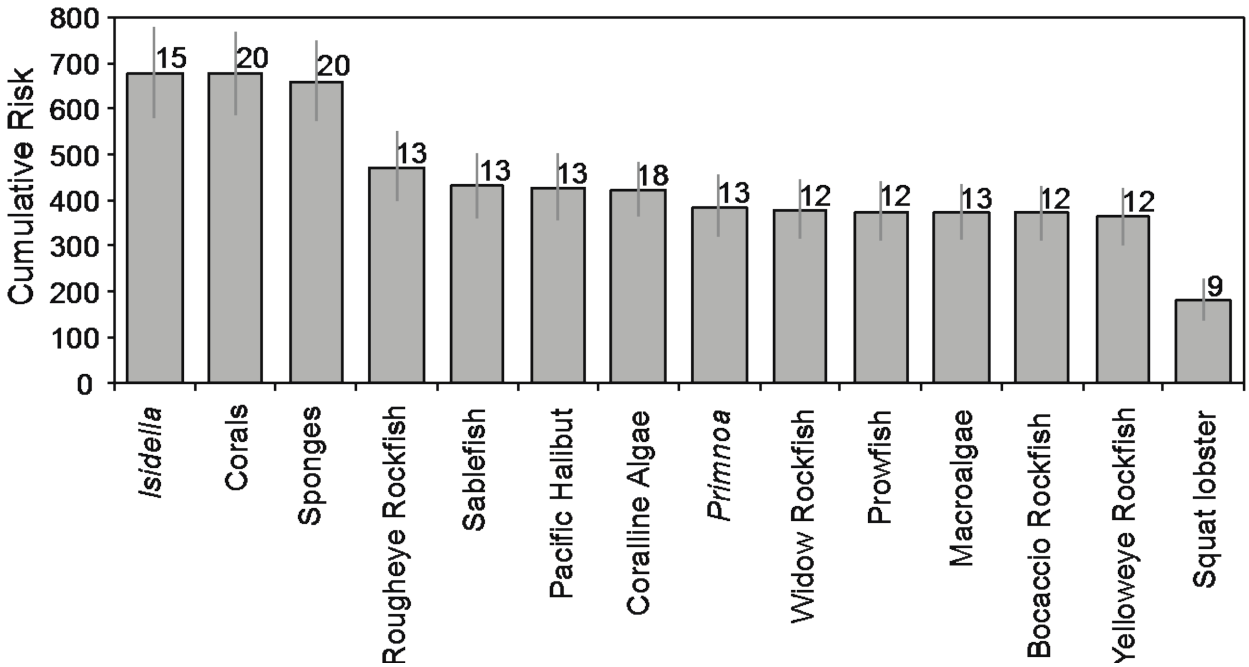


*Figure 11: Bar plot of the estimated cumulative risk (**$CRisk_c$**) for each SEC, with number of stressors included for each SEC listed at the top of each bar. Error bars represent 10th and 90th percentiles.*

3.2.2.8 Cumulative Risk by Stressor *($Potency_S$)*

Cumulative risk by stressor (***$Potency_S$***) was estimated by adding the ***$Risk_{SC}$*** scores for each stressor across SECs together. The results are displayed in Figure 12 and Table 13. The number of SECs contributing to ***$Potency_S$*** scores ranged between 1 – 14. *Oil Spill* came out with the highest ***$Potency_s$*** score out of all stressors included in the risk assessment. This finding is not surprising, given that *oil spills*, when they occur, can be ecologically devastating to entire ecosystems. *Seismic surveys* had the second highest estimated ***$Potency_s$*** (703) and this was driven by its high estimated risk for all of the fish SECs. This result was associated with the uncertainty surrounding the impacts of high-pressure sound on fish populations. The next highest ***$Potency_s$*** values were well below the top two and were those associated with *vessel discharge* (*aquatic invasive species*: 540, *debris*: 458, *contaminants*: 452) and *submersible operations* (*aquatic invasive species*: 510).

Removal of biological material [trap fishing] had an estimated ***$Potency_s$*** of 359, a value higher than 20 of the other stressors, even though it only impacts six of the 14 SECs at the SK-B MPA. Other fishing related stressors also had high ***$Potency_s$*** estimates relative to the number of SECs they impact (e.g., *substrate disturbance (crushing) [trap fishing]* only impacts three SECs but it has a ***Potency*** $_s$ value of 287). With the exception of *aquatic invasive species [submersible operations]*, stressors associated with research activities (*submersible operations*, *sampling*, *equipment installation,* and *scuba diving*) had relatively low ***Potency*** $_s$ estimates ranging from 4 to 103. Stressors that had moderate ***Potency*** $_s$ estimates included *nutrients [discharge],* and *noise disturbance [vessel movement underway].*

*Table 13: Cumulative risk by stressor (**Potency** $_S$) ranked in descending order with 10/90% quantiles, showing the number of SECs contributing to the score.*

Activity	Stressor	***Potency*** $_S$	10%Q	90%Q	SEC count
Oil spill	Oil	834.10	755.89	914.68	14
Seismic testing/air guns	Sound generation	703.15	635.29	772.42	8
Discharge	Aquatic invasive species	540.18	463.23	622.44	14
Submersible operations	Aquatic invasive species	510.52	443.52	581.14	14
Discharge	Debris	458.57	364.15	556.07	14
Discharge	Oils/contaminants	452.36	358.32	550.27	14
Trap/Pot Fishing	Removal of biological material	359.82	284.53	438.93	6
Trap/Pot Fishing	Aquatic invasive species	315.83	260.79	374.46	11
Discharge	Nutrients	303.30	233.65	377.48	13
Trap/Pot Fishing	Substrate disturbance (crushing)	287.40	227.94	350.21	3
Movement underway	Noise disturbance	240.64	177.01	307.66	8
Trap/pot Fishing	Substrate disturbance (sediment resuspension)	226.72	165.16	290.4	3
Trap/pot Fishing	Entrapment/entanglement	143.80	98.55	192.19	7
Vessel grounding	Substrate disturbance (sediment resuspension)	135.00	108.95	162.53	5
Vessel grounding	Substrate disturbance (crushing)	121.71	97.85	146.66	5
Equipment abandonment	Contamination	103.71	78.32	129.85	10
Sampling	Removal of organisms	88.60	73.03	104.86	11
Submersible operations	Substrate disturbance (sediment resuspension)	69.71	47.92	92.99	6
Submersible operations	Substrate disturbance (crushing)	69.43	47.92	91.85	6
Equipment installation	Substrate disturbance (crushing)	66.45	44.65	89.47	6
Equipment installation	Substrate disturbance (sediment resuspension)	60.05	38.11	82.8	5
Equipment installation	Contamination	38.49	19.93	58.45	3
Sampling	Substrate disturbance (sediment resuspension)	32.06	20.24	44.78	3
Sampling	Substrate disturbance (crushing)	32.00	19.82	44.77	3
Submersible operations	Light disturbance	6.04	0.37	12.17	1
Scuba diving	Substrate disturbance (sediment resuspension)	4.91	0.35	9.77	1
	Substrate disturbance (crushing)	4.88	0.31	9.81	1

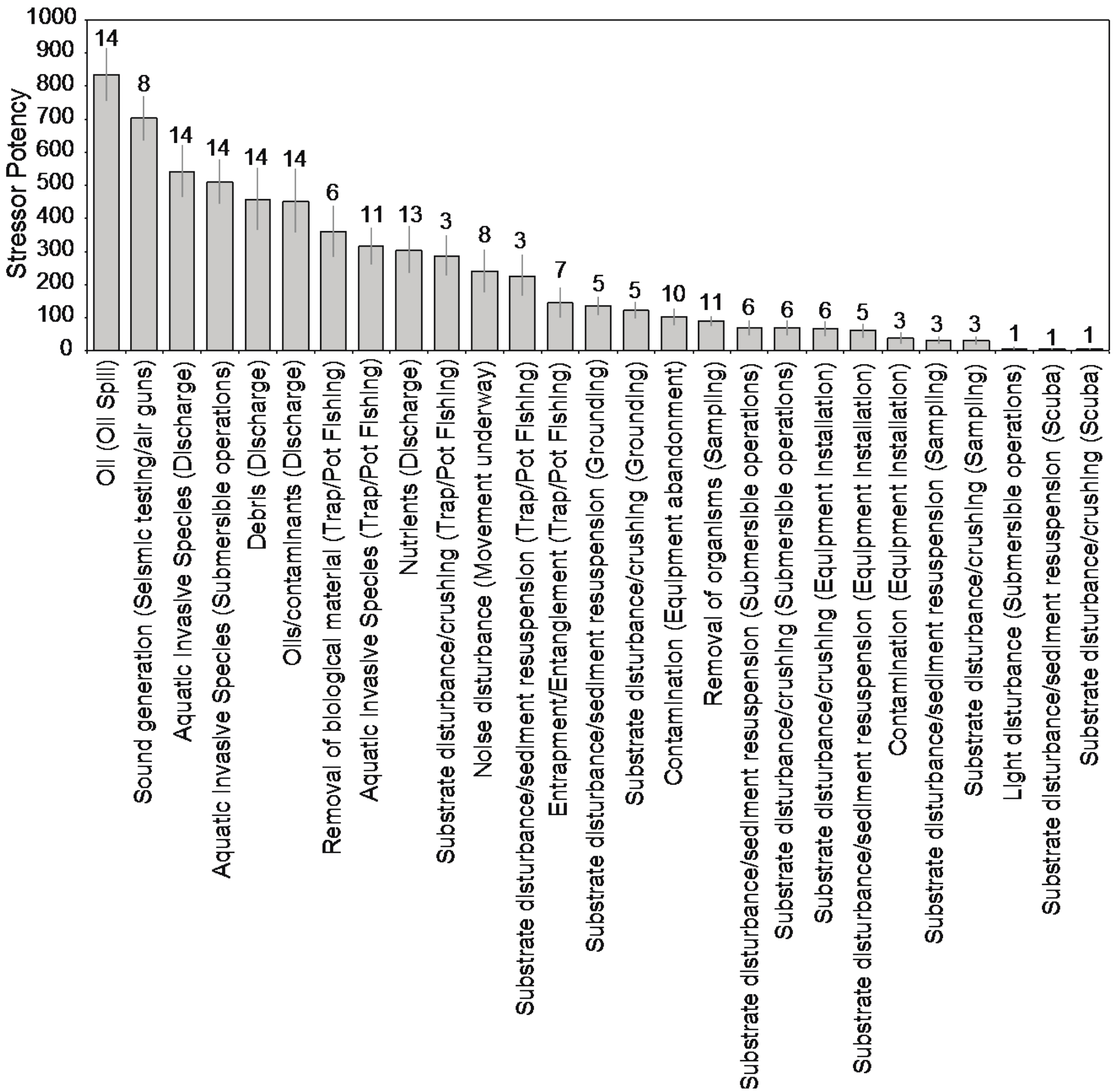


Figure 12: Ranked stressor ***Potency$_s$*** *scores, with number of SECs impacted by each stressor listed at the top of each bar. Error bars represent 10th and 90th percentiles.*

4. DISCUSSION

This project applied the Level 2 Risk Assessment framework proposed by O et al. (2015) to the SK-B MPA in order to estimate the relative risk to the SK-B MPA ecosystem from human activities. The scoping phase identified ecological SECs that appropriately represent the SK-B MPA and identified the human activities and associated stressors in the MPA and surrounding area. The results of the risk assessment determined the interaction between SECs and the stressors using an interaction matrix, and prioritized SECs and stressors on a relative scale within the MPA. This identification and prioritization of SECs and stressors is an important component for the selection of indicators and the development of MPA monitoring plans.

4.1 OUTCOME OF THE APPLICATION OF THE LEVEL 2 RISK ASSESSMENT FRAMEWORK

We identified a total of 16 SECs for the SK-B MPA ecosystem based on the criteria and considerations identified in O et al. (2015). Only 14 SECs (10 species SECs and four habitat SECs) underwent a Level 2 Risk Assessment. Two community property SECs were identified but there was not enough information available to apply the Level 2 assessment to these two SECs (see *4.2.5. Scoring community properties and recovery factors* for more discussion).

The process of identifying SECs for the SK-B MPA highlighted the knowledge gaps underlying the ecology of this seamount ecosystem. Relative to other seamounts in the Pacific Ocean (i.e., Cobb Seamount), there has been very little research conducted at the SK-B MPA. Improved understanding of underlying ecosystem processes including oceanographic processes, species richness, and trophic models will improve our understanding the SECs. However, the information that is available for the SK-B MPA shows that it is a unique ecosystem that supports a highly diverse group of coastal and open-water species. The SECs selected for this analysis fit the criteria of ecologically important species and habitats and are an appropriate representation of the biodiversity and productivity of the area based on the current state of knowledge. The list includes benthic species, slope species, shelf species, and species typically seen in the nearshore, highlighting the unique nature of the SK-B and encompasses the range of species present in the MPA.

It should be noted that Gorgonian Corals were included as species SECs and as a habitat SEC and that could be interpreted as redundant or “double-counting”. Corals were first selected at a habitat SEC because many of the habitat SEC criteria presented in O et al. (2015) was applicable to them; however, based on feedback from the SMEs review of the SEC list, we chose to highlight differences in risk for coral species predominantly found in Zone 1 versus Zone 2. The inclusion of the coral species SECs, Primnoa (predominantly found in Zone 1) and Isidella (found in Zone 2) highlighted this difference, where Isidella is at significantly higher risk than Primnoa due to the detrimental benthic impacts of the trap fishery in Zone 2. Corals, as a habitat SEC has the second greatest estimated risk, but Isidella and Primnoa, and other Gorgonian Corals are all included under this habitat SEC. The inclusion of these two species SECs within the corals habitat SEC will need to be considered when selecting risk-based indicators.

An additional criterion used in SEC selection was that the impacts to selected SECs had to be manageable at the scale of the SK-B MPA. Applying this criterion restricted our SEC selection to mainly SECs that were resident at the SK-B MPA. Although there were some exceptions to this rule (both Sablefish and several rockfish species are known to move on and off the seamount, but their presence at the SK-B MPA appears to be continuous year-round), it is important to also collect information about transient or migratory species under a state of the ecosystem monitoring program (see Appendix F). Species and groups of species that are important to the functioning of the seamount ecosystem, such as phytoplankton and zooplankton, and the use of the MPA by large transient species such as sea birds, marine mammals, and sharks is critical in order to meet the biodiversity and productivity aspects of the conservation objective for the SK-B MPA. A list of potential species to monitor in order to gain an understanding of the productivity of the SK-B MPA is listed in Appendix F.

The list of human activities at the SK-B MPA only includes activities that are permitted to occur, excluding illegal activities that could be occurring within the MPA boundaries. When interpreting the risk results, there is a distinction between stressors that were scored in terms of potential and current snapshot of each stressor-SEC combination. Scoring of potential stressors from activities such as *debris [discharge]*, *aquatic invasive species [submersible operations,* *discharge, and trap/pot fishing]*, and *oil [oil spills]* was conducted conservatively with a precautionary approach, resulting in relatively high risk scores and associated uncertainties, particularly for terms of ***Exposure**$_{sc}$*. All stressors that were scored in this manner had high ***Potency**$_{s}$* scores. The addition of quantitative information would improve the accuracy of current exposure at the SK-B MPA to these potential stressors, particularly with a better understanding of: the amount of *debris* and *aquatic invasive species* in vessel discharge released at the SK-B MPA and the likelihood of *aquatic invasive species* becoming established; and, whether or not *seismic survey* locations are accurately recorded and reported, and the measured distance of sound propagation. As *oil spills* happen so unpredictably and the resulting impacts are highly dependent on the type of oil and amount of oil spilled, it will likely remain a potential stressor with high uncertainty about ***Exposure**$_{sc}$* and ***Consequence**$_{sc}$* in future risk assessments.

Benthic species whose range overlaps with Zone 2 at the SK-B MPA, where trap fishing is permitted, are under the highest degree of risk from human activities at the SK-B MPA. The Bamboo Coral species, Isidella, is the SEC with the highest estimated cumulative risk score and the three stressors that are estimated to contribute the greatest degree of risk to this species are *substrate disturbance (crushing) [trap fishing], substrate disturbance (sediment resuspension) [trap fishing],* and *removal of biological material [trap fishing]*. Two biogenic habitat SECs that occur within Zone 1 and Zone 2 have the second highest estimated cumulative risk scores (Corals and Sponges). Given the importance of these species in providing habitat and refuge to numerous other species (Cocito 2004; Krieger and Wing 2002), the detrimental impacts of fishing on these species and habitats may have indirect and cascading effects on the rest of the SK-B MPA ecosystem.

Rougheye Rockfish was the rockfish species SEC with the highest estimated cumulative risk mainly due to the fact that removals through the Sablefish trap fishery are much greater for this SEC than other rockfish species SECs. Like all rockfish species, Rougheye Rockfish is long-lived with relatively low recovery times, further increasing the potential risk to human activities. Sablefish and the remaining fish SECs all had similar estimated risk scores despite being exposed to different number of stressors. This finding is the result of the varying life history traits of these species (see Appendix H for ***Recovery**$_{c}$* scores) and whether or not they were exposed to the Sablefish trap fishery. Despite being the target of the trap fishery, and the fish SEC with the second highest estimated cumulative risk score, Sablefish had a risk score comparable to other species SECs. The scores associated with the Sablefish trap fishery were better quantified (with lower uncertainty), particularly in terms of ***Exposure**$_{sc}$*, than other stressors impacting fish.

Seismic surveys had the highest relative rank as a stressor for all fish SECs. This result was somewhat surprising given that few reported *seismic surveys* have occurred in the SK-B MPA and vicinity. Studies show that air-gun signals from marine seismic exploration surveys have been recorded (with unknown levels) over more than 3,000 km distance (Nieukirk et al. 2004) but the pressure associated with the blast changes dramatically over that distance (Caldwell and Dragoset 2000; Dragoset 2000). However, the uncertainty around both the ***Exposure**$_{sc}$* and the ***Consequence**$_{sc}$* of this activity at the SK-B MPA is high, inflating the overall median risk score. Also, in comparison to stressors associated with fishing, for example, that mostly affect the adult life stage of fishes (scored as a 1 in the ***Recovery**$_{c}$* factors), there is evidence to suggest that seismic air guns can be fatal to fish eggs and larvae in addition to impacting adults (Hirst and Rodhouse 2000; Slotte et al. 2004). Therefore, seismic air gun blasts can potentially impact all life stages and thus received a higher score for the “life stages affected” ***Recovery**$_{c}$* factor (3 in the ***Recovery**$_{c}$* factors – see Appendix H). Finally, most of the literature on the impacts of seismic air guns focuses on higher taxa (e.g., Gordon et al. 2004), leaving a knowledge gap related to the impacts on fish populations (although see McCauley et al. 2000;

2003). Monitoring the frequency of *seismic surveys* in the vicinity of the SK-B MPA and the changes in the sound pressure moving away from the air gun blast is needed to better quantify ***Exposure$_{sc}$*** at the SK-B MPA ecosystem to this stressor and therefore more accurately estimate the risk to fish species at the SK-B MPA.

4.2 CHALLENGES, LIMITATIONS, AND FUTURE WORK

The main limitation in applying the Level 2 framework to the SK-B MPA is related to the lack of baseline knowledge about the ecology of Bowie Seamount. The absence of baseline data made the interpretation and application of some SEC selection criteria challenging. We used the ERAF selection criteria by restricting our SEC list to species that are present at the SK-B MPA year-round, and ensuring the unique juxtaposition of coastal and deep-water species were represented in our SEC list. However, this approach excludes transient species from consideration as SECs in the SK-B MPA. The lack of baseline data also hindered our ability to apply the community level analyses proposed by O et al. (2015) to the community SECs that were selecting during the scoping phase. However, aspects of the selected communities (Rockfish Assemblage and Benthic Invertebrate Assemblage) were well-represented in the species and habitat SECs that were selected.

Limiting the activities assessed to activities permitted to occur at the SK-B MPA may miss some important risks to the SK-B ecosystem. Although it was not feasible to complete the risk assessment on illegal activities, it is important to attempt to better understand the nature and frequency of illegal activities in and around the SK-B MPA.

Despite these limitations, the framework was effective in prioritizing stressor and SECs on a relative scale within the SK-B MPA. Based on the estimated cumulative risk, Isidella and other Corals and Sponges are the SECs under the greatest risk in the SK-B MPA. These results also highlighted that for these SECs, the stressors associated with fishing were the largest drivers of the estimated risk scores.

At this stage, and without further development of the relative risk to the ecosystem structure and function method proposed by O et al. (2015), this assessment is not sensitive enough to detect changes on an ecosystem level nor are there enough data on the SK-B MPA to complete this type of analysis (see *4.2.4. Relative Risk to the Ecosystem Structure and Function*).

4.2.1 The Challenges of the Level 2 Semi-Quantitative Method

Perfect information on all aspects of an ecosystem and activities impacting it is rare. The semi-quantitative approach of the Level 2 ERAF developed by O et al. (2015) attempts to incorporate the use of quantitative data when available, and qualitative data when quantitative data are not available. When quantitative information was available, there was higher confidence and lower uncertainty in the scoring of each term in the risk equation. Given that high uncertainty increases the risk score, activities and/or stressors that we were able to quantify from data available at the SK-B MPA, had lower risk scores than those stressors for which no data were available from the SK-B MPA and for which we used general knowledge or data from other areas to estimate scores for the terms in the risk equation. This makes the interpretation of the results less straightforward. The results can be interpreted as a gap analysis, where high estimated risk scores associated with high uncertainty (e.g., seismic surveys for the fish SECs) are indicative of a lack of quantitative information for these SEC-stressor combinations and thus may be a guide to developing future monitoring and research priorities.

4.2.2 Interpretation of Uncertainty Incorporation

The uncertainty incorporation method was developed during the Pacific North Coast Integrated Management Area (PNCIMA) pilot study using the Level 1 ERAF (Clarke Murray et al. 2016) and approved (DFO 2014B) in order to better deal with the uncertainty associated with qualitative scoring. By incorporating the uncertainty of each score into the risk score, the uncertainty is explicitly considered in risk estimation and subsequent decision-making based on the estimated risks. This method also avoids the likelihood that uncertainty in the estimated risk will be overlooked, as would occur if risk and uncertainty are separated as proposed in the original ERAF methodology (O et al. 2015). The incorporation of the uncertainty for every scored variable (see *2.2.2.8 Uncertainty Scoring and Incorporation*) inflates the risk score (recall that each variable is a randomly generating array with a mean of the score and a standard deviation in accordance with the uncertainty value – see Table 7**).** The advantage of this approach is that uncertainty provides considerable information on the drivers of risk and can be used to guide the development of monitoring and research programs.

Better monitoring and quantification of the ***Exposure**$_{sc}$* of the SK-B MPA ecosystem to *vessel discharge, debris, seismic surveys, vessel noise*, and the benthic impacts of *fishing* are needed to better understand the estimated risks to SECs of these activities within the MPA. In addition, the ERAF is set up to measure population changes, but with little information on current population sizes or abundance at the SK-B MPA, there is high uncertainty associated with the ***Resilience**$_{C}$* scores (see Appendix H). Baseline abundance data on the SECs as well as more detailed information about the location, timing, frequency, and density of human activities and their impact on SECs is needed to reduce the uncertainty around the relative risk scores.

4.2.3 Cumulative Impacts by SEC (CRisk$_{C}$)

The results of the cumulative risk analyses are discussed in ***Error! Reference source not found.****. Challenges, Limitations, and Future Work*. The methods of estimating cumulative impacts presented here assume that risk is additive, rather than some other relationship (multiplicative, synergistic, etc.). There is little known about the interaction of stressors and additional study is required to investigate the nature of these relationships using both ecological experimentation and modeling.

4.2.4 Relative Risk to the Ecosystem Structure and Function

In the original ERAF presented by O et al. (2015) a method was developed to calculate relative risk to ecosystem structure and function. This calculation was not possible for the present study. Ecosystem risk is a reinterpretation of a SEC's cumulative risk based on the component's perceived contribution to ecosystem structure and function (O et al. 2015). Two approaches were proposed: (1) ecosystem risk associated with risks to individual SECs; and (2) ecosystem risk associated with defined ecosystem structure and functions. The first approach involved estimating ecosystem sensitivity to the loss of each SEC across a set of criteria (ecosystem roles) to be calculated using equations proposed by Park et al. (2010). The second approach involved calculating the risk to ecosystem structure and function to estimate the potential risk of loss in ecosystem structure and function, using a set of defined ecological roles or functions. Neither approach was successfully applied to the SK-B MPA. This lack of success is attributed primarily to the lack of available information on the weighting of the ecosystem structure and function. Both approaches required allocating a weight for role *R* (role in the ecosystem structure and function), and while no specific method for defining this term was proposed, alternate methods were suggested including using ecosystem function or food web criteria. Without extensive information on the structure, functioning, food web, and specific role of SECs, the relative weighting for role *R* was not possible in the present application of the Level 2 ERAF methodology. Future work should include further investigation into relative measures of the role of SECs in ecosystem structure and function.

4.2.5 Scoring community properties and recovery factors

The testing of the ERAF methodology (O et al. 2015) has pointed to a number of drawbacks in the procedure related to community properties. First, the scoring is relative, making it challenging to apply to community SECs given the lack of baseline data for comparison in the SK-B MPA. Second, there are few community level impact studies available in the literature, most are habitat or species specific and not appropriate for the SK-B MPA ecosystem.

Finally, we were not able to score the recovery factors identified in the ERAF due to the lack of baseline data for the SK-B MPA. Here, we discuss potential alternatives that may help to overcome some of the identified limitations to the community properties aspect of the ERAF. Hobday et al. (2007) noted a number of common problems with community analyses: lack of knowledge of all known species; difficulties defining community boundaries; lack of a full understanding of community functions (predation, grazing, filter feeding, etc.); imprecise estimation of community metrics without extensive sampling and incomplete knowledge of whether communities may already be significantly changed following decades of influences. A possible way around some of the difficulties of working with communities would be to consider the productivities and susceptibilities of functional groups directly, rather than trying to estimate the effects of disruption on the parent communities (Cotter and Lart 2011).

The Ecological Risk Assessment for the Effects of Fishing (ERAEF) (Hobday et al. 2011b) is based on an exposure–effects approach (productivity/susceptibility analysis (PSA)), rather than a likelihood–consequence approach as used in the ERAF. Impacts in the ERAEF are assessed against ecological components representing the ecosystem, one of which is ‘ecological communities’ (Smith et al. 2007). Ecological communities are incorporated into the ERAEF by grouping species in the community into boxes of a generic foodweb, each representing trophic groups. This approach can be applied to data poor situations, as a species can be assigned to a functional group to which congeners or close allies are assigned (Hobday et al. 2011a). The ERAEF then assesses the community using the PSA approach.

Creating foodwebs for communities, even in data-poor situations is a potential approach to community analysis in the ERAF. A basic foodweb can provide an overview of how a community functions and its trophic balance as well as identifying key species, and may permit modeling of foodweb structure. It would be well suited for later examination of recovery factors and assessing change and other community aspects. The main drawback of a foodweb approach is that it requires species presence/absence data and information on their likely roles in the ecosystem. The basic foodweb approach described by Hobday et al. (2011a) could be adapted to the SK-B MPA, while referencing foodwebs from similar systems found in the literature. Some analysis on the overall trophic structure and foodweb at Bowie Seamount has been completed (Beamish and Neville 2003) using an Ecopath model to represent trophic relationships. Although this modeling was based on very limited information, the results could be used to provide a first order approximation of risk to communities at the SK-B MPA.

Unlike the ERAEF (Hobday et al. 2011b), where communities are classified broadly using bioregions and biotic provinces and depth classification, a challenge with the ERAF approach (O et al. 2015) is that communities are selected from *within* the MPA boundary rather than representing the MPA ecosystem as a whole. This community selection approach may limit the inclusion of interactions beyond the MPA boundaries in future assessments and monitoring.

The testing of the Level 2 ERAF methodology in the present application also highlighted limitations in the ***Recovery***$_{\boldsymbol{C}}$ factors listed in the method, and here we look at other options for this method. Although there is little in the literature on ways to quantify recovery in communities, a study by Barnthouse (2004) has provided a methodology to quantify recovery in a broad range of populations. Consideration of an approach to analyse the populations within each community and assess these together to evaluate potential impacts to the community is a potential way forward, especially in tandem with a foodweb approach, where the focus is on analysis of species within each trophic level. The approach recommended by Barnthouse (2004) has been used successfully to merge modelling and mesocosm experiment results for a wide range of aquatic biota and data poor situations.

4.2.6 Long-Range Impacts

The present application of the Level 2 risk assessment framework does not account for long-range stressors. Long-range impacts impacting the Pacific Region MPAs include: noise; and, long-range transport of contamination (persistent organic pollutants from both atmospheric and marine transport) and debris resulting from the 2011 Japan earthquake and tsunami. Other long-range impacts considered biospheric changes include climate change related phenomena such as ocean acidification, species range changes, and temperature changes. The current assessment considers vessel noise not originating from within the MPA, but did not include long-range debris transport or climate change stressors. These are factors that should be considered in future iterations of the risk assessment as baselines are established through monitoring.

4.2.7 Indicators

The next stage in development of a risk-based monitoring plan for the SK-B MPA is to develop appropriate indicators from the knowledge gained in the present study. These indicators should be selected for both SECs and stressors, taking into consideration measureable components such as population abundance, size or condition of habitat, etc. For example, Isidella had the highest estimated cumulative risk. An indicator for this SEC could be abundance, condition, and/or fragmentation. One of the most significant stressors on this SEC is *substrate disturbance crushing) [trap fishing]*. A potential indicator of trap fishing may be the benthic footprint or areal extent of fishing impacts on the substrate. Species or groups of species that are important to the functioning of the ecosystem, but were not appropriate for SEC selection (e.g. phytoplankton, zooplankton, marine mammals etc.) are suggested as potential state of the ecosystem indicators, and should be considered when selecting for these types of indicators.

5. CONCLUSIONS AND RECOMMENDATIONS

- The application of the Level 2 risk assessment framework to the SK-B MPA was effective in selecting and prioritizing SECs (10 species SECs, four habitat SECs).
- The SECs with the highest estimated cumulative risk were Isidella, Coral habitats, and Sponge habitats.
- Pathway of Effects models were effective in determining the activities and associated stressors capable of affecting the SECs at the SK-B MPA. The use of the stressor-SEC matrix was helpful in identifying which interactions should be put forward into the risk assessment.
- The activities with the highest estimated ***Potency****$_s$* were *oil spill* and *seismic surveys*. The high value of ***Potency****$_s$* for *seismic surveys* was driven by the uncertainty surrounding the consequences of high pressure sound on fish SECs.

- Risk scores were inflated by high uncertainty and identified knowledge gaps, particularly for stressors that were scored under a potential scenario in contrast to a current snapshot. Higher uncertainty inflates overall median risk scores. These results were expected, given the design of the ERAF and subsequent modifications to the method.
- This method was deemed effective in prioritizing SECs and stressors on a relative scale within the SK-B MPA. The risk results cannot be compared across MPAs or other areas.
- This risk assessment does not account for biospheric scale stressors such as climate change, long-range transport of stressors such as debris and contaminants, or illegal activities in or near the SK-B MPA.

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7. GLOSSARY AND ACRONYMS

Activity – An action that may impose one or more stressors on the ecosystem being assessed.

Biodiversity - The full range of variety and variability within and among living organisms and the ecological complexes in which they occur. Encompasses diversity at the ecosystem, community, species, and genetic levels and the interaction of these components" (DFO). Biodiversity includes the number of species and their abundance (species richness is the number of species, whereas species abundance is a measure of how common the species is in that environment).

Biogenic habitat - habitat created by a living organism, e.g. coral, sponge, kelp.

Bycatch - see Non-target species

Community – a group of actually or potentially interacting species living in the same place. A community is bound together by the network of influences that species have on one another.

COSEWIC, The Committee on the Status of Endangered Wildlife in Canada - a committee of experts that assesses and designates which wildlife species are in some danger of disappearing from Canada.

Cumulative Impacts - The combined total of incremental effects that multiple human activities through space and time can have on an environment.

Ecosystem – A dynamic complex of plant, animal, and microorganism communities, climatic factors and physiography, all influenced by natural disturbance events and interacting as a functional unit.

Ecosystem-based Management (EBM) - An integrated approach to making decisions about ocean-based activities, which considers the environmental impact of an activity on the whole ecosystem, not only the specific resource targeted. Ecosystem-based management should also take into account the cumulative impact of all human activities on the ecosystem within that area.

Ecosystem components – Components selected through a defined process to represent the ecosystem of interest

Ecosystem component groups - Used to represent the ecosystem, three categories are considered in this process: Species, Habitats and Community/Ecosystem properties.

Ecosystem function – the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of the ecosystem, for example nutrient cycling.

Endangered – Species facing imminent extirpation or extinction.

Endemic species – A species unique to a defined geographic area and only existing in that location.

Fitness - the ability to survive and reproduce

Functional groups – a way to group organisms in an ecosystem by their functional role, usually mode of feeding, for example grazers, filter feeders, deposit feeders, and trophic level.

Habitat - Habitats can be defined in many ways, but one of the simplest is the "place where an organism lives". Habitats not only represent the fundamental ecological unit in which species interact, but it is the matrix that supports an essential range of ecological processes. The loss or impairment of habitat integrity can result in direct impacts to species, communities and ecosystem structure and function (Bax et al.1999; Bax and Williams 2001).

Infauna - Benthic animals that live in the substrate of a body of water, especially in a soft sea bottom. Infauna usually construct tubes or burrows and are commonly found in deeper and subtidal waters. Examples include clams, tubeworms, and burrowing crabs.

Keystone species – A species that exerts control on the abundance of others by altering community or habitat structure, usually through predation or grazing, and usually to a much greater extent than might be surmised from its abundance (Pitcher and McClanahan 2007).

Nutrient importing/exporting species - Species which play a crucial role in maintaining ecosystem structure and function through the transfer of energy or nutrients—that would otherwise be limiting to an ecosystem—into that system from sources outside the spatial boundaries of the ecosystem.

Pathways of Effects (PoE) Model- A PoE model is a representation of cause-and-effect relationships between human activities, their associated sources of effects (stressors or pressures), and their impact on specific ecosystem components. These models illustrate cause-effect relationships and identify the mechanisms by which stressors ultimately lead to effects in the environment.

Population - Group of individuals of the same species that live in the same place and that (potentially) interact with one another to influence each other's reproductive success.

Productivity - A measure of a habitat's current yield of biological material (DFO) - Species richness and abundance have been hypothesized to increase with ecosystem productivity.

Resilience – the capacity of an ecosystem to respond to a stressor by resisting damage and/or recovering quickly.

Risk (ecological risk) – A measure of the probability that adverse ecological effects may occur, or are occurring, as a result of the exposure to one or more stressors.

***Risk – (specific for this process)* -** the likelihood that a Valued Ecosystem Component will experience unacceptable adverse consequences due to exposure to one or more identified stressors

SARA, Species at Risk Act - The purposes of the SARA are to prevent wildlife species in Canada from disappearing, to provide for the recovery of wildlife species that are extirpated (no longer exist in the wild in Canada), endangered, or threatened as a result of human activity, and to manage species of special concern to prevent them from becoming endangered or threatened.

Significant Ecosystem Component (SEC) – Ecosystem components deemed to have particular significance due to fulfilling specific criteria or roles. Though SECs can be ecological, socioeconomic, or cultural in nature, the focus in this process is only on those of ecological significance, which include biological, oceanographic and physical components important to the ecosystem.

Species richness - often given simply as the number of species, more commonly used is an index which incorporates the total number of individuals.

Species at Risk - An extirpated, endangered or threatened species or a species of special concern (formerly called vulnerable) (BC Conservation Data Centre)

Species of special concern – Species particularly sensitive to human activities or natural events but not necessarily endangered or threatened [as used by COSEWIC - A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.] Special Concern was formerly referred to as Vulnerable (BC Conservation Data Centre).

Stressor – Any physical, chemical, or biological means that, at some given level of intensity, has the potential to negatively affect an ecosystem

Susceptibility - Susceptibility is composed of three aspects: availability, encounterability and selectivity

Taxonomic distinctness - A univariate biodiversity index which, in its simplest form, calculates the average 'distance' between all pairs of species in a community sample, where this distance is defined as the path length through a standard Linnean or phylogenetlc tree connecting these species. It attempts to capture phylogenetic diversity rather than simple richness of species and is more closely linked to functional diversity; it is robust to variation in sampling effort and there exists a statistical framework for assessing its departure from 'expectation'; in its simplest form it utilises only simple species lists (presence/absence data) (Clarke and Warwick 1999)

Target species - Species targeted by a fishery in the area of interest, information from the literature and DFO sources.

Vulnerable species – Species that are particularly sensitive to human activities or natural events. [As used by NatureServe - Vulnerable due to a restricted range, relatively few populations, recent and widespread declines, or other factors making it vulnerable to extirpation (BC Conservation Data Centre)].

8. APPENDICES

APPENDIX A. SK-B LOCATION AND BOUNDARIES

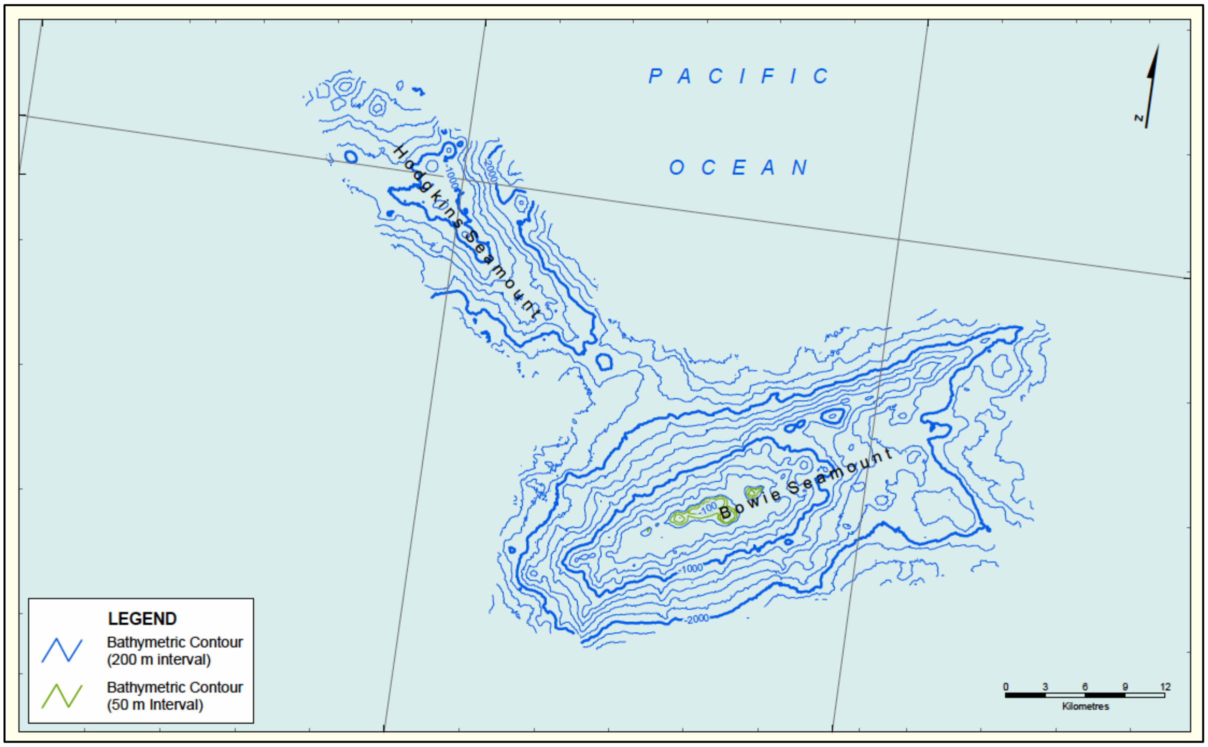

Figure A.1. Bathymetric contours for Bowie and Hodgkins Seamounts ***(Source: Canessa et al. 2003)***

A.2. Important physical habitats at the SK-B MPA: Habitat classification and considerations for monitoring design

There is no formal habitat classification system applied to the SK-B MPA. Clark et al. (2011) developed a broad scale global seamount classification system based on "biologically meaningful" physical attributes (summit depth, oxygen levels, seamount proximity and export production) whereas at a local scale, others have suggested classifying habitats by major sediment type (Auster et al. 2005). A habitat classification scheme is needed at Bowie when designing a sampling protocol for monitoring to ensure that sampling is stratified across major habitat classes thus ensuring all biological communities are sampled. In addition, the development of a habitat map, including the spatial distribution of different biogenic and physical habitat types, would be useful to provide a better understanding of the location of critical and sensitive habitats within the MPA boundaries. Although a sampling design and habitat classification system has not yet been determined at the SK-B MPA, different depth zones designated using the topology of the seamount, including the pinnacle and the terraces, are important factors to consider in the development of stratified monitoring of the MPA (Table A.2).

Table A.2. Important topographical features and depth zones to consider in stratified sampling design of the SK-B MPA.

Depth Zones	***Description***
Summit including two distinct terraces one at 65-100 m, the other at 220-250 m	• Summit at highest point reaches within 24 m of the surface in the photic zone allowing for a rich community of primary producers such as macroalgae. Macroalgae then provides food and habitat upon which other species depend. • Terraces provide topographical complexity and are in the known depth range for effective of "topographic trapping" of zooplankton (100-250 m) – a key process of nutrient import and the basis of ecosystem function at seamounts.

APPENDIX B. CONSIDERATIONS FOR SELECTION OF SPECIES, HABITAT AND COMMUNITY/ECOSYSTEM PROPERTIES SECS

Table B.1. Considerations for Selecting Species SECs (from O et al. 2015)

Species Criteria	Description
Nutrient Importer/Exporter	Crucial role in maintaining ecosystem structure and function through the transfer of energy or nutrients that would otherwise be limiting to an ecosystem
Specialized or keystone role in food web	Species has a highly specialized relationship with another species or guild; has an important food web relationship where an impact to it would cause vertical or horizontal change in food web; species supports a temporally or spatially explicit event important for other species. Examples include highly influential predators and forage species (see glossary for definitions).
Habitat creating species	Species which create habitat for infauna and aerate substrates Species which create habitat on the seafloor
Rare, Unique, or Endemic Species	Existence of a species at relatively low abundance or whose populations are globally or nationally significant within the boundaries of the area of interest.
Sensitive Species	Low tolerance and more time needed for recovery from stressors
Depleted Species	Listed under SARA/COSEWIC/IUCN/BCCDC Target and non-target species impacted beyond their sustainable level.

Table B.2. Considerations for Selecting Habitat SECs (from O et al. 2015)

Habitat Considerations	Description
Biogenic habitat types	Habitats formed by biogenic species.
Rare or unique habitats	Habitat types with very restricted distribution in the area of interest, or habitats that are globally or nationally significant within the boundaries of the area of interest.
Sensitive habitats	Habitats with low tolerance to disturbance requiring more time to recover, or no tolerance to disturbance. May be fragile habitat, such as biogenic coral. The loss or impairment of habitat integrity can result in direct impacts to species, communities and ecosystem structure and function.
Habitats critical for sensitive species	Habitats supporting species with low tolerance which need more time for recovery from stressors.
Threatened or depleted habitats	Habitats in danger of disappearance in their natural range. Determined from literature reviews, expert review, or relevant conservation lists.
Habitats critical for depleted species	Habitats critical for supporting species listed under SARA/COSEWIC/IUCN/BCCDC and target and non-target species impacted beyond their sustainable level.
Habitats critical for supporting rare, unique or endemic species	Habitats supporting species at relatively low abundance or whose populations are globally or nationally significant within the boundaries of the area of interest.
Habitats supporting critical life cycle stages	For example, habitat important for the shelter, feeding, spawning and rearing of seamount associated fish.
Habitats providing critical ecosystem function(s) or service(s)	Habitats that provide critical physical, chemical, and biological processes or functions contributing to the self-maintenance of an ecosystem. Ecosystem services are the beneficial outcomes, for the natural environment or people, which result from ecosystem functions.

Table B.3. Considerations for Selecting Community/Ecosystem Properties SECs (from O et al. 2015)

Community/Ecosystem Property Considerations	Description
Unique communities	Communities (species assemblage) that are unique within the region, or within the area of interest
Ecologically significant community properties	Communities that are ecologically "significant" because of the functions that they serve in the ecosystem and/or because of features that they provide for other parts of the ecosystem to use (EBSA national document definition)
Functional groups which play a critical role in ecosystem functioning	Biodiversity and productivity of functional groups which are central to the functioning and resilience of the ecosystem
Ecological processes critical for ecosystem functioning	Ecological processes which are central to the functioning of the ecosystem. Include oceanographic factors critical to ecosystem functioning. Material flows, or the cycling of organic matter and inorganic nutrients (e.g., nitrogen, phosphorus), can mediate how energy travels through the food web.
Sensitive functional groups	Functional groups which are sensitive to disturbance, and if impacted would result in significant effects on community composition and ecosystem function. Includes functional groups with low functional redundancy, and low response diversity. For example, a food web containing several species of herbivores would be considered to have high functional redundancy with respect to the ecosystem function of grazing, if species of herbivores show a differential response to hypoxia, there is also high response diversity.

APPENDIX C. RECOVERY SCORING TABLES

Table C.1. Recovery factor attributes for assessing potential risks posed by activities and stressors to Species SECs (O et al. 2015).

Description	Category		
Recovery factors	**High (1)**	**Moderate (2)**	**Low (3)**
Fecundity The population-wide average number of offspring produced by a female each year	>100,000	100-100,000	<100
Natural mortality rate Instantaneous mortality rate. Populations with naturally higher instantaneous mortality rates likely have higher recovery rates	>0.4	0.2-0.4	<0.2
Age at maturity Age at first sexual reproduction	<2 years	2-4 years	>4 years
Life stage The life stage(s) affected by a stressor. If stressor affects individuals before they have the opportunity to reproduce, recovery	Not affected or only mature stages	Only immature stages	All stages
Population connectivity Realized exchange with other populations based on spatial patchiness of distribution, degree of isolation, and potential dispersal capability	Regular (not a distinct DPs or ESU)	Occasional	Negligible (DPS or ESU)
Listed species Describes the status of protected, species of concern, threatened or endangered species for COSEWIC/SARA/IUCN species. If not listed or not under consideration do not include this term in the calculation.	Data deficient	Species of concern	Endangered or threatened
Additional recovery factors for fish (Hobday et al. 2007)			
Maximum age	<10 years	10-30 years	>30 years
Maximum size	<60 cm	60-150 cm	>150 cm
von Bertalanffy growth coefficient (k)	>0.25	0.15-0.25	<0.15

Table C.2. Recovery factor attributes for assessing potential risks posed by activities and stressors to Habitat SECs (O et al. 2015).

Description	Category		
Recovery factors	**High (1)**	**Moderate (2)**	**Low (3)**
Life Stage Affected (biotic habitats) Life stages affected by a stressor.	Not affected or only mature stages	Only immature stages	All stages
Frequency of Natural Disturbance Frequency of natural disturbances of a similar type to the stressor.	Daily to weekly	Several times per year	Annual or less often
Natural Mortality Rate (biotic habitats) Describes instantaneous morality rate.	>0.4	0.2-0.4	<0.2
Natural Recruitment Rate (biotic habitats)	Annual or more frequent	1-2 years	>2 years
Age at Maturity/recovery time	<1 year	1-10 years	>10 years
Distribution Range/Fragmentation Estimated extent of occurrence and fragmentation or number of locations. Values are based on 2010 COSEWIC assessment process.	Extent of occurrence > 20,000 km^2; low fragmentation	Extent of occurrence 5,000-20,000 km^2; somewhat fragmented, known to exist at <50 locations	Extent of occurrence <5,000 km^2; severely fragmented or known to exist at <10 locations
Connectivity Rating Based on spatial patchiness of distribution, degree of isolation, and potential dispersal capability.	Regular (not a distinct DPs or ESU); High dispersal (>100 km)	Occasional; Medium dispersal (10-100 km)	Negligible (DPS or ESU); Low dispersal (<10 km)

APPENDIX D. PATHWAYS OF EFFECTS MODELS

Table D.1. List of Pathways of Effects Models and date last modified.

Developed PoE model	Date last modified	Formal review?
Vessel grounding	29/11/12	No
Discharge	29/11/12	No
Movement Underway	29/11/12	No
Oil spill	29/11/12	No
Equipment abandonment	11/01/13	No
Equipment installation	20/12/12	No
Scuba diving	18/01/13	No
Sampling	11/01/12	No
Submersible operations	21/12/12	No
Seismic testing / air guns	23/12/12	No
Trap/Pot Fishing	15/07/13	No

APPENDIX E. R CODE USED TO CALCULATE RISK AND INCORPORATE UNCERTAINTY

Results of the SK-B MPA risk assessment scoring and risk calculations (input file and R script) can be found through the Government of Canada's Open Data Portal.

Table E.1. Example of .csv datasheet for use with the uncertainty propagation code for SECs. Row 2 is an example of each risk relationship scored.

SEC Type	SEC	Activity	Stressor	Area	U_area	Depth	U_depth	Temporal	U_temp	Intensity	U_int	Intensity2	U_int2	AcuteChange	U_ac	ChronicChange	U_cc	MaxAge	U_ma	MaxSize	U_ms	vonBert	U_vb	AgeMat	U_am	LifeStage	U_ls	PopConn	U_pc	NatMort	U_nm	Listed	U_list	Fecundity	U_fec

APPENDIX F. SPECIES LISTS

Available upon request from the authors.

APPENDIX G. SEC-STRESSOR MATRIX

Available upon request from the authors.

APPENDIX H. EXPOSURE, RESILIENCE AND RECOVERY SCORES FOR ALL SECS (SPECIES, HABITAT AND COMMUNITY/ECOSYSTEM PROPERTIES)

H.1. *Isidella tentaculum* and White Primnoa Species SECs: Exposure, Consequence and Recovery Scores

Two Gorgonian Coral species were selected as species SECs. White Primnoa sp. is prevalent at the seamount and is found predominantly in the protected zone (above 457 m) at the SK-B MPA (J. Boutillier, DFO Science, Pacific Biological Station, Nanaimo, B.C., pers. comm.). White Primnoa is known in Alaska but has not been identified within BC waters and there are no reports anywhere else of the large concentrations seen at the SK-B MPA, making the high prevalence unique to the SK-B MPA (J. Boutillier, DFO Science, Pacific Biological Station, Nanaimo, B.C., pers. comm.). The other coral species SEC selected is a Bamboo Coral that occurs outside of Zone 1. It inhabits greater depths than Primnoa and is a newly described species named *Isidella tentaculum* (Etnoyer 2008). This species is not endemic to the SK-B MPA but like Primnoa there is very little information about these animals in BC waters (J. Boutillier, DFO Science, Pacific Biological Station, Nanaimo, B.C., pers. comm.). *Isidella tentuaculum* (referred to in this document as Isidella) ranges in depths from 720–1050 m and is known from Northeast Pacific seamount peaks, continental slopes, and shelf canyons. This species is a large (up to 132 cm high), abundant, and conspicuous habitat former (Etoyner 2008). The taxonomy of the Isidella group is not yet well understood and aging in this family of corals has shown that they can live hundreds if not thousands of years (Andrews et al. 2005a, 2005b). These species were also chosen because they fit several of the species criteria including rare, unique, sensitive and habitat creating species. A comparison of these two ecologically similar species will highlight the differential risk of species that occur in different management zones with the MPA.

Summary of $\textbf{\textit{Exposure}}_{sc}$ scores for Isidella and Primnoa to human activities and associated stressors at the SK-B MPA are listed below. Highlighted rows indicate where scores vary between the two SECs. All other $\textbf{\textit{Exposure}}_{sc}$ scores are the same for both coral species. Scoring justifications can be provided upon request to the authors. Note that only activities with associated stressors that directly interact with the SEC are given.

Table H.1.1. Summary of Exposuresc scores for Isidella and Primnoa species SECs to human activities and associated stressors at the SK-B MPA. Scoring justifications provided can be provided upon request to the authors. Isidella specific scores shown in yellow(Trap/Pot Fishing), Primnoa specific scores shown in blue (Scuba Diving). All other scores the same for both species. Note that Primnoa is in Zone 1 and therefore not subjected to fishing activities.

Activity	Stressor	$Area_{sc}$	$Area_{sc}$ U	$Depth_{sc}$	$Depth_{sc}$ U	$Temporal_{sc}$	$Temporal_{sc}$ U	i $(amount)_{sc}$	i $(amount)_{sc}$ U	i $(frequency)_{sc}$	i $(frequency)_{sc}$ U
Discharge	Debris	2	4	2	4	4	1	2	5	4	2
	Oils/contaminants	2	5	2	5	4	3	2	5	4	2
	Nutrients	1	5	1	5	1	3	2	5	4	3
	Aquatic invasive species	2	4	2	4	4	5	2	5	1	5
Oil Spill	Oil	2	5	2	4	4	3	4	5	1	2
Equipment installation	Contamination	2	4	2	4	4	3	1	1	3	1
	Substrate disturbance (crushing)	2	4	2	4	1	3	1	1	3	1
	Substrate disturbance (sediment resuspension)	2	4	2	4	1	4	1	1	3	1
Sampling	Removal of organisms	2	3	2	3	1	3	1	1	3	1
	Substrate disturbance (crushing)	2	3	2	3	1	3	1	1	3	1
	Substrate disturbance (sediment resuspension)	2	3	2	3	1	3	1	1	3	1
Scuba diving	Substrate disturbance (crushing)	1	3	1	3	1	3	1	3	1	1
	Substrate disturbance (sediment resuspension)	1	3	1	3	1	3	1	3	1	1
Submersible operations	Invasive species	2	5	2	5	4	4	4	5	1	5
	Substrate disturbance (crushing)	2	3	4	3	1	3	1	1	3	1
	Substrate disturbance (sediment resuspension)	2	3	4	3	1	3	1	1	3	1
Trap/Pot Fishing	Substrate disturbance (crushing)	3	5	4	3	3	2	2	4	4	3
	Substrate disturbance (sediment resuspension)	3	5	4	3	3	2	2	4	4	3
	Removal of biological material	3	5	4	3	3	2	2	4	3	2
	Aquatic invasive species	2	5	4	3	4	5	1	4	1	5

*Table H.1.2. Summary of **Consequence**$_{SC}$ scores for Isidella and Primnoa to human activities and associated stressors. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Acute Change	Acute Change U	Chronic Change	Chronic Change U
Discharge	Debris	1	5	1	5
	Oils/contaminants	1	5	1	5
	Nutrients	*0*	*4*	*0*	*4*
	Aquatic invasive species	3	5	3	3
Oil Spill	Oil	3	3	3	3
Equipment installation	Contamination	0	4	1	4
	Substrate disturbance (crushing)	0	4	1	4
	Substrate disturbance (sediment resuspension)	0	4	1	4
Sampling	*Removal of organisms*	*0*	*3*	*0*	*3*
	Substrate disturbance (crushing)	*0*	*4*	*0*	*4*
	Substrate disturbance (sediment resuspension)	*0*	*3*	*0*	*3*
Scuba diving	*Substrate disturbance (crushing)*	*0*	*4*	*0*	*4*
	Substrate disturbance (sediment resuspension)	*0*	*4*	*0*	*4*
Submersible operations	Aquatic invasive species	3	5	3	3
	Substrate disturbance (crushing)	0	4	1	4
	Substrate disturbance (sediment resuspension)	0	4	1	4
Trap/Pot Fishing	Substrate disturbance (crushing)	2	5	2	5
	Substrate disturbance (sediment resuspension)	2	5	2	5
	Removal of biological material	3	5	2	5
	Aquatic invasive species	3	5	3	5

*Table H.1.3. **Recovery**$_{C}$ Factor Scores for Primnoa and Isidella and associated uncertainty score. Scores based on Lacharite and Metaxas (2013) and Stone and Shotwell (2007).*

Recovery factor	Data	Score	Uncertainty
Life Stage(s) affected	Mature stage	1	5
Frequency of natural disturbance	Annually or less often	3	3
Natural mortality rate	N/A	N/A	N/A
Natural recruitment rate	Slow	3	3
Age at Maturity	1 to 10 years	2	4
Distribution range/fragmentation	Patchy distribution	3	3
Connectivity rating	Bowie isolated	3	5

H.2. Squat Lobster SEC: Exposure, Consequence, and Recovery Scores

The Squat Lobster, *Munida quadrispina*, is a highly abundant species at the SK-B MPA (Canessa et al. 2003, McDaniel et al. 2003). Because of this abundance, this SEC likely plays a key role in nutrient cycling as a detritivore and also a key prey species (J. Boutillier, DFO Science, Pacific Biological Station, Nanaimo, B.C., pers. comm.). In addition, because Squat Lobster is known to be resilient to certain stressors (such as oxygen deficiency, Mataboas et al. 2012) a change in the abundance in Squat Lobster may indicate an extreme change in the environment.

Table H.2.1. Summary of ***Exposure$_{sc}$*** *scores for Squat Lobster to human activities and associated stressors at the SK-B MPA. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Area$_{sc}$	Area$_{sc}$ U	Depth$_{sc}$	Depth$_{sc}$ U	Temporal$_{sc}$	Temporal$_{sc}$ U	i (amount)$_{sc}$	i (amount)$_{sc}$ U	i (frequency)$_{sc}$	i (frequency)$_{sc}$ U
Discharge	Debris	2	4	2	4	4	3	2	4	4	2
	Oils/contaminants	2	4	2	4	3	3	2	5	4	2
	Nutrients	1	5	1	4	2	3	2	5	4	2
	Aquatic invasive species	2	4	2	4	4	5	2	5	1	5
Movement underway	Noise disturbance	4	2	4	2	4	2	1	4	4	1
Oil Spill	Oil	2	5	2	5	4	3	2	5	1	2
Equipment abandonment	Contamination	1	4	1	4	4	3	4	3	3	1
Equipment installation	Substrate disturbance (crushing)	1	5	4	5	1	4	1	4	3	1
	Substrate disturbance (sediment resuspension)	1	5	4	5	1	4	1	4	3	1
	Light disturbance	1	5	4	5	1	4	1	4	3	1
	Noise disturbance	4	2	4	2	1	1	1	3	3	1
Sampling	Removal of organisms	1	2	1	2	1	1	1	1	3	1
	Substrate disturbance (crushing)	1	3	1	3	1	3	1	1	3	1
	Substrate disturbance (sediment resuspension)	1	4	1	4	1	3	1	4	3	1
Seismic surveys	Sound generation	4	2	4	2	1	3	4	3	2	3
Submersible operations	Aquatic invasive species	2	5	2	5	4	4	2	4	1	5
	Light disturbance	2	4	2	4	1	2	1	1	2	3
	Noise disturbance	4	4	4	4	1	2	1	1	2	1
	Substrate disturbance (crushing)	1	3	1	3	1	3	1	1	2	1
	Substrate disturbance (sediment resuspension)	1	3	1	3	1	3	1	3	2	1
Traps	Substrate disturbance (crushing)	1	4	4	4	1	3	2	4	4	3
	Substrate disturbance (sediment resuspension)	1	4	4	3	1	3	2	4	4	3
	Entrapment	2	5	4	4	3	5	1	4	4	2
	Aquatic invasive species	2	5	4	3	4	5	1	4	1	5

*Table H.2.2. Summary of **Consequence$_{SC}$** scores for Squat Lobster to human activities and associated stressors. Scoring justifications provided upon request from the authors. Rows in grey font indicate stressor/SEC interactions that likely do not result in a detectable change at the population level.*

Activity	Stressor	Acute Change	Acute Change U	Chronic Change	Chronic Change U
Discharge	Debris	1	5	1	5
	Oils/contaminants	1	4	1	4
	Nutrients	*0*	*5*	*0*	*5*
	Aquatic invasive species	0	5	1	5
Movement underway	Noise disturbance	0	4	1	4
Oil Spill	Oil	3	5	3	5
Equipment abandonment	*Contamination*	*0*	*3*	*0*	*3*
Equipment installation	*Substrate disturbance (crushing)*	*0*	*3*	*0*	*3*
	Substrate disturbance (sediment resuspension)	*0*	*3*	*0*	*3*
	Light disturbance	0	4	1	4
	Noise disturbance	*0*	*3*	*0*	*3*
Sampling	*Removal of organisms*	*0*	*1*	*0*	*1*
	Substrate disturbance (crushing)	*0*	*3*	*0*	*3*
	Substrate disturbance (sediment resuspension)	*0*	*3*	*0*	*3*
Seismic surveys	Sound generation	1	5	2	4
Submersible operations	Aquatic invasive species	0	5	1	5
	Light disturbance	0	3	1	5
	Noise disturbance	*0*	*3*	*0*	*3*
	Substrate disturbance (crushing)	*0*	*3*	*0*	*3*
	Substrate disturbance (sediment resuspension)	*0*	*3*	*0*	*3*
Traps	*Substrate disturbance (crushing)*	*0*	*3*	*0*	*3*
	Substrate disturbance (sediment resuspension)	*0*	*3*	*0*	*3*
	Entrapment	*0*	*5*	*0*	*5*
	Aquatic invasive species	0	5	1	5

*Table H.2.3. **Recovery$_C$** Scores for Squat Lobster and associated uncertainty score. Scoring based on Dellatorre and González-Pisani (2011), Lovrich and Theil (2011), Rowden et al. (2010), Roa and Bahamonde (1993), and Thiel et al. (2012).*

Recovery factor	Data	Score	Uncertainty
Maximum Age	Fish specific less than 10 years	1	3
Maximum Size	Fish specific 1	N/A	N/A
Von Bertalanffy Growth coefficient	Fish specific 1 or 2	N/A	N/A
Age at Maturity	2 (2 to 4 years)	2	N/A
Life Stage(s) affected	All (depending on stressor)	3	5
Population Connectivity	occasional	2	5
Natural Mortality	1 greater than 0.4	2	5
Listed status	N/A	N/A	N/A
Fecundity	>10000	2	4

H.3. Prowfish SEC: Exposure, Consequence, and Recovery Scores

Prowfish, *Zaprora silenus*, are the only species and only genus of the Family Zaproridae. This taxonomically distinct and somewhat rare species is distributed in the North Pacific from California north through the Gulf of Alaska, west through the Bering Sea and Aleutian Islands to the Asiatic shelf and then south to Hokkaido (Fishbase 2013; Smith et al. 2004). It inhabits depths between 0-800 m but is most often encountered between 10-675 m (Fishbase 2013; Smith et al. 2004). There are unusually large numbers of Prowfish present at Bowie Seamount, and they are found at much shallower depths (over the seamount pinnacle and near surface) than adults are normally recorded (Canessa et al. 2003, McDaniel et al. 2003). McDaniel et al (2003) describe these fish as "common" and “curious” and often swimming up to divers to nibble on their plastic sampling bags while conducting a research dive at Bowie. Prowfish are pelagic as larvae and become demersal as adults (Smith et al. 2004). Juvenile Prowfish use Jellyfish aggregations for rearing in order to seek refuge from surface predators (Brodeur 1998). However, Jellyfish become one of the main prey items as adults (Smith et al. 2004).

Table H.3.1. Summary of ***Exposure$_{sc}$*** *scores for Prowfish to human activities and associated stressors at the SK-B MPA. Given the redundancy in some of the exposure justifications for all fish SECs, those that differ for this specific SEC are highlighted in yellow below. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Area$_{sc}$	Area$_{sc}$ U	Depth$_{sc}$	Depth$_{sc}$ U	Temporal$_{sc}$	Temporal$_{sc}$ U	i (amount)$_{sc}$	i (amount)$_{sc}$ U	i (frequency)$_{sc}$	i (frequency)$_{sc}$ U
Discharge	Debris	2	5	2	5	4	3	2	4	4	2
	Oils/contaminants	2	5	2	5	3	3	2	5	4	2
	Nutrients	2	5	2	5	2	3	2	5	4	1
	Aquatic invasive species	2	4	2	4	4	5	2	5	1	5
Movement underway	Noise disturbance	4	2	4	2	4	2	1	4	4	1
Oil Spill	Oil	2	5	2	5	4	3	2	5	1	2
Equipment abandonment	Contamination	1	4	1	4	4	3	1	1	3	1
Equipment installation	Light disturbance	1	5	1	5	1	1	1	1	3	1
	Noise disturbance	4	2	4	2	1	1	1	1	3	1
Sampling	Removal of organisms	1	1	1	1	1	1	1	1	3	1
Scuba diving	Light disturbance	1	3	2	3	1	3	1	1	1	1
	Noise disturbance	1	3	2	3	1	3	1	1	1	1
Seismic testing/air guns	Sound generation	4	2	4	2	1	2	4	1	2	3
Submersible operations	Light disturbance	2	4	2	4	1	2	1	1	1	1
	Noise disturbance	4	5	4	5	1	2	1	1	1	1
	Aquatic invasive species	2	4	2	4	4	4	2	4	1	5
Trap/pot fishing	Entrapment/entanglement	1	5	3	3	4	3	1	4	4	2
	Removal of biological material	2	5	4	3	3	1	-	3	-	1
	Aquatic invasive species	2	5	3	5	4	5	1	4	1	5

Table H.3.2. Summary of ***Consequence$_{SC}$*** *scores for Prowfish to human activities and associated stressors. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Acute Change	Acute Change U	Chronic Change	Chronic Change U
Discharge	Debris	1	3	1	5
	Oils/contaminants	1	3	1	5
	Nutrients	1	5	1	5
	Aquatic invasive species	0	5	2	5
Movement underway	Noise disturbance	0	3	1	4
Oil Spill	Oil	3	3	3	3
Equipment abandonment	Contamination	0	3	1	3
Equipment installation	*Light disturbance*	*0*	*3*	*0*	*3*
	Noise disturbance	*0*	*3*	*0*	*3*
Sampling	Removal of organisms	1	1	0	3
Scuba diving	*Light disturbance*	*0*	*3*	*0*	*3*
	Noise disturbance	*0*	*4*	*0*	*4*
Seismic testing/air guns	Sound generation	3	3	3	3
Submersible operations	Light disturbance	0	3	0	3
	Noise disturbance	0	3	0	3
	Aquatic invasive species	0	5	2	5
Trap/pot fishing	Entrapment/ entanglement	1	5	0	3
	Removal of biological material	*0*	*0*	*0*	*0*
	Aquatic invasive species	0	5	1	5

Table H.3.3. ***Recovery$_{C}$*** *Scores for Prowfish and associated uncertainty score. Scoring based on Fishbase (2013) and Smith et al. (2004).*

Recovery Factor	Data	Score	Uncertainty
Maximum Age	9 years	1	2
Maximum Size	88 - 100 cm	2	2
Von Bertalanffy Growth coefficient	0.18 +/- 0.05/year	2	2
Age at Maturity	5.1 +/-0.7	3	2
Life Stage(s) affected	All	3	5
Population Connectivity	Low	3	5
Natural Mortality	N/A	N/A	N/A
Listed status	None	N/A	N/A
Fecundity	N/A	N/A	N/A

H.4. Pacific Halibut SEC: Exposure, Consequence, and Recovery Scores

The Pacific Halibut (*Hippoglossus stenolepis*) has been identified as a keystone predator in coastal ecosystems (Lee et al. 2010) and their diet includes Walleye Pollock, Pacific Cod, (*Gadus macrocephalus*), rockfish, (*Sebastes*), Pacific Herring (*Clupea pallasi*), Pacific Sandlance (*Ammodytes hexapterus*), Arrowtooth Flounder (*Atheresthes stomias*), Sculpins (Cottidae), Pacific Salmon (*Oncorhynchus* spp.), Eelpouts (*Lycodes* spp.), Crabs, Shrimps, Squids, and Octopi among other species (reviewed in Moukhametov et al. 2008). The fish assemblage at the SK-B MPA lacks a small-pelagic fish community and therefore has simplified trophic interactions (Beamish and Neville 2003). Halibut are a key top predator in the seamount ecosystem and prey upon rockfish, Sablefish and benthic invertebrates (e.g., King Crab). A trophic model of the seamount developed by Beamish and Neville (2003) showed that a reduction in the Halibut population increased the production of Sablefish, rockfish, and crab in the ecosystem because these species are key items in the Halibut diet. Halibut fishing has occurred at the seamount (either longline or bottom trawls) since the 1950s but there have been no records of commercial Halibut landings from the seamount since 1991 (reviewed in Canessa et al. 2003). Currently, no legal Halibut fishery occurs within the SK-B MPA boundary. Due to its importance as a top predator at the SK-B MPA, Pacific Halibut was selected as a species level SEC for the ecological risk assessment.

*Table H.4.1. Summary of **Exposure$_{sc}$** scores for Pacific Halibut species SEC to human activities and associated stressors at the SK-B MPA. Scoring justifications provided upon request from the authors. Given the redundancy in some of the exposure justifications for all fish SECs, those that differ for this specific SEC are highlighted in yellow below.*

Activity	Stressor	Area$_{sc}$	Area$_{sc}$ U	Depth$_{sc}$	Depth$_{sc}$ U	Temporal$_{sc}$	Temporal$_{sc}$ U	i (amount)$_{sc}$	i (amount)$_{sc}$ U	i (frequency)$_{sc}$	i (frequency)$_{sc}$ U
Discharge	Debris	2	5	2	5	4	3	2	4	4	2
	Oils/contaminants	2	5	2	5	3	3	2	5	4	2
	Nutrients	2	5	2	5	2	3	2	5	4	2
	Aquatic invasive species	2	4	2	4	4	5	2	5	1	5
Movement underway	Noise disturbance	4	2	4	2	4	2	1	4	4	1
Oil Spill	Oil	2	5	2	5	4	3	2	5	1	2
Equipment abandonment	Contamination	1	4	1	4	4	3	1	1	3	1
Equipment installation	Light disturbance	1	4	1	4	1	1	1	1	3	1
	Noise disturbance	4	2	4	2	1	1	1	1	3	1
Sampling	Removal of organisms	1	1	1	1	1	1	1	1	3	1
Seismic testing/air guns	Sound generation	4	2	4	2	1	2	4	1	2	3
Submersible operations	Light disturbance	2	4	2	4	1	2	1	1	1	1
	Noise disturbance	4	4	4	4	1	2	1	1	1	1
	Aquatic invasive species	2	4	2	4	4	5	2	4	1	5
Trap/pot fishing	Entrapment/entanglement	2	5	3	3	4	3	1	4	4	2
	Removal of biological material	2	5	4	2	3	1	2	3	4	1
	Aquatic invasive species	2	5	4	3	4	5	1	4	1	5

*Table H.4.2. Summary of **Consequence$_{SC}$** scores for Pacific Halibut to human activities and associated stressors. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Acute Change	Acute Change U	Chronic Change	Chronic Change U
Discharge	Debris	1	3	1	5
	Oils/contaminants	1	3	1	5
	Nutrients	1	5	0	5
	Aquatic invasive species	0	5	2	5
Movement underway	Noise disturbance	0	3	1	4
Oil Spill	Oil	3	3	3	3
Equipment abandonment	Contamination	0	3	1	3
Equipment installation	Light disturbance	*0*	*3*	*0*	*3*
	Noise disturbance	*0*	*3*	*0*	*3*
Sampling	Removal of organisms	1	1	0	3
Seismic testing/air guns	Sound generation	3	3	3	3
Submersible operations	Light disturbance	*0*	*3*	*0*	*3*
	Noise disturbance	*0*	*3*	*0*	*3*
	Aquatic invasive species	1	5	2	5
Trap/pot fishing	Entrapment/entanglement	1	5	0	4
	Removal of biological material	1	4	0	3
	Aquatic invasive species	0	4	2	5

*Table H.4.3. **Recovery$_{C}$** scores based on life history traits for Pacific Halibut and associated uncertainty score (Fishbase 2013).*

Recovery Factor	Data	Score	Uncertainty
Maximum Age	55	3	3
Maximum Size	250 cm	3	3
Von Bertalanffy Growth coefficient	0.05	3	3
Age at Maturity	8 to 12	3	3
Life Stage(s) affected	All (dependent on stressor)	3	5
Population Connectivity	Moderate	2	5
Natural Mortality	N/A	N/A	N/A
Listed status	N/A	N/A	N/A
Fecundity	500000-4 million	1	3

H.5. Sablefish SEC: Exposure, Consequence, and Recovery Scores

Sablefish, *Anoplopoma fimbria*, is a demersal fish endemic to the North Pacific Ocean and a key predator associated with the SK-B MPA (Beamish and Neville 2003, Beamish et al. 2005). Although there has been some debate over whether or not Sablefish at Bowie Seamount are a distinct population from the coast (see Beamish and Neville 2003, Kabata et al. 1988, Kimura et al. 1998, Whitaker and McFarlane 1997), the most recent data show that fish at the seamount do not form a distinct population and that these fish regularly move from the coast to the seamount and vice versa (DFO tagging studies results - DFO seamount database: http://svbcpbsgfiis/sql/SABLE/Seamount/Seamount_Front_Page.aspx). Although Sablefish may not be a year-round resident at Bowie Seamount their presence at the seamount is consistent temporally. Landing data show that Sablefish are caught every year at the seamount (DFO database, Canessa et al. 2003). Sablefish were selected as a

SEC because they fill two species SEC selection criteria as outlined in O et al. (2015). First, the movement of Sablefish on and off the seamount could justify this species as an important nutrient importer/exporter, defined by O et al. (2015) as "*Species that play a crucial role in maintaining ecosystem structure and function through the transfer of energy or nutrients that would otherwise be limiting to an ecosystem*". Other important groups of species important to the transfer of nutrients and energy on Bowie Seamount include primary producers (Phytoplankton, Macroalgae), detritvores (e.g., Squat Lobsters, Crabs, Seastars), sediment reworkers (e.g., Sea Cucumbers) and benthic filter/suspension feeders (Bivalves and Barnacles). Second, Sablefish are a top (mainly piscivorous) predator in the system and fluctuations in the Sablefish population will influence the population dynamics of other key predators (Halibut, rockfish) and prey (rockfish, other demersal fishes, cephalopods, crustaceans etc.; Beamish and Neville 2003; Whitaker and McFarlane 1997). Their role as a top predator fulfills the SEC criteria of a species that has "*an important food web relationship where an impact to it would cause vertical or horizontal change in food web*".

Table H.5.1. Summary of ***Exposure*****$_{sc}$** *scores for Sablefish species SEC to human activities and associated stressors at the SK-B MPA. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Area$_{sc}$	Area$_{sc}$ U	Depth$_{sc}$	Depth$_{sc}$ U	Temporal$_{sc}$	Temporal$_{sc}$ U	i (amount)$_{sc}$	i (amount)$_{sc}$ U	i (frequency)$_{sc}$	i (frequency)$_{sc}$ U
Discharge	Debris	2	5	2	5	4	3	2	4	4	2
	Oils/contaminants	2	5	2	5	3	3	2	5	4	2
	Nutrients	2	5	2	5	2	3	2	5	4	1
	Aquatic invasive species	2	4	2	4	4	5	2	5	1	5
Movement underway	Noise disturbance	4	2	4	2	4	2	1	4	4	1
Oil Spill	Oil	2	5	2	5	4	3	2	5	1	2
Equipment abandonment	Contamination	1	4	1	4	4	3	1	1	3	1
Equipment installation	Light disturbance	1	5	1	5	1	1	1	1	3	1
	Noise disturbance	4	2	4	2	1	1	1	1	3	1
Sampling	Removal of organisms	1	2	1	2	1	1	1	1	3	1
Seismic surveys	Sound generation	4	2	4	2	1	2	4	1	2	3
Submersible operations	Light disturbance	2	4	2	4	1	2	1	1	1	1
	Noise disturbance	4	5	4	5	1	2	1	1	1	1
	Aquatic invasive species	2	5	2	5	4	5	2	1	1	5
Trap/pot fishing	Entrapment/entanglement	3	5	3	3	4	3	1	4	4	2
	Removal of biological material	3	5	4	2	3	1	2	3	4	1
	Aquatic invasive species	2	5	4	3	4	5	1	4	1	5

*Table H.5.2. Summary of **Consequence$_{SC}$** scores for Sablefish to human activities and associated stressors. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Acute Change	Acute Change U	Chronic Change	Chronic Change U
Discharge	Debris	1	3	1	5
	Oils/contaminants	1	3	1	5
	Nutrients	1	5	0	5
	Aquatic invasive species	0	5	2	5
Movement underway	Noise disturbance	0	3	1	4
Oil Spill	Oil	3	3	3	3
Equipment abandonment	Contamination	0	3	1	3
Equipment installation	*Light disturbance*	*0*	*3*	*0*	*3*
	Noise disturbance	*0*	*3*	*0*	*3*
Sampling	Removal of organisms	1	1	0	3
Seismic surveys	Sound generation	3	3	3	3
Submersible operations	*Light disturbance*	*0*	*3*	*0*	*3*
	Noise disturbance	*0*	*3*	*0*	*3*
	Aquatic invasive species	0	5	2	5
Trap/pot fishing	Entrapment/entanglement	1	4	1	2
	Removal of biological material	3	5	1	5
	Aquatic invasive species	0	4	2	5

*Table H.5.3. **Recovery$_C$** scores for Sablefish and associated uncertainty score. Scoring based on Mason et al. (1983), and DFO 2011.*

Recovery Factor	Data	Score	Uncertainty
Maximum Age	92 years	3	4
Maximum Size	110 cm	2	4
Von Bertalanffy Growth coefficient	0.2	2	4
Age at Maturity	5 years	3	4
Life Stage(s) affected	All	3	5
Population Connectivity	Medium	2	3
Natural Mortality	N/A	N/A	N/A
Listed status	N/A	N/A	N/A
Fecundity	200000-400000	1	3

H.6. Rockfish SECs: Exposure, Consequence, and Recovery Scores

The fish community at the SK-B MPA is dominated by rockfish (25 species), including seven listed species. The most abundant rockfish species in the MPA are Rougheye, Yelloweye, and Widow Rockfish (Canessa et al. 2003; McDaniel et al. 2003; Yamanaka 2005). Rockfish are a key component of the Bowie ecosystem but rather than complete the risk assessment on all 25 species that are present in the MPA, we have selected representative rockfish species from: 1) each rockfish community assemblage (inshore, shelf and slope), 2) species that are of high conservation concern (threatened or endangered), and 3) species that are known to be highly abundant at the MPA.

H.6.1. Slope species: Rougheye/Blackspotted Rockfish complex, *Sebastes aleutianus/S. melanostictus*

The Rougheye/Blackspotted Rockfish complex is made up of two species, *S. aleutianus* and *S. melanostictus*, which are nearly impossible to distinguish from external morphology. The most effective method for distinguishing between the two species in the complex is through DNA analyses. For the purposes of this risk assessment, we assessed the two species in the complex together and refer to them as Rougheye Rockfish. The Rougheye Rockfish are highly abundant and the dominant rockfish species at Bowie Seamount (Canessa et al 2003; McDaniel et al. 2003; Beamish and Neville 2003; Yamanaka 2005). Rougheye Rockfish are in the slope rockfish group and generally inhabit depths between 25-2000 m (Love et al. 2002). Their COSEWIC status is "Special Concern" and they are listed under SARA in "Schedule 1, Special Concern". Because of the simplified fish community at Bowie, Rougheye Rockfish are considered both a key predator and prey in the ecosystem, and modelling results indicate that fluctuations in the Rougheye Rockfish population will impact the sablefish and halibut populations at the SK-B MPA (Beamish and Neville 2003). Although a prey switch from rockfish to crab may occur, Beamish and Neville (2003) speculate that Sablefish and Halibut would likely leave the ecosystem if the rockfish population significantly declined. Rougheye Rockfish are the most common non-target catch species at the SK-B MPA (Canessa et al. 2003; DFO 2013) and legally, fisherman can keep up to 2.2 metric tonnes (5,000 lbs) of Rougheye Rockfish each month of the fishing season (DFO 2013). In general, however, landed catch is much lower than allowable catch. For example, between 2006 and 2012, the average monthly catch of Rougheye Rockfish at the SK-B MPA was 0.5 metric tonnes (1,100 lbs; DFO seamount database).

*Table H.6.1.1. Summary of **Exposure$_{sc}$** scores for all rockfish species SEC to human activities and associated stressors at the SK-B MPA. Highlighted rows indicate SEC specific exposure for Rougheye Rockfish. All other exposure scores are the same for all rockfish SECs where interactions occur. * Not included for slope rockfish species (Rougheye/Blackspotted Rockfish complex) as stressors from SCUBA do not overlap with this species. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Area$_{sc}$	Area$_{sc}$ U	Depth$_{sc}$	Depth$_{sc}$ U	Temporal$_{sc}$	Temporal$_{sc}$ U	i (amount)$_{sc}$	i (amount)$_{sc}$ U	i (frequency)$_{sc}$	i (frequency)$_{sc}$ U
Discharge	Debris	2	5	2	5	4	3	2	4	4	2
	Oils/contaminants	2	5	2	5	3	3	2	5	4	2
	Nutrients	2	5	2	5	2	3	2	5	4	2
	Aquatic invasive species	2	4	2	4	4	5	2	5	1	5
Movement underway	Noise disturbance	4	2	4	2	4	2	1	4	4	1
Oil Spill	Oil	2	5	2	5	4	3	2	5	1	2
Equipment abandonment	Contamination	1	4	1	4	4	3	1	1	3	1
Equipment installation	Light disturbance	1	4	1	4	1	1	1	1	3	1
	Noise disturbance	4	2	4	2	1	3	1	1	3	1
Sampling	Removal of organisms	1	2	1	2	1	3	1	1	3	1
*Scuba diving	Light disturbance	1	3	2	3	1	3	1	1	1	1
	Noise disturbance	2	3	2	3	1	3	1	1	1	1
Air Guns	Sound generation	4	2	4	2	1	3	4	3	2	3
Submersible operations	Light disturbance	2	4	2	4	1	2	1	1	2	1
	Noise disturbance	4	4	4	4	1	2	1	3	1	1
	Aquatic invasive species	2	4	2	4	4	4	2	1	1	5
Trap/Pot Fishing	Entrapment/entanglement	3	5	4	2	3	4	1	4	4	2
	Removal of biological material	3	5	4	3	3	1	2	3	4	1
	Aquatic invasive species	2	5	2	5	4	5	1	4	1	5

*Table H.6.1.2. Summary of **Consequence$_{SC}$** scores for rockfish species SECs to human activities and associated stressors. Highlighted rows indicate SEC-specific consequences, in this case, for Rougheye Rockfish. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Acute Change	Acute Change U	Chronic Change	Chronic Change U
Discharge	Debris	1	3	1	5
	Oils/contaminants	1	3	1	5
	Nutrients	1	5	0	5
	Aquatic invasive species	0	5	3	5
Movement underway	Noise disturbance	0	3	1	4
Oil Spill	Oil	3	3	3	3
Equipment abandonment	Contamination	0	3	1	3
Equipment installation	*Light disturbance*	*0*	*3*	*0*	*3*
	Noise disturbance	*0*	*3*	*0*	*3*
Sampling	Removal of organisms	1	1	0	3
*Scuba diving	*Light disturbance*	*0*	*3*	*0*	*3*
Scuba diving	*Noise disturbance*	*0*	*4*	*0*	*4*
Air Guns	Sound generation	3	3	3	3
Submersible operations	*Light disturbance*	*0*	*3*	*0*	*3*
	Noise disturbance	*0*	*3*	*0*	*3*
	Aquatic invasive species	0	5	3	5
Trap/Pot Fishing	Entrapment/entanglement	1	4	0	5
	Removal of biological material	2	4	1	5
	Aquatic invasive species	0	4	3	5

*Table H.6.1.3. **Recovery$_C$** Scores for rockfish and associated uncertainty score. Scoring based on COSEWIC (2007) and Love et al. (2002).*

Recovery Factor	Data	Score	Uncertainty
Maximum Age	205 years	3	2
Maximum Size	80 cm	2	2
Von Bertalanffy Growth coefficient	0.0212 (both Male & Female)	3	2
Age at Maturity	20 years	3	2
Life Stage(s) affected	Dependent on activity	3	4
Population Connectivity	Occasional	2	4
Natural Mortality	0.035	3	2
Listed status	COSEWIC and SARA listed	3	1
Fecundity	Not Available	N/A	N/A

H.6.2. Inshore species: Yelloweye Rockfish, *Sebastes ruberrimus*

Yelloweye Rockfish (*S. ruberrimus*) are an abundant species of inshore rockfish found at the SK-B MPA (Canessa et al. 2003, McDaniel et al. 2003, Yamanaka et al. 2005). This SEC is a representative species SEC for the inshore rockfish group. Yelloweye Rockfish have a COSEWIC status of “Special Concern” and the Puget Sound/Georgia Basin Distinct Population Segment is listed under USA Endangered Species Act as “Threatened”. In general, they are found at depths between 15-549 m (Love et al. 2002). Due to their depth and habitat preferences, Yelloweye Rockfish do not overlap much with the Sablefish trap fishery and this species has not been reported as non-target catch between 2006 and 2012 (DFO seamount database).

*Table H.6.2.1. Summary of **Exposure**$_{sc}$ scores for Yelloweye Rockfish species SEC to human activities and associated stressors at the SK-B MPA. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Area$_{sc}$	Area$_{sc}$ U	Depth$_{sc}$	Depth$_{sc}$ U	Temporal$_{sc}$	Temporal$_{sc}$ U	i (amount)$_{sc}$	i (amount)$_{sc}$ U	i (frequency)$_{sc}$	i (frequency)$_{sc}$ U
Trap/pot fishing	Entrapment/ entanglement	2	5	4	3	4	3	1	4	4	2
	Removal of biological material	*2*	*5*	*3*	*3*	*3*	*2*	-	-	*4*	*2*
	Aquatic invasive species	2	5	3	3	4	5	1	4	1	5

*Table H.6.2.2. Summary of **Consequence**$_{SC}$ scores for Yelloweye Rockfish species SECs to human activities and associated stressors. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Acute Change	Acute Change U	Chronic Change	Chronic Change U
Trap/pot fishing	*Removal of biological material*	*0*	*1*	*0*	*1*

*Table H.6.2.3. **Recovery**$_C$ scores for Yelloweye Rockfish and associated uncertainty score. Scoring based on COSEWIC (2008), Love et al. (2002), and Yamanaka and Lacko (2001).*

Recovery Factor	Data	Score	Uncertainty
Maximum Age	115 years	3	2
Maximum Size	91 cm	2	2
Von Bertalanffy Growth coefficient	0.04 - 0.06	3	2
Age at Maturity	17 years	3	2
Life Stage(s) affected	Dependent on activity	3	4
Population Connectivity	moderate	2	4
Natural Mortality	0.015-0.02	3	2
Listed status	COSEWIC and SARA listed	3	1
Fecundity	1,200,000-2,700,000	1	2

H.6.3. Shelf species: Widow Rockfish, *Sebastes entomelas*

The Widow Rockfish, *S. entomelas*, like both the Rougheye and Yelloweye Rockfish is highly abundant at the SK-B MPA (Canessa et al. 2003, McDaniel et al. 2003, Yamanaka 2005). The complete age range of Widow rockfish has been observed at Bowie indicating that it is a self-sustaining population. Perhaps most interesting are the high numbers of juveniles present at the seamount, suggesting that this species is likely a key prey fish for other rockfish species, Halibut and Sablefish (L. Yamanaka, DFO Science, Pacific Biological Station, Nanaimo, B.C., pers. comm.). Due to its abundance, its potentially self-sustaining resident population, and its likely importance in the trophic dynamics at the seamount, Widow Rockfish was selected as a SEC. In general, Widow Rockfish are found at depths between 24-549 m (Love et al. 2002) and at the SK-B MPA, large schools of many thousands have been observed at 25 m depth (McDaniel et al. 2003).

Table H.6.3.1. Summary of **Exposure$_{sc}$** scores for Widow Rockfish species SEC to human activities and associated stressors at the SK-B MPA. Scoring justifications provided upon request from the authors.

Activity	Stressor	Area$_{sc}$	Area$_{sc}$ U	Depth$_{sc}$	Depth$_{sc}$ U	Temporal$_{sc}$	Temporal$_{sc}$ U	i (amount)$_{sc}$	i (amount)$_{sc}$ U	i (frequency)$_{sc}$	i (frequency)$_{sc}$ U
Trap/pot fishing	Entrapment/entanglement	2	5	4	3	4	3	1	4	4	2
	Removal of biological material	*2*	*5*	*3*	*3*	*3*	*2*	-	-	*4*	*1*
	Aquatic invasive species	2	5	3	5	4	5	1	4	1	5

Table H.6.3.2. Summary of **Consequence$_{SC}$** scores for Widow Rockfish species SECs to human activities and associated stressors. Scoring justifications provided upon request from the authors.

Activity	Stressor	*Acute Change*	*Acute Change U*	*Chronic Change*	*Chronic Change U*
Trap/pot fishing	*Removal of biological material*	*0*	*1*	*0*	*1*

Table H.6.3.3. **Recovery$_{C}$** Scores for Widow Rockfish and associated uncertainty score. Scoring based on Love et al. (2002).

Recovery Factor	Data	Score	Uncertainty
Maximum Age	60	3	2
Maximum Size	59	1	3
Von Bertalanffy Growth coefficient	N/A	N/A	N/A
Age at Maturity	between 3 - 8	3	2
Life Stage(s) affected	All	3	4
Population Connectivity	occasional	2	4
Natural Mortality	N/A	N/A	N/A
Listed status	N/A	N/A	N/A
Fecundity	95,000-1,113,000	1	2

H.6.4. Shelf species: Boccacio Rockfish, *Sebastes paucipinus*

Bocaccio have been documented at the SK-B MPA (Yamanaka and Brown 1999) and are a designated as “Threatened” by COSEWIC, listed as “Endangered” under US ESA and IUCN has designated this species as “Critically Endangered”. Given their slow recovery time and internationally threatened status, it is important to better understand the impacts of human activities on this species within the SK-B MPA. Bocaccio are a shelf species that are most common between 50-250 m in depth, but may be found between 12-478 m (Love et al. 2002).

*Table H.6.4.1. Summary of **Exposure$_{sc}$** scores for Bocaccio to human activities and associated stressors at the SK-B MPA. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Area$_{sc}$	Area$_{sc}$ U	Depth$_{sc}$	Depth$_{sc}$ U	Temporal$_{sc}$	Temporal$_{sc}$ U	i (amount)$_{sc}$	i (amount)$_{sc}$ U	i (frequency)$_{sc}$	i (frequency)$_{sc}$ U
Trap/Pot Fishing	Entrapment/Entanglement	2	5	4	3	4	3	1	4	4	2
	Removal of biological material	*2*	*5*	*3*	*3*	*3*	*1*	*0*	*3*	*4*	*1*
	Aquatic invasive species	2	5	3	5	4	5	1	4	1	5

*Table H.6.4.2. Summary of **Consequence$_{SC}$** scores for Bocaccio species SECs to human activities and associated stressors. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Acute Change	Acute Change U	Chronic Change	Chronic Change U
Trap/pot fishing	*Removal of biological material*	*0*	*1*	*0*	*1*

*Table H.6.4.3. **Recovery$_C$** scores for Bocaccio and associated uncertainty score. Scoring based on Love et al. (2002) and COSEWIC (2002).*

Recovery Factor	Data	Score	Uncertainty
Maximum Age	50	3	2
Maximum Size	91	2	3
Von Bertalanffy Growth coefficient	0.13	3	2
Age at Maturity	4 to 6	3	2
Life Stage(s) affected	Dependent on activity	3	4
Population Connectivity	occasional	2	4
Natural Mortality	0.2	2	3
Listed status	IUCN, COSEWIC	3	1
Fecundity	20,000 - 2,300,000	1	2

H.7. Crustose Corraline Algae and Macroalgae Habitat SECs: Exposure, Consequence, and Recovery Scores

Macroalgae was chosen as a habitat SEC at the SK-B MPA because it provides habitat for numerous invertebrates and fish species (particularly juvenile rockfish, including sensitive and listed species). Macroalgae encompass the dominant large algae group at Bowie Seamount. They are present only in restricted shallowest areas at pinnacle, but reach much deeper depths at seamount than along the coast. Crustose Coralline Algae was also chosen as a habitat SEC at the SK-B MPA for several reasons: 1) it plays a critical role in binding reef materials into sturdy structure; 2) they provide two-dimensional structure for larval settlement; and 3) they are vulnerable to ocean acidification so can act as a good indicator species and finally, they are associated with numerous other algal and invertebrate species.

*Table H.7.1. Summary of **Exposure$_{sc}$** scores for Algae to human activities and associated stressors at the SK-B MPA. *Wave disturbance only affects Macroalgae not Crustose Coralline Algae. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Area$_{sc}$	Area$_{sc}$ U	Depth$_{sc}$	Depth$_{sc}$ U	Temporal$_{sc}$	Temporal$_{sc}$ U	i (amount)$_{sc}$	i (amount)$_{sc}$ U	i (frequency)$_{sc}$	i (frequency)$_{sc}$ U
Vessel grounding	Substrate disturbance (crushing)	3	2	3	2	1	3	4	3	1	3
	Substrate disturbance (sediment resuspension)	3	2	3	2	1	3	4	3	1	3
Discharge	Debris	2	4	2	4	3	1	2	5	4	2
	Oils/contaminants	2	5	2	5	4	3	2	5	4	2
	Nutrients	2	5	4	5	1	3	2	5	4	2
	Aquatic invasive species	2	4	2	4	4	5	2	5	1	5
Movement Underway	*Wave disturbance	1	5	1	5	1	1	1	5	4	1
Oil Spill	Oil	4	5	4	4	4	3	4	5	1	2
Equipment installation	Contamination	1	4	1	4	4	3	1	1	3	1
	Substrate disturbance (crushing)	2	4	2	4	1	1	1	1	3	1
	Substrate disturbance (sediment resuspension)	2	3	4	3	1	3	1	1	3	1
Sampling	Removal of organisms	1	2	1	2	1	3	1	1	3	1
	Substrate disturbance (crushing)	2	3	2	3	1	3	1	1	3	1
	Substrate disturbance (sediment resuspension)	2	3	2	3	1	3	1	1	3	1
Scuba diving	Substrate disturbance (crushing)	2	3	2	3	1	3	1	1	1	1
	Substrate disturbance (sediment resuspension)	2	3	2	3	1	3	1	1	1	1
Submersible operations	Aquatic invasive species	2	5	2	5	4	5	2	5	2	1
	Substrate disturbance (crushing)	2	3	2	3	1	3	1	1	3	1
	Substrate disturbance (sediment resuspension)	2	3	2	3	1	3	1	1	3	1

*Table H.7.2. Summary of **Consequence**$_{SC}$ scores for Algae to human activities and associated stressors. Rows in gray italics have no detectable impact to biogenic habitat SECs at the population level given current exposure levels. Highlighted rows are specific to Crustose Coralline Algae. Macroalgae less likely to show detectable population change to sediment resuspension given its structure and exposure to current. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Acute Change	Acute Change U	Chronic Change	Chronic Change U
Vessel grounding	Substrate disturbance (crushing)	3	3	1	4
	Substrate disturbance (sediment resuspension)	3	3	1	4
Discharge	Debris	1	5	1	5
	Oils/contaminants	1	5	1	5
	Nutrients	2	4	1	4
	Aquatic invasive species	2	5	3	3
Movement Underway	*Wave disturbance*	*0*	*3*	*0*	*3*
Oil Spill	Oil	3	3	3	3
Equipment installation	Contamination	0	4	1	4
	Substrate disturbance (crushing)	*0*	*4*	*0*	*4*
	Substrate disturbance (sediment resuspension)	0	3	1	4
Sampling	*Removal of organisms*	*0*	*3*	*0*	*3*
	Substrate disturbance (crushing)	0	3	1	3
	Substrate disturbance (sediment resuspension)	0	3	1	3
Scuba diving	Substrate disturbance (crushing)	0	5	1	4
	Substrate disturbance (sediment resuspension)	0	3	1	4
Submersible operations	Aquatic invasive species	2	5	3	5
	Substrate disturbance (crushing)	0	3	1	3
	Substrate disturbance (sediment resuspension)	0	3	1	3

*Table H.7.3. **Recovery**$_C$ scores for Crustose Coralline Algae and associated uncertainty score. Scoring based on Druehl (2001) and Steneck (1986).*

Recovery factor	Data	Score	Uncertainty
Life Stage(s) affected	Adult stages (spores unlikely impacted but unknown)	1	5
Frequency of natural disturbance	Storm surges large enough to expose pinnacle likely frequent at Bowie therefore species are disturbance adapted (as they are on the coast).	2	3
Natural mortality rate	N/A	N/A	N/A
Natural recruitment rate	Crustose Coralline Algae a successional species and often first algae species to settle a new substrate	1	3
Age at Maturity	Mature in less than one year	1	4
Distribution range/ fragmentation	Difficult to score because fragmentation pattern depends upon scale but Crustose Coralline Algae are patchily distributed locally but widely distributed regionally.	1	3
Connectivity rating	Bowie is isolated but population structure of algae unknown and dispersal events somewhat likely. SK-B isolated	3	5

Table H.7.4. ***Recovery$_C$*** *scores for Macroalgae and associated uncertainty score. Scoring based Druehl (2001).*

Recovery factor	Data	Score	Uncertainty
Life Stage(s) affected	Adults only	1	5
Frequency of natural disturbance	Storm surges large enough to expose pinnacle likely frequent at Bowie therefore Macroalgae species disturbance adapted (as they are on the coast).	2	3
Natural mortality rate	n/a	N/A	N/A
Natural recruitment rate	Some species of Kelp are annuals and recruit every year.	1	5
Age at Maturity	Depending on the severity of the impact, recovery time could be longer than one year (e.g., urchin barrens)	2	4
Distribution range/fragmentation	Difficult to score because fragmentation pattern depends upon scale but Kelp and other Macroalgae are patchily distributed locally but widely distributed regionally.	1	3
Connectivity rating	Bowie is isolated but population structure of Macroalgae unknown and dispersal events somewhat likely.	3	5

H.8. Corals and Sponges Habitat SECs: Exposure, Consequence, and Recovery Scores

Deep water Gorgonian Corals were chosen as a habitat SEC because they are sensitive to disturbance and slow to recover; they provide a three dimensional and complex structure and are associated with numerous species that utilize corals for food, settlement, and protection. Similarly, Encrusting Demosponges were chosen as a habitat SEC at the SK-B MPA because they are sensitive to disturbances, slow to recover and provides three-dimensional structure and food source for many associated species.

*Table H.8.1. Summary of **Exposure**$_{sc}$ scores for Corals and Sponges to human activities and associated stressors at the SK-B MPA. Highlighted rows indicate where scores vary between SECs. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Area$_{sc}$	Area$_{sc}$ U	Depth$_{sc}$	Depth$_{sc}$ U	Temporal$_{sc}$	Temporal$_{sc}$ U	i (amount)$_{sc}$	i (amount)$_{sc}$ U	i (frequency)$_{sc}$	i (frequency)$_{sc}$ U
Vessel grounding	Substrate disturbance (crushing)	1	4	1	4	1	4	4	5	1	2
	Substrate disturbance (sediment resuspension)	1	4	1	4	1	4	3	5	1	2
Discharge	Debris	2	4	2	4	3	4	2	5	4	3
	Oils/contaminants	2	4	2	4	4	3	2	5	4	2
	Nutrients	1	4	1	4	2	3	2	5	4	3
	Aquatic invasive species	2	4	2	4	4	5	2	5	1	5
Oil Spill	Oil	2	5	2	4	4	3	4	5	1	2
Equipment abandonment	Contamination	2	4	2	4	4	3	1	1	3	1
Equipment installation	Substrate disturbance (crushing)	2	4	2	4	1	3	1	1	3	1
	Substrate disturbance (sediment resuspension)	2	4	2	4	1	4	1	1	3	1
Sampling	Removal of organisms	2	3	2	3	1	3	1	1	3	1
	Substrate disturbance (crushing)	2	3	2	3	1	3	1	1	3	1
	Substrate disturbance (sediment resuspension)	2	3	2	3	1	3	1	1	3	1
Scuba diving	Substrate disturbance (crushing)	1	3	1	3	1	3	1	3	1	1
	Substrate disturbance (sediment resuspension)	1	3	1	3	1	3	1	3	1	1
Submersible operations	Aquatic invasive species	2	5	2	5	4	4	4	5	3	1
	Substrate disturbance (crushing)	2	3	4	3	1	3	1	1	3	1
	Substrate disturbance (sediment resuspension)	2	3	4	3	1	3	1	1	3	1
Coral-specific scores											
Trap/pot fishing	Substrate disturbance (crushing)	3	5	4	3	1	3	2	4	4	3
	Substrate disturbance (sediment resuspension)	3	5	4	3	1	3	2	4	4	3
	Removal of biological material	3	5	4	3	2	4	2	4	3	2
	Aquatic invasive species	2	5	4	3	4	5	1	4	1	5
Sponge-specific scores											
Trap/pot fishing	Substrate disturbance (crushing)	3	5	4	4	1	3	2	4	4	3
	Substrate disturbance (sediment resuspension)	3	5	4	3	1	3	2	4	4	3
	Removal of biological material	3	5	4	3	2	4	2	4	2	2
	Aquatic invasive species	2	5	4	3	4	5	1	4	1	5

Table H.8.2. Summary of ***Consequence***$_{SC}$ *scores for Gorgonian Corals and Encrusting Demosponges to human activities and associated stressors. Scoring justifications provided upon request from the authors.*

Activity	Stressor	Acute Change	Acute Change U	Chronic Change	Chronic Change U
Vessel grounding	Substrate disturbance (crushing)	2	5	1	4
	Substrate disturbance (sediment resuspension)	2	5	1	4
Discharge	Debris	1	5	1	5
	Oils/contaminants	1	5	1	5
	Nutrients	1	4	0	4
	Aquatic invasive species	3	5	3	3
Oil Spill	Oil	3	3	3	3
Equipment installation	Contamination	0	4	1	4
	Substrate disturbance (crushing)	0	4	1	4
	Substrate disturbance (sediment resuspension)	0	4	1	4
Sampling	*Removal of organisms*	*0*	*3*	*0*	*3*
	Substrate disturbance (crushing)	*0*	*3*	*0*	*3*
	Substrate disturbance (sediment resuspension)	*0*	*3*	*0*	*3*
Scuba diving	*Substrate disturbance (crushing)*	*0*	*3*	*0*	*5*
	Substrate disturbance (sediment resuspension)	*0*	*3*	*0*	*5*
Submersible operations	Aquatic invasive species	3	5	3	3
	Substrate disturbance (crushing)	0	3	1	3
	Substrate disturbance (sediment resuspension)	0	3	1	3
Trap/pot fishing	Substrate disturbance (crushing)	3	5	3	5
	Substrate disturbance (sediment resuspension)	2	5	2	5
	Removal of biological material	2	5	2	5
	Aquatic invasive species	3	5	3	5

Table H.8.3. ***Recovery***$_{C}$ *scores for Corals and associated uncertainty score. Scoring based on Lacharite and Metaxas (2013).*

Recovery factor	Data	Score	Uncertainty
Life Stage(s) affected	Mature stage	1	5
Frequency of natural disturbance	Annually or less often	3	3
Natural mortality rate	N/A	N/A	N/A
Natural recruitment rate	Slow	3	3
Age at Maturity	1 to 10 years	2	4
Distribution range/fragmentation	Patchy distribution	3	3
Connectivity rating	Bowie isolated	3	5

*Table H.8.4. **Recovery$_C$** scores for Sponges and associated uncertainty score. Scoring based on Leys and Lauzon (1998),*

Recovery factor	Data	Score	Uncertainty
Life Stage(s) affected	Mature stages	1	5
Frequency of natural disturbance	Annually or less often	3	3
Natural mortality rate	N/A	N/A	N/A
Natural recruitment rate	Slow	3	3
Age at Maturity	1 to 10 years	2	4
Distribution range/fragmentation	Patchy distribution	3	3
Connectivity rating	Bowie isolated	3	5

APPENDIX I. MEDIAN RISK SCORES AND ASSOCIATED ERROR FOR EACH SEC

I.1. Bocaccio Rockfish: Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	$Risk_{sc}$	10% Q	90% Q	Mean Exposure	Mean Consequence
Seismic testing/ air guns	Sound generation	91.51	67.04	118.76	7.06	13.05
Oil spill	Oil	45.16	29.57	71.1	3.68	13.01
Movement underway	Noise disturbance	44.36	23.67	68.77	8.63	5.23
Submersible operations	Aquatic invasive species	40.56	24.13	58.36	5.93	6.96
Discharge	Debris	30.21	11.25	59.63	6.76	4.96
Discharge	Oils/contaminants	27.35	9.96	55.6	6.22	4.98
Discharge	Aquatic invasive species	25.62	13.54	42.66	3.92	6.89
Discharge	Nutrients	23.66	6.68	51.04	5.38	4.98
Trap/Pot fishing	Aquatic invasive species	22.55	13.19	37.95	3.54	6.89
Trap/Pot fishing	Entrapment/ entanglement	17.40	3.21	35.58	6.67	2.81
Equipment abandonment	Contamination	8.81	3.06	17.46	3.29	2.93
Sampling	Removal of organisms	5.70	3.84	9.33	2.08	2.97

I.2. Rougheye Rockfish: Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	$Risk_{sc}$	10% Q	90% Q	Mean Exposure	Mean Consequence
Seismic testing/ air guns	Sound generation	102.31	77.32	129.22	7.08	14.48
Trap/Pot fishing	Removal of biological material	62.95	33.56	97.26	8.85	7.32
Oil spill	Oil	51.08	33.59	77.77	3.68	14.55
Discharge	Debris	31.59	11.78	65.05	6.65	5.25
Discharge	Oils/contaminants	30.06	10.95	59.09	6.15	5.35
Submersible operations	Aquatic invasive species	29.21	17.12	47.19	3.97	7.83
Discharge	Aquatic invasive species	28.34	14.35	48.44	3.90	7.77
Trap/Pot fishing	Aquatic invasive species	27.24	15.68	45.15	3.85	7.57
Movement underway	Noise disturbance	26.55	4.03	55.48	8.62	3.35
Discharge	Nutrients	26.25	6.32	58.43	5.53	5.45
Trap/Pot fishing	Entanglement/ entrapment	20.74	2.71	42.92	7.00	3.23
Equipment abandonment	Contamination	9.76	3.33	18.62	3.26	3.27
Sampling	Removal of organisms	6.02	4.12	9.81	2.03	3.23

I.3. Widow Rockfish: Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	$Risk_{sc}$	10% Q	90% Q	Exposure Mean	Consequence Mean
Seismic surveys	Sound generation	81.68	60.25	106.78	7.09	11.69
Oil Spill	Oil	40.86	26.51	62.34	3.68	11.68
Discharge	Aquatic invasive species	28.14	15.34	49.54	3.89	7.90
Discharge	Debris	27.47	10.04	53.39	6.72	4.46
Discharge	Oils/contaminants	24.58	8.91	48.99	6.20	4.40
Submersible operations	Aquatic invasive species	23.43	14.12	36.3	3.93	6.23
Discharge	Nutrients	22.16	6.39	46.78	5.43	4.57
Movement underway	Noise disturbance	21.29	3.79	43.78	8.57	2.70
Trap/ pot Fishing	Aquatic invasive species	15.84	6.34	29.55	3.58	4.79
Trap/ pot Fishing	Entrapment/ entanglement	13.44	2.32	28.42	6.15	2.40
Equipment abandonment	Contamination	8.19	2.64	15.3	3.28	2.66
Sampling	Removal of organisms	5.09	3.36	8.15	2.10	2.61

I.4. Yelloweye Rockfish: Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	*Risk$_{sc}$*	10% Q	90% Q	Exposure Mean	Consequence Mean
Seismic testing/ air guns	Sound generation	91.43	68.31	117.11	7.11	12.96
Oil Spill	Oil	45.35	29.54	68.83	3.68	12.95
Movement underway	Noise disturbance	40.00	14.82	70.99	8.60	4.86
Discharge	Debris	29.82	10.57	58.29	6.69	4.87
Discharge	Oils/contaminants	27.88	10.2	55.07	6.23	4.93
Submersible operations	Aquatic invasive species	25.92	15.55	39.65	3.87	6.96
Discharge	Aquatic invasive species	25.22	13.84	42.46	3.92	6.90
Discharge	Nutrients	24.29	6.71	51.12	5.42	5.03
Trap/Pot Fishing	Aquatic invasive species	20.27	11.88	33.24	3.13	6.91
Trap/Pot Fishing	Entrapment/ entanglement	15.80	2.93	32.84	6.17	2.80
Equipment abandonment	Contamination	9.15	2.88	16.87	3.28	2.95
Sampling	Removal of organisms	5.62	3.78	9.03	2.10	2.90

I.5. Sablefish: Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	*Risk$_{sc}$*	10% Q	90% Q	Exposure Mean	Consequence Mean
Seismic testing/ air guns	Sound generation	84.90	63.43	109.02	7.13	12.01
Trap/Pot fishing	Removal of biological material	63.71	40.2	96.8	8.87	7.49
Oil spill	Oil	42.00	26.96	63.99	3.67	11.99
Discharge	Debris	27.40	10.29	54.04	6.71	4.51
Discharge	Oils/contaminants	25.53	9.36	51.48	6.20	4.54
Discharge	Aquatic invasive species	23.12	10.07	44.06	3.91	6.52
Movement underway	Noise disturbance	22.10	3.68	45.13	8.63	2.77
Trap/Pot fishing	Aquatic invasive species	20.79	8.22	37.67	4.41	5.04
Submersible operations	Aquatic invasive species	18.63	7.23	33.64	3.93	5.04
Trap/Pot fishing	Entrapment/ entanglement	15.95	2.65	33.76	6.50	2.70
Discharge	Nutrients	14.82	1.23	35.39	5.45	3.18
Equipment abandonment	Contamination	8.34	2.71	15.75	3.28	2.72
Sampling	Removal of organisms	5.00	3.37	8.04	2.01	2.69

I.6. Pacific Halibut: Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	$Risk_{sc}$	10% Q	90% Q	Exposure Mean	Consequence Mean
Seismic testing/ air guns	Sound generation	97.43	73.3	123.26	7.11	13.78
Oil spill	Oil	48.22	31.21	73.22	3.66	13.80
Discharge	Debris	32.10	11.75	63.11	6.69	5.27
Discharge	Oils/ contaminants	29.04	10.46	58.3	6.21	5.20
Trap/Pot fishing	Entrapment/ entanglement	27.90	7.59	56.07	6.18	4.92
Discharge	Aquatic invasive species	26.66	11.78	50.93	3.91	7.55
Movement underway	Noise disturbance	25.73	4.47	51.91	8.61	3.20
Submersible operations	Aquatic invasive species	21.66	8.54	38.93	3.94	5.83
Trap/Pot fishing	Removal of biological material	21.59	6.9	39.97	7.85	2.91
Trap/Pot fishing	Aquatic invasive species	21.34	8.51	39.12	3.90	5.86
Discharge	Nutrients	17.12	1.41	40.66	5.38	3.68
Equipment abandonment	Contamination	9.64	2.93	17.98	3.27	3.11
Sampling	Removal of organisms	5.57	3.81	8.91	1.93	3.11

I.7. Prowfish: Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	$Risk_{sc}$	10% Q	90% Q	Exposure Mean	Consequence Mean
Seismic surveys	Sound generation	86.05	64.26	109.47	7.12	12.15
Oil spill	Oil	42.88	27.8	65.18	3.70	12.17
Discharge	Debris	27.95	10.29	55.76	6.71	4.61
Discharge	Aquatic invasive species	26.07	14.33	45.96	3.92	7.26
Discharge	Oils/contaminants	25.63	9.33	51.56	6.19	4.59
Discharge	Nutrients	23.30	6.46	49.73	5.52	4.74
Movement underway	Noise disturbance	22.76	3.66	45.89	8.59	2.84
Submersible operations	Aquatic invasive species	22.10	12.85	35.31	3.95	5.91
Trap/pot fishing	Entrapment/ entanglement	12.80	2.29	26.5	5.46	2.55
Trap/pot fishing	Aquatic invasive species	10.23	0.85	23.91	3.57	3.30
Equipment abandonment	Contamination	8.53	2.73	16.05	3.28	2.77
Sampling	Removal of organisms	5.10	3.45	8.2	2.02	2.74

I.8. Squat Lobster: Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	*$Risk_{sc}$*	10% Q	90% Q	Exposure Mean	Consequence Mean
Seismic testing/ air guns	Sound generation	34.43	17.62	56.09	7.11	5.05
Oil spill	Oil	30.20	18.18	47.49	3.69	8.61
Discharge	Debris	21.60	6.13	44.56	6.70	3.56
Discharge	Oils/ contaminants	19.40	6.93	38.49	6.17	3.45
Movement underway	Noise disturbance	17.85	3.21	36.64	8.58	2.26
Trap/Pot fishing	Aquatic invasive species	8.23	0.68	19.6	3.93	2.44
Discharge	Aquatic invasive species	8.08	0.48	19.76	3.91	2.43
Submersible operations	Aquatic invasive species	7.94	0.56	19.63	3.94	2.41
Submersible operations	Light disturbance	5.01	0.31	11.32	2.55	2.20

I.9. Primnoa: Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	*$Risk_{sc}$*	10% Q	90% Q	Mean Exposure	Mean Consequence
Oil Spill	Oil	62.83	44.07	87.87	4.93	13.13
Discharge	Aquatic invasive species	56.96	35.81	87.83	4.69	12.77
Submersible operations	Aquatic invasive species	46.42	28.76	75.96	3.92	12.73
Discharge	Oils/contaminants	30.64	8.51	64.39	6.71	5.10
Discharge	Debris	28.91	8.2	59.46	6.23	5.12
Grounding	Substrate disturbance (crushing)	21.35	14.23	31.34	2.50	8.85
Grounding	Substrate disturbance (sediment resuspension)	21.33	14.14	31.35	2.50	8.88
Discharge	Nutrients	11.53	1.77	25.74	4.05	3.23
Submersible operations	Substrate disturbance (sediment resuspension)	11.12	2.08	22.89	3.72	3.24
Submersible operations	Substrate disturbance (crushing)	11.10	1.95	22.59	3.72	3.22
Equipment installation	Substrate disturbance (sediment resuspension)	10.95	1.91	22.66	3.69	3.23
Equipment installation	Contamination	9.85	1.84	19.87	3.28	3.24
Equipment installation	Substrate disturbance (crushing)	9.76	1.8	19.95	3.26	3.22

I.10. *Isidella*: Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	$Risk_{sc}$	10% Q	90% Q	Mean Exposure	Mean Consequence
Trap/Pot fishing	Substrate disturbance (crushing)	105.66	69.88	148.81	8.71	12.38
Trap/Pot fishing	Substrate disturbance (sediment resuspension)	88.43	53.98	132.32	8.48	10.75
Trap/Pot fishing	Removal of biological material	68.46	36.61	108.64	7.72	9.22
Oil Spill	Oil	62.63	43.9	88.73	4.93	13.14
Trap/Pot fishing	Aquatic invasive species	51.69	34.32	79.59	4.45	12.37
Submersible Operations	Aquatic invasive species	47.05	28.98	76.2	3.95	12.76
Discharge	Aquatic invasive species	46.54	28.95	74.08	3.90	12.74
Discharge	Debris	31.49	9.13	64.13	6.76	5.13
Discharge	Oils/contaminants	30.74	8.76	64.88	6.71	5.13
Submersible Operations	Substrate disturbance (sediment resuspension)	11.25	2.1	22.63	3.73	3.24
Submersible Operations	Substrate disturbance (crushing)	11.18	2.03	22.53	3.72	3.22
Discharge	Nutrients	10.07	1.74	22.35	3.52	3.23
Equipment installation	Contamination	9.71	1.65	19.91	3.27	3.21
Equipment installation	Substrate disturbance (sediment resuspension)	9.68	1.65	20.06	3.28	3.20
Equipment installation	Substrate disturbance (crushing)	9.53	1.7	19.62	3.22	3.20

I.11. Corals (Habitat SEC): Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	$Risk_{sc}$	10% Q	90% Q	Exposure Mean	Consequence Mean
Trap/pot fishing	Substrate disturbance (crushing)	76.27	48.51	110.48	6.35	12.27
Oil Spill	Oil	62.36	44.31	84.73	4.88	13.10
Submersible operations	Aquatic invasive species	60.06	39.31	82.33	4.73	12.77
Trap/pot fishing	Removal of biological material	59.71	29.27	97.1	6.71	9.19
Trap/pot fishing	Substrate disturbance (sediment resuspension)	55.33	30.61	92.93	6.48	8.97
Trap/pot fishing	Aquatic invasive	46.09	30.34	72.95	3.99	12.43

Activity	Stressor	$Risk_{sc}$	10% Q	90% Q	Exposure Mean	Consequence Mean
	species					
Discharge	Aquatic invasive species	44.29	28.4	72.86	3.83	12.66
Discharge	Oils/contaminants	31.79	8.64	68.72	6.79	5.18
Discharge	Debris	28.48	8.66	58.39	5.97	5.26
Grounding	Substrate disturbance (crushing)	17.28	7.36	29.04	2.58	6.98
Grounding	Substrate disturbance (sediment resuspension)	15.18	7.15	26.63	2.28	7.08
Equipment abandonment	Contamination	12.89	2.61	26.8	4.37	3.25
Discharge	Nutrients	11.02	1.55	24.56	3.98	3.16
Submersible operations	Substrate disturbance (sediment resuspension)	10.50	3.16	19.24	3.72	2.97
Submersible operations	Substrate disturbance (crushing)	10.36	2.81	18.89	3.73	2.92
Equipment installation	Substrate disturbance (crushing)	8.92	1.52	18.57	2.98	3.27
Equipment installation	Substrate disturbance (sediment resuspension)	8.85	1.66	20.16	3.07	3.25
Sampling	Substrate disturbance (crushing)	8.59	2.68	15.28	3.00	2.98
Sampling	Substrate disturbance (sediment resuspension)	8.27	2.45	15.51	2.99	2.98
Sampling	Removal of organisms	8.20	2.54	15.55	3.00	2.92

I.12. Sponges (Habitat SEC): Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	$Risk_{sc}$	10% Q	90% Q	Exposure Mean	Consequence Mean
Trap/pot fishing	Substrate disturbance (crushing)	76.32	50.85	108.52	6.28	12.47
Oil Spill	Oil	62.64	44.27	86.3	4.92	13.09
Submersible operations	Aquatic invasive species	58.53	39.74	84.57	4.72	12.82
Trap/pot fishing	Substrate disturbance (sediment resuspension)	56.27	29.93	90.6	6.35	9.18
Trap/pot fishing	Removal of biological material	47.42	23.07	78.33	5.45	9.11
Discharge	Aquatic invasive species	46.52	28.83	73.65	3.91	12.74
Trap/pot fishing	Aquatic invasive species	33.91	18.04	56.44	3.96	9.17
Discharge	Oils/contaminants	29.75	6.93	63.34	6.70	4.95
Discharge	Debris	28.88	7.26	64.38	6.08	5.30
Grounding	Substrate disturbance (crushing)	17.23	8.09	27.95	2.57	7.02
Grounding	Substrate disturbance (sediment resuspension)	15.70	7.2	27.65	2.34	7.04
Equipment installation	Substrate disturbance (sediment resuspension)	14.03	5.51	26.94	3.04	4.99
Equipment	Substrate disturbance	13.99	5.32	26.83	2.98	5.04

Activity	Stressor	$Risk_{sc}$	10% Q	90% Q	Exposure Mean	Consequence Mean
installation	(crushing)					
Equipment installation	Contamination	12.92	2.09	26.97	4.32	3.26
Discharge	Nutrients	11.42	1.95	25.91	4.05	3.28
Submersible operations	Substrate disturbance (sediment resuspension)	10.76	3.38	19.85	3.75	3.02
Submersible operations	Substrate disturbance (crushing)	10.70	3.29	19.39	3.72	3.02
Sampling	Removal of organisms	8.63	2.75	15.57	3.00	3.03
Sampling	Substrate disturbance (sediment resuspension)	8.44	2.62	16.19	2.96	3.06
Sampling	Substrate disturbance (crushing)	8.35	2.7	16.22	2.99	3.04

I.13. Crustose Coralline Algae (Habitat SEC): Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	$Risk_{sc}$	10% Q	90% Q	Exposure Mean	Consequence Mean
Oil Spill	Oil	65.95	48.95	85.48	7.40	9.01
Grounding	Substrate disturbance (sediment resuspension)	28.22	18.95	41.28	4.73	6.21
Grounding	Substrate disturbance (crushing)	27.93	19.12	40.83	4.72	6.19
Discharge	Aquatic invasive species	27.58	16.22	46.16	3.90	7.64
Submersible operations	Aquatic invasive species	27.41	16.09	45.79	3.86	7.65
Discharge	Nutrients	24.44	12.01	43.61	5.40	4.91
Discharge	Oils/contaminants	21.05	5.89	44.17	6.74	3.52
Discharge	Debris	19.54	5.44	40.63	6.21	3.50
Sampling	Substrate disturbance (crushing)	9.47	4.44	15.94	2.99	3.31
Sampling	Substrate disturbance (sediment resuspension)	9.42	4.47	15.94	2.99	3.32
Submersible operations	Substrate disturbance (crushing)	7.10	2.2	13.3	3.71	2.03
Submersible operations	Substrate disturbance (sediment resuspension)	7.10	2.17	13.45	3.72	2.03
Equipment abandonment	Contamination	6.63	1.16	13.77	3.29	2.21
Sampling	Removal of organisms	6.60	3.16	11	2.09	3.30
Equipment installation	Substrate disturbance (sediment resuspension)	5.99	1.06	12.86	3.00	2.22
Equipment installation	Substrate disturbance (crushing)	5.86	1.08	12.27	2.88	2.21
Scuba diving	*Substrate disturbance (crushing)*	*3.47*	*0.25*	*7.76*	*1.79*	*2.15*
Scuba diving	*Substrate disturbance (sediment resuspension)*	*3.42*	*0.22*	*7.72*	*1.79*	*2.14*

I.14. Macroalgae (Habitat SEC): Median Risk Score results and associated 10% and 90% quantiles, ranked by risk score plus mean exposure and consequence scores

Activity	Stressor	$Risk_{sc}$	10% Q	90% Q	Exposure Mean	Consequence Mean
Oil Spill	Oil	71.69	52.69	93.77	7.42	9.77
Grounding	Substrate disturbance (sediment resuspension)	29.95	19.64	44.18	4.73	6.59
Discharge	Aquatic invasive species	29.70	17.51	50.46	3.89	8.30
Submersible operations	Aquatic invasive species	29.01	16.16	49.09	3.89	8.02
Discharge	Nutrients	26.62	13	48.08	5.43	5.33
Discharge	Oils/contaminants	22.87	6.22	47.33	6.73	3.77
Discharge	Debris	20.97	5.91	44.39	6.20	3.80
Grounding	Substrate disturbance (crushing)	16.11	10.83	23.77	2.50	6.73
Submersible operations	Substrate disturbance (sediment resuspension)	7.49	2.34	14.02	3.57	2.23
Submersible operations	Substrate disturbance (crushing)	7.41	2.35	13.89	3.57	2.21
Equipment abandonment	Contamination	7.33	1.38	15.13	3.29	2.42
Equipment installation	Substrate disturbance (crushing)	6.50	1.22	13.79	2.99	2.40
Sampling	Removal of organisms	4.39	1.35	8.16	2.10	2.22

APPENDIX J. CUMULATIVE CATCH OF ALL SPECIES IN SABLEFISH TRAP FISHERY AT BOWIE SEAMOUNT FROM 2006-2012.SOURCE: DFO SEAMOUNT DATABASE

Species name	Landed catch (kg)	Released catch (kg)	Released counts
Aurora Rockfish	33.6	-	-
Basket Stars	-	0.5	-
Bearded Rattail	-	-	3
Black Corals, Thorny Corals	-	0.5	
Blacktail Snailfish	-	1.4	
Cephalopods	-	0.9	
Deepsea Sole	-	1.4	
Dover Sole	10.2	0.5	25
Eels	-	-	1
Giant Grenadier	-	894.4	-
Giant Pacific Octopus	-	4.5	-
Golden king crab	-	32.2	-
Gorgonian Corals	-	6.3	-
Longspine thornyhead	-	0.5	6
Octupus	-	-	55
Pacific Cod	-	-	9
Pacific flatnose	-	21.8	-
Pacific grenadier	-	1282.8	-
Pacific Halibut	-	-	11
Pacific Sleeper Shark	-	36.3	-
Pacific Viperfish	-	0.9	-
Ragfishes	-	2.7	-
Red King Crab	-	50.4	-
Redbanded Rockfish	11.4	-	278
Rosethorn Rockfish	2.8	-	1
Rougheye Rockfish	21128.4	273	13157
Sea Lilies and Feather Stars	-	1.8	-
Sablefish	377646.9	2009	-
Shortraker Rockfish	284.4	-	10
Shortspine Thornyhead	718.2	10.4	45
Smalldisk Snailfish	-	2.3	-
Snailfishes	-	-	-
Snipe eels	-	1	-
Spiny dogfishes	-	-	4
Sponges	-	2.3	-
Spotted ratfish	-	-	361
Starfish	-	2.3	-
Tanner crabs	-	1876.6	3035
True crabs	-	3.6	-
Twoline eelpout	-	0.5	-
Viperfishes	-	0.5	-
Total (kg) of all species but sablefish	*22189.0*	*4512.3*	-

APPENDIX K. APPENDIX REFERENCES

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