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Risk assessment of permitted human activities in Rockfish Conservation Areas in British Columbia

Thornborough[1], K.J., Lancaster[2], D., Dunham[3], J.S., Yu[3], F., Ladell[3], N., Deleys[4], N., Yamanaka[4], L.

[1]Independent Researcher
2/51 Ashburner Street
Manly, NSW,
Australia, 2095

[2]Fisheries and Oceans Canada
Regional Headquarters
East White Hills Road
P.O. Box 5667
St John’s, NL, A1C 5X1

[3]Fisheries and Oceans Canada
Regional Headquarters
401 Burrard St #200
Vancouver, BC, V6C 3S4

[4]Fisheries and Oceans Canada
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

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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.

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ABSTRACT

The Government of Canada has committed to reaching domestic marine conservation targets (MCTs) of protecting 10% of Canada's marine and coastal areas by 2020. One area of action that supports reaching Canada's MCTs is the identification and advancement of "other effective area based conservation measures" (OEABCM). To determine whether Rockfish Conservation Areas (RCAs) in Canada's Pacific marine waters contribute to the MCTs as OEABCMs, RCAs were evaluated against the five criteria for inclusion as OEABCMs. In 2016, an internal evaluation of RCAs by DFO determined that a more fulsome review was required, including a risk assessment to assess whether permitted human activities inhibit RCAs from meeting criterion 5. To this end, a literature review of RCA documents provides evidence that RCAs align with OEABCM criteria 1 through 3, while greater clarity that RCAs will be in place for a long-term duration is required to meet criterion 4. A Level 1 qualitative risk assessment was conducted to assess RCAs against OEABCM criterion 5. The assessment was conducted on three significant ecosystem components: Inshore Rockfish, their Prey and Rocky Reef habitat, and the impact of twenty-one currently permitted activities. Eight activities were identified as having the potential to prevent RCAs from fulfilling the OEABCM criteria: outfalls, Crab by Trap, coastal infrastructure, oil spill, Prawn and Shrimp by Trap, FSC dual fishing groundfish hook and line, movement and storage of logs, and finfish aquaculture. Future assessments at the scale of individual RCAs will provide clarity regarding the impacts of stressors in each RCA. Recommendations include: developing clear long-term conservation and/or stock management objectives; collecting empirical observations of habitat in RCAs; improving research and monitoring efforts to reduce uncertainties about activities with highest relative risks; and improving fishery monitoring and catch reporting of sectors fishing inside RCAs.

INTRODUCTION

In 2010, the Government of Canada committed to conserving at least ten percent of Canada's coastal and marine areas through protected areas and other effective area-based conservation measures by 2020 (United Nations Convention on Biological Diversity Aichi Target 11). In 2016, the Minister of Fisheries and Oceans Canada (DFO) announced a plan to reach our domestic marine conservation targets (MCTs) of protecting five percent of Canada's marine and coastal areas by 2017 and ten percent by 2020. As of December 2017, Canada exceeded the interim target set for 2017, bringing the total ocean territory under protection to 7.75 percent. There are five areas of action that support reaching Canada's MCTs, one of which is the advancement of "other effective area based conservation measures" (OEABCM) by identifying existing OEABCMs and by establishing new ones.

Operational Guidance for Identifying 'Other Effective Area-Based Conservation Measures' in Canada's Marine Environment (DFO 2016A) has been developed to ensure that a "consistent and science-based approach to identifying and reporting on marine OEABCMs that contribute to Canada's international and domestic marine conservation targets" is used. The guidance has been informed by international direction[1] (International Union for Conservation of Nature and Convention on Biological Diversity; GOC 2014), domestic discussions, and Fisheries and Oceans Canada (DFO) science advice (DFO 2016B). It identifies five criteria that area-based management measures must meet in order to be considered for designation as OEABCMs:

1. Clearly defined geographic location
2. Conservation or stock management objectives
3. Presence of ecological components of interest
4. Long-term duration of implementation
5. The ecological components of interest are effectively conserved

Area-based management measures (ABMMs) are spatially-defined management measures in coastal or marine waters implemented to achieve one or more objectives (i.e. conservation, socio-economic, or cultural). An ABMM cannot be considered an OEABCM in the context of domestic and international biodiversity targets unless it is demonstrated or inferred that it is providing one or more biodiversity conservation benefits (DFO 2016B).

Rockfish Conservation Areas (RCAs) are ABMMs implemented by DFO in the Pacific Region. RCAs were established between 2003 and 2007 as a spatial management tool to protect a portion of the Inshore Rockfish population from fishing activity to safesguard against management failures and promote the rebuilding of stocks. At the time of writing, there are 164 RCAs[2] coast-wide, totalling approximately 4,800 km^2. In 2016, an internal evaluation of RCAs

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[1] In November 2018, international voluntary guidance on other effective area based conservation measures was adopted at the Convention on Biological Diversity (CBD) Conference of the Parties. At the time of writing, Fisheries and Oceans Canada was still in the process of reviewing the new CBD guidance. This paper assesses RCAs against DFO's existing Operational Guidance on OEABCMs. The information contained in this paper can support an assessment of RCAs against any updates to the Operational Guidance.

[2] On May 1, 2019, South Moresby and Lyell Island Rockfish Conservation Areas were replaced by new zones for the Gwaii Haanas Gina 'Waadlux̱an KilG̱uhlG̱a Land-Sea-People Management Plan. There are now 162 RCAs totalling approximately 4,350 km^2.

was conducted by DFO to assess RCAs against the OEABCM criteria. DFO Fisheries Management requested a more fulsome review, including a formal risk assessment to assess whether permitted human activities inhibit RCAs from meeting criterion 5.

The objectives of the current paper are to:

1. Identify current RCA management measures (i.e. permitted human activities) that may inhibit RCAs from fulfilling their conservation objectives by not meeting particular OEABCM criteria:
    a. Identify if and how RCAs meet OEABCM criteria 1 through 4.
    b. Conduct a risk assessment of activities permitted in RCAs in relation to OEABCM criteria 5.
2. Identify knowledge and data gaps, and uncertainties in the method that may contribute to inconclusive results.

The outline for this paper is as follows: Section 1 provides an overview of Inshore Rockfish, prey, habitat, and the history of RCAs; Section 2 discusses OEABCM criteria 1 through 4; Section 4 discusses elements of adaptive management of enforcement, compliance and ecological monitoring that are necessary to ensure effective conservation in OEABCMs over time; Section 5 discusses an ecological risk assessment of permitted fishing and other human activities to evaluate RCAs against OEABCM criterion 5; Section 5 presents an analysis focused on answering whether all 164 RCAs, as an aggregate, meet the OEABCM criteria, and Section 6 provides recommendations.

1 ROCKFISH CONSERVATION AREAS

1.1 INSHORE ROCKFISHES

At least 36 species of rockfishes (genus Sebastes) live along the coast of British Columbia (BC). Some species are bottom-dwelling while others are more pelagic (Love et al. 2002). They all possess life history characteristics that make them vulnerable to overfishing. Rockfish are long-lived, slow to mature, large sized, and some have high site fidelity (Leaman 1991). Rockfish also have a closed swim bladder and often suffer fatal barotrauma injuries when pulled to the surface by fishing hooks or nets (Parker et al. 2006). For management purposes, rockfish species are grouped into three categories according to habitat preference: slope, shelf, and inshore. Slope rockfish generally occupy the deepest habitats (100-2,000 m) near the continental shelf slope and include on-bottom, near-bottom, or off-bottom schooling species. Shelf rockfish occupy mid-water ranges (0-600 m) typically near the edge of the continental shelf and are schooling and near-bottom dwellers.

In Canada’s Pacific waters, Inshore Rockfish species[3] include Yelloweye Rockfish (*Sebastes ruberrimus*), Quillback Rockfish (*Sebastes maliger*), Copper Rockfish (*Sebastes caurinus*), Black Rockfish (*Sebastes melanops*), Tiger Rockfish (*Sebastes nigrocinctus*), China Rockfish (*Sebastes nebulosus*), Deacon Rockfish (*Sebastes diaconus*), and Brown Rockfish (*Sebastes auriculatus*) rockfish. Inshore Rockfish are generally found nearshore in shallower depth ranges (0-200 m) and favour a sedentary lifestyle associated with high-relief rocky habitat (Frid et al. 2018; Love et al. 2002), kelp forests (Love et al. 2002), eelgrass beds (juvenile rockfish; Love et al. 2002), and glass sponge reefs (Dunham et al. 2018). These nearshore, shallow habitats

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[3] DFO Fisheries Management lists of species inshore, slope, and shelf rockfish species

favoured by Inshore Rockfish, along with their life history traits, make this group particularly vulnerable to overfishing.

Inshore Rockfish diets consist of marine invertebrates, fish, and algae. Studies have reported a wide array of prey items in the diets of each species of Inshore Rockfish (Murie 1991). However, multiple factors make it difficult to describe the complete food habits of rockfish, including empty stomachs, rapid digestion, stomach eversion (barotrauma effect), food preferences by different life stages, changes in prey distribution due to spatiotemporal variation in abundance, and the sporadic occurrence of rare prey items (Lea et al. 1999). In hook and line surveys, rockfish stomach contents may be partially or fully regurgitated during ascent to surface, especially at depths greater than 18 metres, and may not be fully recorded (e.g. Steiner 1978). Non-lethal hook-and-line survey methods experience potentially incomplete evacuation of the stomach during lavage (e.g. Turner et al. 2017). Spearfishing dive survey methods can minimize the risk of stomach content losses but are constrained by shallow diving depths (e.g. Murie 1991). A recent pilot study (Favaro and Duff 2015) suggests that underwater camera methods may assist in future research of rockfish feeding behaviour at deeper depths.

Prey size can vary by rockfish species. For example, the small mouths of Deacon Rockfish are adapted for prey ≤ 5 mm (Hobson et al. 1996 as cited in Dick et al. 2018), whereas species such as Copper, Quillback, and Yelloweye Rockfish are capable of consuming larger prey. Murie (1991) reports the average[4] (mean) prey species size and mass consumed by Copper and Quillback Rockfish: fish species averaged 64.0 mm (±34.2 mm) and 8.62 g (±16.14 g); demersal crustaceans averaged 23.1 mm (±18.1 mm) and 1.68 g (±1.67 g); pelagic crustaceans averaged 8.6 mm (±3.8 mm) and 0.014 g (±0.007 g); and other prey were within the ranges of fish and crustacean prey (numbers in parentheses are within one standard deviation). The NOAA Fisheries' Alaska Fisheries Science Center (AFSC 2011) maintains a North Pacific groundfish diet time series through the Resource Ecology and Ecosystem Modeling Program. Limited information on Yelloweye rockfish stomach contents was available from assessment surveys in 2007, 2009, and 2011. These surveys retained 24 Yelloweye Rockfish, but prey length[5] measurements are only reported from four specimen stomachs, one prey per specimen: *Bathymaster signatus* (250 mm), *Anoplopoma fimbria* (190 mm), *Sebastes sp.* (86 mm), and *Pandalus platyceros* (47 mm) (AFSC 2011).

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[4] Murie (1991) calculates the mean fish lengths and masses using a combination of vertebral column length, standard length, mass and, for some species, regression estimates. The demersal crustaceans means are calculated using carapace length and flexed body length, carapace mass and, for some species, regression estimates.

[5] AFSC (2011) provides the standard length measurement for each prey fish and carapace length for each prawn.

Table 1: Prey categories of each species of Inshore Rockfish.

Rockfish Species	Generalized Prey Categories	References
Black Rockfish	Annelida, Cephalopoda, Cnidaria, Crustacea**, Ctenophora, Detritus, Fishes*, Mollusca, Phaeophyceae, Tunicata, Other (shell)	Bizzarro et al. 2017; Lea et al. 1999; Rosenthal et al. 1988; Steiner 1978
Brown Rockfish	Cephalopoda, Crustacea*, Fishes**, Polychaeta, Mollusca	Bizzarro et al. 2017
China Rockfish	Cnidaria, Crustacea*, Fishes, Mollusca, Echinodermata**, Rhodophyta, Rhynchocoela, Tunicata	Lea et al. 1999; Rosenthal et al. 1988; Steiner 1978
Copper Rockfish	Annelida, Bryozoa, Cephalopoda, Cnidaria, Crustacea**, Echinodermata, Fishes*, Mollusca, Nematoda, Rhodophyta, Tunicata, Other (shell, unidentified items)	Bizzarro et al. 2017; Murie 1995; Olson 2017; Prince and Gotshall 1976; Lea et al. 1999; Rosenthal et al. 1988; Turner et al. 2017
Deacon Rockfish (combined with Blue Rockfish)	Annelida, Cephalopoda, Chaetognatha, Cnidaria**, Crustacea, Ctenophora, Detritus**, Fishes, Mollusca, Phaeophyceae, Rhodophyta, Tunicata, Other (gelatinous zooplankton)**	Dick et al. 2018; Steiner 1978
Quillback Rockfish	Bryozoa, Cephalopoda, Cnidaria, Crustacea*, Detritus, Echinodermata, Fishes**, Mollusca, Polychaeta, Tunicata, Other (shell)	Murie 1995; Olson et al. (in prep.[6]); Rosenthal et al. 1988
Tiger Rockfish	Annelida, Crustacea**, Detritus**, Echinodermata, Fishes**, Other (gelatinous zooplankton)	Rosenthal et al. 1988
Yelloweye Rockfish	Cephalopoda, Crustacea**, Fishes*	Bizzarro et al. 2017; AFSC 2011; Rosenthal et al. 1988; Steiner 1978

* ≥ 50% of prey by volume or biomass observed in one or more study
** ≥ 10% of prey by volume or biomass observed in one or more study

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[6] Findings from Olson et al. (in prep) were provided to the authors of the present paper by Angeleen Olson and Alejandro Frid. Specimen collection for Olson et al. (in prep) are part of: Frid, A., McGreer, M., Haggarty, D.R., Beaumont, J., and Gregr, E.J. 2016. Rockfish size and age: The crossroads of spatial protection, central place fisheries and indigenous rights, Global Ecology and Conservation, 8: 170-182.

1.2 ESTABLISHMENT OF ROCKFISH CONSERVATION AREAS

Inshore rockfish populations have declined dramatically following the development of a commercial rockfish hook and line fishery in the 1970s (Haggarty 2014; Kronlund 1997; Yamanaka et al. 2012A, 2012B; Yamanaka et al. 2018; Yamanaka and Lacko 2001; Yamanaka and Logan 2010). Conservation concerns are most apparent for frequently harvested species like Quillback and Yelloweye Rockfish, but all Inshore Rockfish species have been affected by directed fisheries and incidental catch.

To address the decline of Inshore Rockfish populations, DFO began developing the Inshore Rockfish Conservation Strategy (RCS) in 1999 (Yamanaka and Lacko 2001). Efforts increased substantially in late 2001 after fishers and non-government organizations (NGOs) lobbied for measures to address marked declines in Inshore Rockfish populations.

The four components of the RCS included:

- Account for all catch;
- Substantially reduce fishing mortality;
- Establish areas closed to all fishing (RCAs);
- Improve stock assessment and monitoring.

With respect to establishing areas closed to fishing, three types of fishing closure areas were applied over the course of implementing the RCS: 18 Rockfish Protection Areas (RPAs) were established in 1999 as closures mainly to the commercial groundfish fisheries, except Sablefish. Thirty-two Interim Areas of Restricted Fishing (IARFs) or /Interim RCAs were established in 2002 and closed to a broader list of commercial and recreational fisheries (four of the IARFs were rescinded in 2003). Ultimately, 164 RCAs were established between 2004 and 2007, which incorporated, modified, or rescinded each of the RPAs and IARFs (Figure 1).

During implementation of the RCAs, the RCS proposed protecting 30% of rockfish habitat in Inside Waters (all waters east of Vancouver Island to the mainland), and 20% of rockfish habitat in Outside Waters (remainder of the coast). Habitat was identified in multiple phases. In 2002, rockfish habitat was identified and mapped by participants during five months of public consultation meetings. In 2003, this habitat information was incorporated into an internal DFO review that mapped data from commercial hook-and-line fishery logbooks, onboard observer programs, recreational creel surveys, and internal expertise. In 2004, a rockfish habitat model was developed by DFO using 100 m × 100 m resolution bathymetry data and rockfish catch data from commercial and recreational fisheries. Proposed RCA locations and boundaries were made available for comment during multiple stages of public consultation between 2003 and 2006 before final adjustments were completed. Boundaries were designed to be enforceable on the water through landmarks (e.g. islands, bays, channels).

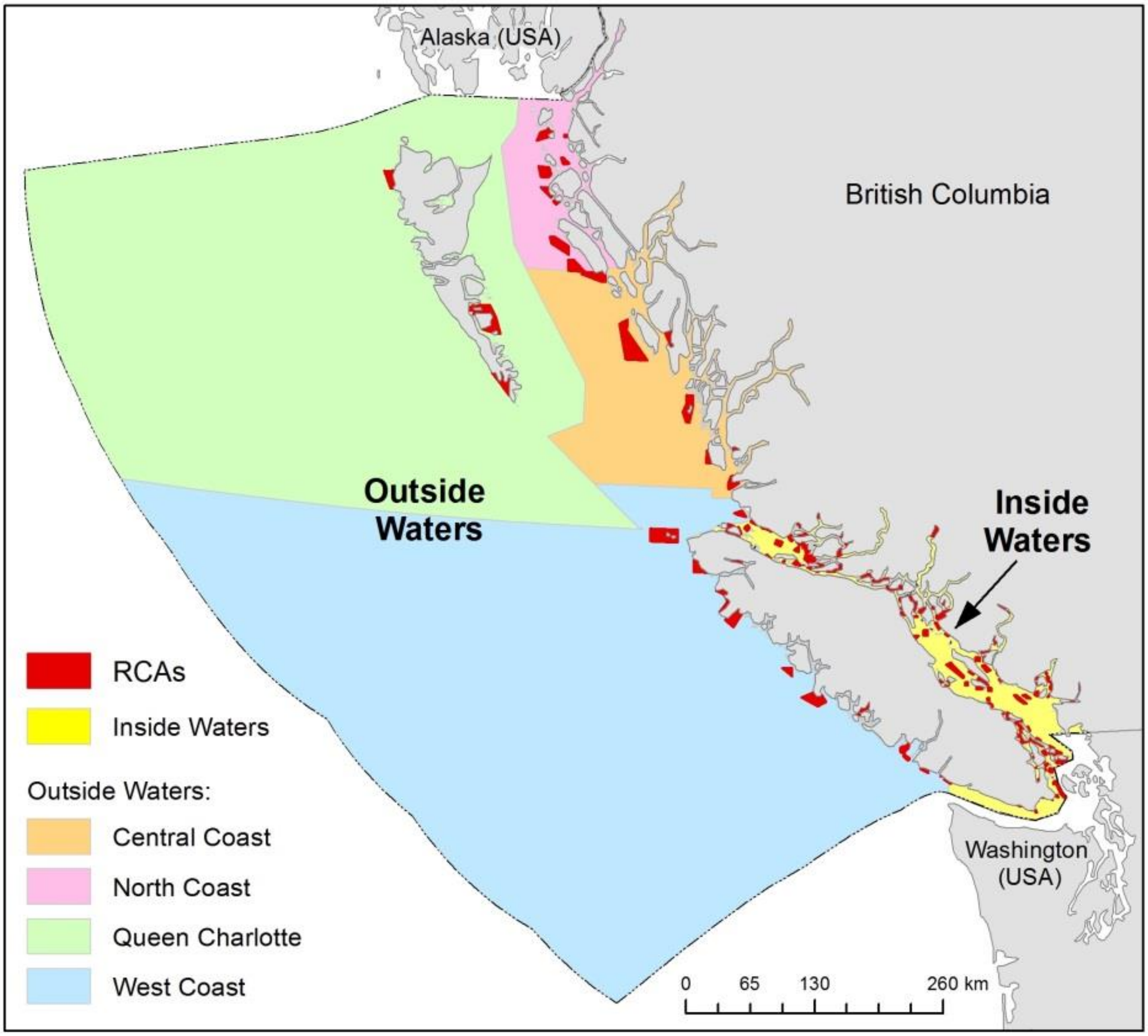

Figure 1: Location of Rockfish Conservation Areas in inside and outside waters. Inside Waters include area shown in yellow; Outside Waters include Central Coast (orange), North Coast (pink), Queen Charlotte (green) and West Coast (blue).

RCAs were implemented under the *Fisheries Act* by a variation order for fisheries management measures. Their legal basis differs from, Marine Protected Areas (MPAs), which are designated under the *Oceans Act* as fully protected, multiple use, or integrated combination of fully protected zones and multiple use areas. RCAs currently protect 4,819 km^2 of the BC coast and, when established, were believed to protect 28% and 15% of rockfish habitat in inside and outside waters, respectively (Yamanaka and Logan 2010). Cognizant that other marine spatial planning initiatives underway (e.g. Gwaii Haanas) would benefit rockfish, some areas of the coast did not achieve the closed habitat area target for RCAs by 2007.

During the development of RCAs, DFO decided that commercial and recreational fisheries assessed as posing a moderate to high risk of rockfish or Lingcod catch (directed and incidental), or affecting their habitat would be prohibited from these areas, including hook-and-line, commercial shrimp and groundfish bottom trawl, commercial Sablefish trap, and recreational spearfishing. Fishing activities that were considered to pose a low risk of causing rockfish mortality were permitted. First Nations' rights to fish for food, social, and ceremonial (FSC) purposes were not excluded. Permitted fishing activities within RCAs are summarized in Table 2.

Table 2: Permitted fishing activities within RCAs.

Commercial fishing	Recreational fishing	First Nations
• Invertebrates by hand picking or dive • Crab by trap • Shrimp/prawn by trap • Scallops by trawl • Salmon by seine or gillnet • Herring by gillnet, seine, and spawn-on-kelp • Sardine by gillnet, seine, and trap (fishery closed since 2015 - may reopen) • Smelt by gillnet (fishery closed since 2012 - may reopen) • Euphausiid (krill) by mid-water trawl • Groundfish by mid-water trawl	• Invertebrates by hand picking or dive • Crab by trap • Shrimp/prawn by trap • Smelt by gillnet	• Food, social, ceremonial fishing

2 RCAS AND OEABCM CRITERIA 1 TO 4

The first part of objective one of this work is to identify if and how RCAs meet OEABCM criteria 1 through 4 (see section 1). The 2016 internal evaluation conducted by DFO Fisheries Management suggested that these criteria are currently being met by RCAs (Fisheries and Oceans Canada, Fisheries Management, Pacific Region, unpublished data, 2017). This section investigates these questions further. We consider the science advice (DFO 2016B) related to criteria 1 through 4, and present details from a literature review of RCA materials that are relevant to determining whether OEABCM criteria 1 through 4 are being met by RCAs.

2.1 CRITERION 1: CLEARLY DEFINED GEOGRAPHIC LOCATION

DFO science advice states that the geographic location of an ABMM must be spatially well-defined, as conservation benefits are more challenging to deliver if an ABMM is mobile (DFO 2016B). The high degree of site fidelity of Inshore Rockfish also favours non-mobile spatially defined protection measures (Hannah and Rankin 2011).

To assess whether RCAs have clearly defined geographic locations, we reviewed information published by DFO in fishery notices[7], RCA booklets[8], and on the DFO website[9]. A 2007 fishery notice (number FN0047) confirmed the legal descriptions and maps were published on the DFO website and in the RCA booklet. We found both the DFO website and RCA booklets provided charts and coordinates (latitude and longitude) for each RCA, including described landmarks where possible. We also observed that the location information became available in 2018 through a third-party navigation software company, Navionics.

2.2 CRITERION 2: CONSERVATION OR STOCK MANAGEMENT OBJECTIVES

The second criterion requires the measure to have a conservation or stock management objective and directly reference at least one of the ecological components of interest in its conservation or stock management objective (DFO 2016A). The science advice states, “It is expected that the likelihood of an ABMM providing net biodiversity conservation benefits increases where the conservation of biodiversity is its primary objective and further increases where objectives address multiple elements of biodiversity (e.g. genetic diversity, groups of species, habitats, etc.)” (DFO 2016B, p.6).

To assess whether there are conservation or stock management objectives for RCAs we reviewed materials from their implementation (see Appendix A). RCAs were established by DFO in response to the dramatic decline of Inshore Rockfish following the development of a commercial rockfish hook and line fishery in the 1970s (see section 2.2). The primary goal for RCAs is the long-term protection and conservation of a portion of Inshore Rockfish populations (and Lingcod) and their habitat from the effects of fishing (Fisheries and Oceans 2007). Conservation objectives were described in a 2002 discussion paper used for consultation at that time (DFO 2002B). Unfortunately, a unifying document (e.g. management plan) that outlines specific details of the objectives for RCAs was never developed.

2.3 CRITERION 3: PRESENCE OF ECOLOGICAL COMPONENTS OF INTEREST

In order for a measure to meet this criterion, it must contain at least two ecological components of interest: a habitat that is important to biodiversity conservation and a species of regional importance that uses the habitat (Fisheries and Oceans 2016A). DFO science advice states “The likelihood that an ABMM will provide biodiversity conservation benefits increases if it encompasses habitat or oceanographic features that are known to support important life history events and/or biological processes (e.g. feeding and spawning areas) of single or multiple species” (Fisheries and Oceans 2016B; p.6). Further, a minimum size for an ABMM may be determined by the life history or habitat requirements of the ecological component of interest (Fisheries and Oceans 2016B). Finally, the presence of multiple habitat types and/or structure-forming species infers a higher likelihood of providing biodiversity conservation benefits, but a single habitat type can still produce important biodiversity conservation benefits if habitat types are of particular interest to the conservation of biodiversity (e.g. inherently rare, unique, highly threatened, or a biodiversity “hotspot”) (Fisheries and Oceans 2016B).

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[7] Fishery notices are accessible online

[8] Two editions of the RCA coordinates and map booklet have been published, first in 2006 and second in 2013. Second edition: Fisheries and Oceans Canada. 2013. Rockfish Conservation Areas: Protecting British Columbia’s Rockfish. Pacific Region.

[9] Maps and coordinates for each RCA can be accessed online

Inshore Rockfish and their habitat are the main ecological components of interest within RCAs. The secondary goal of protecting and conserving Lingcod and their habitat is not assessed within this report. However, it is recognized that there is a large degree of overlap between Inshore Rockfish and Lingcod habitat. In RCAs, there are four main types of Inshore Rockfish habitat based on usage at various life history stages and for biological processes (e.g. feeding and spawning). These habitats are rocky reefs, kelp forests, glass sponge reefs[10], and eelgrass beds (see section 4.3.1).

Yamanaka and Logan (2010) explain what information DFO used to identify the locations of Inshore Rockfish and their habitat and how habitat coverage was measured when RCAs were being established. To identify areas with Inshore Rockfish and/or their habitat, public and industry input[11], expert opinions from DFO staff, and georeferenced rockfish catch data records[12] were used between 2002-2003. The first 89 RCAs were selected based on this information. Subsequently, a rockfish habitat model was developed as a surrogate for coastwide rockfish habitat by merging data from commercial and recreational rockfish catch records and bathymetry data. This habitat information provided a means to measure the proportion of habitat within RCAs and to support the development of the final 75 RCAs. According to this model, RCAs contain 897.41 km^2 (28%) of rockfish habitat area out 3,156.18 km^2 on the inside waters and 1,662.94 km^2 (15%) of out 10,928.39 km^2 on the outside waters.

A companion research document and Science Response to this risk assessment examines ecological attributes of RCAs using higher resolution habitat models (Dunham et al. 2019), but not catch data. We provide a brief summary here. Literature review and consultation with subject matter experts identified four Inshore Rockfish habitats: rocky reefs, eelgrass beds, kelp beds, and glass sponge reefs. Spatial analysis of these habitats and the proportion of RCA area they cover found that 26% of the total RCA area is covered by these habitats (Figure 3 and 4). As Table 3 shows, rocky reefs are the primary habitat type in RCAs with significantly more spatial coverage in RCAs as compared to other habitat types (sponge reefs [Figure 5]); kelp [Figure 6]; eelgrass [Figure 7]). Rocky reefs are found in all 164 RCAs and 23.58% of total RCA area contains this habitat (Table 3); kelp forests are found in 83 RCAs and cover 3.48% of total RCA area; eelgrass beds are found in 37 RCAs and cover 0.47% of total RCA area; and, sponge reefs are found in 15 RCAs and cover 0.16% of total RCA area (Table 3).

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[10] Along BC's coast, the majority of the largest, and dozens of smaller, glass sponge reefs have been mapped and protected in Hecate Strait/Queen Charlotte Sound Glass Sponge Reefs MPA and Strait of Georgia and Howe Sounds Glass Sponge Reef Conservation Areas (Fisheries and Oceans 2018B). These areas already contribute to the marine conservation targets as either MPAs or OEABCMs, some of which partially or fully overlaps with RCAs.

[11] Yamanaka and Logan (2010) states, during a five month public consultation period in 2002, "Participants were asked to draw areas on the charts where (1) quillback rockfish and yelloweye rockfish were present; (2) spawning, nursery, or feeding grounds were present; and (3) historically productive but presently depleted fishing areas were located" (p.38).

[12] Includes catch data between 1995 and 2002 from commercial hook-and-line fishery logbooks, onboard observer programs, and recreational creel surveys (Yamanaka and Logan 2010).

Table 3: Habitat types found in RCAs and the area and proportion of each type in RCAs.

	Eelgrass	Kelp	Sponge Reefs	Rocky Reefs[1]	Total[2]
RCA Count	37	83	15	164	164
Area (km^2) of Habitat Type in All RCAs	22.67	167.93	7.91	1136.19	1253.90
Proportion (%) of Total RCA Area Containing Habitat Type	0.47	3.48	0.16	23.58	26.02
Habitat Area (km^2) by Bioregion/Management Area[3] (Number of overlapping RCAs shown in brackets):					
Strait of Georgia Bioregion (84 RCAs)[4]	6.47	16.47	1.78	124.70	142.55
Northern Shelf Bioregion (61 RCAs)	11.96	117.68	6.13	878.63	957.89
Southern Shelf Bioregion (19 RCAs)	4.25	33.78	0.00	132.85	153.46
Inside Management Area (128 RCAs)	6.65	44.63	1.85	248.57	283.91
Outside Management Area (36 RCAs)[5]	16.02	123.30	6.06	887.62	969.99

[1] Based on 20 m^2 and 5 m^2 rocky reef habitat models.

[2] Areas overlapping between habitat types were removed.

[3] Bioregions and Management Areas (also referred to as Inside/Outside Waters) are not mutually exclusive areas. The Inside Management Area includes Pacific Fishery Management Areas (PFMAs; Figure 2) 12 (except Subarea 12-14) to 20, 28, and 29. The Outside Management Area includes PFMAs 1-11, 21-27, 101-111, 121-127, 130, 142 and Sub-areas 12-14.

[4] Walken Island to Hemming Bay RCA is included in the Strait of Georgia Bioregion.

[5] Carmanah RCA is included in the Outside Management Area.

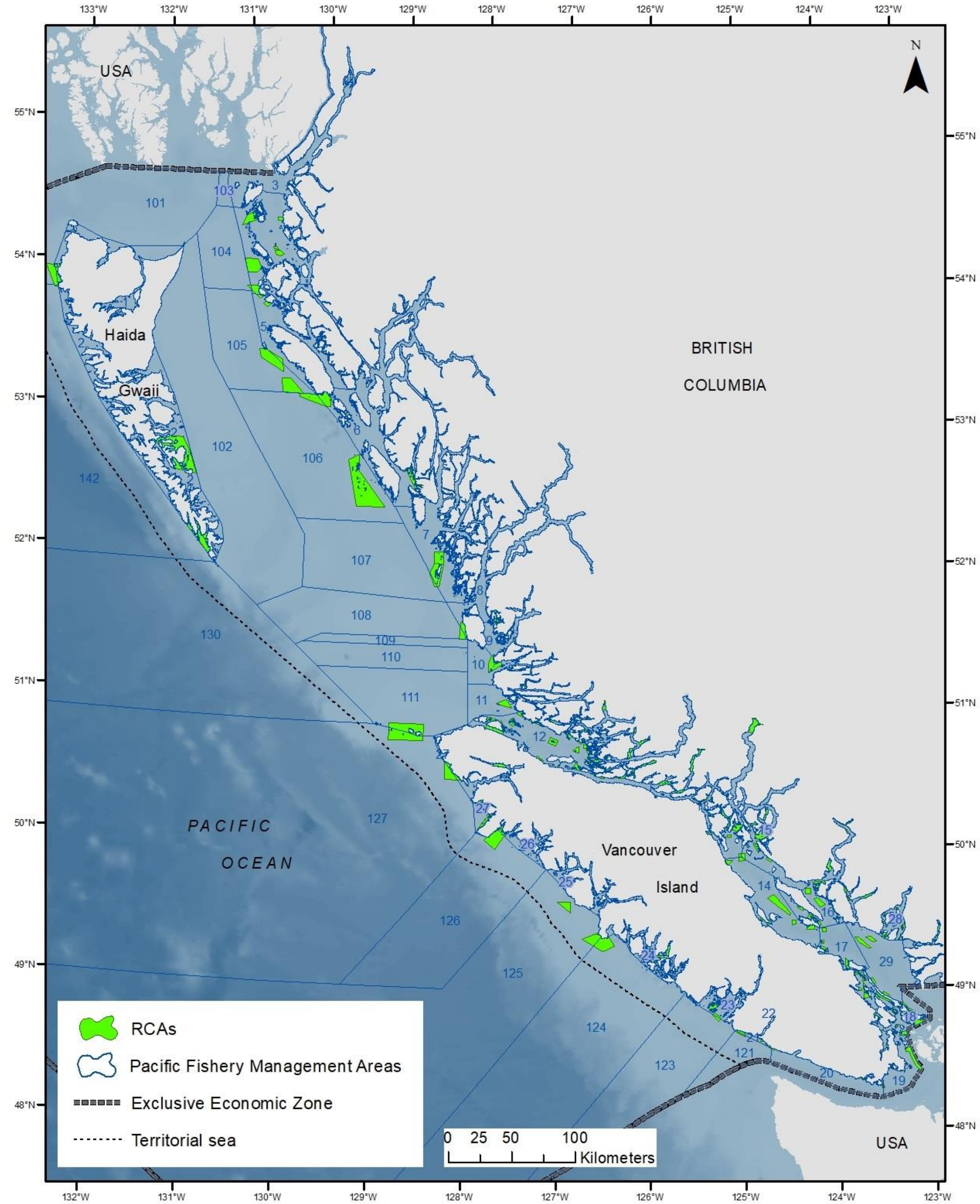


Figure 2: Pacific Fishery Management Areas.

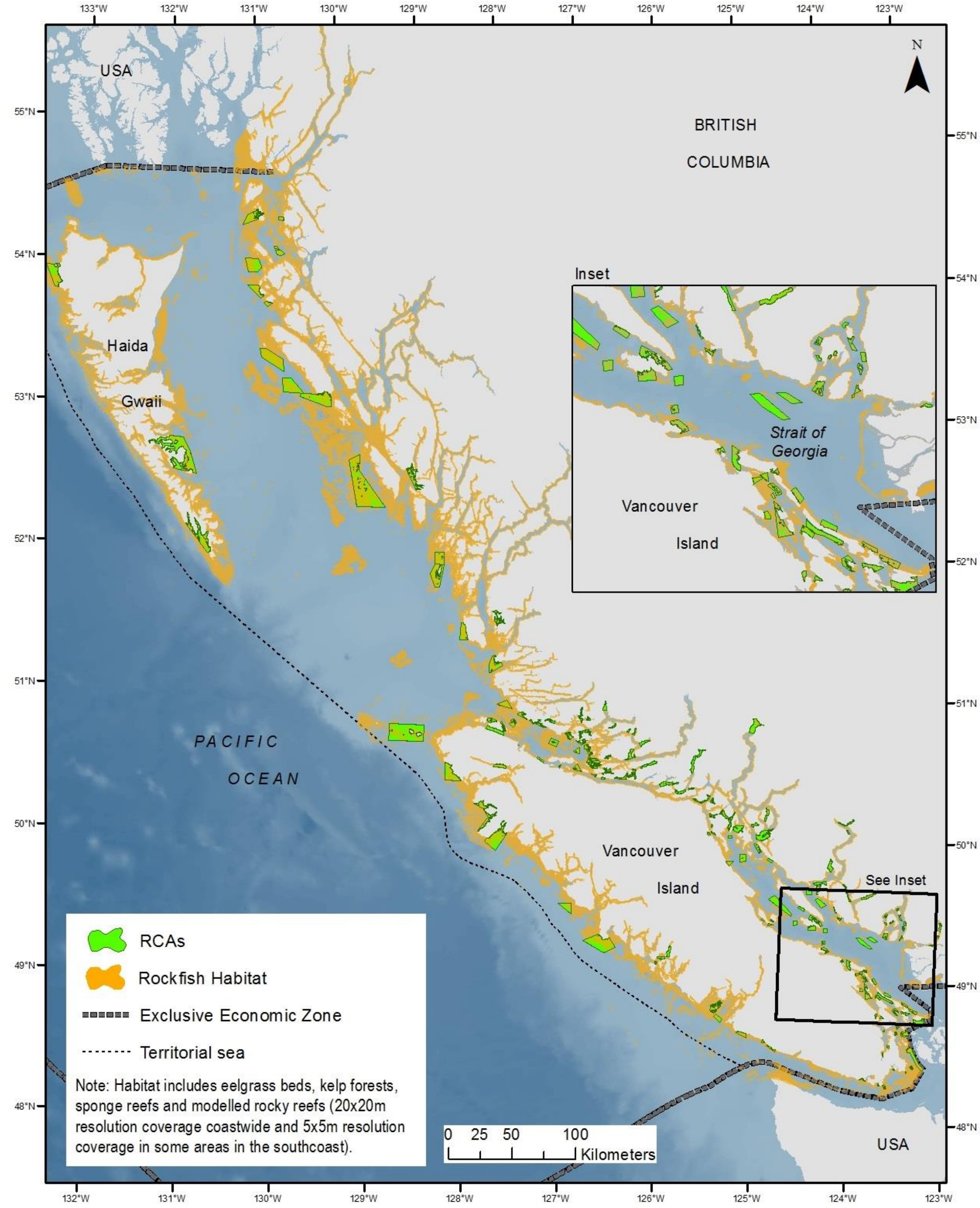


Figure 3: RCAs and rockfish habitat (includes rocky reefs, eelgrass beds, kelp forests and sponge reefs).

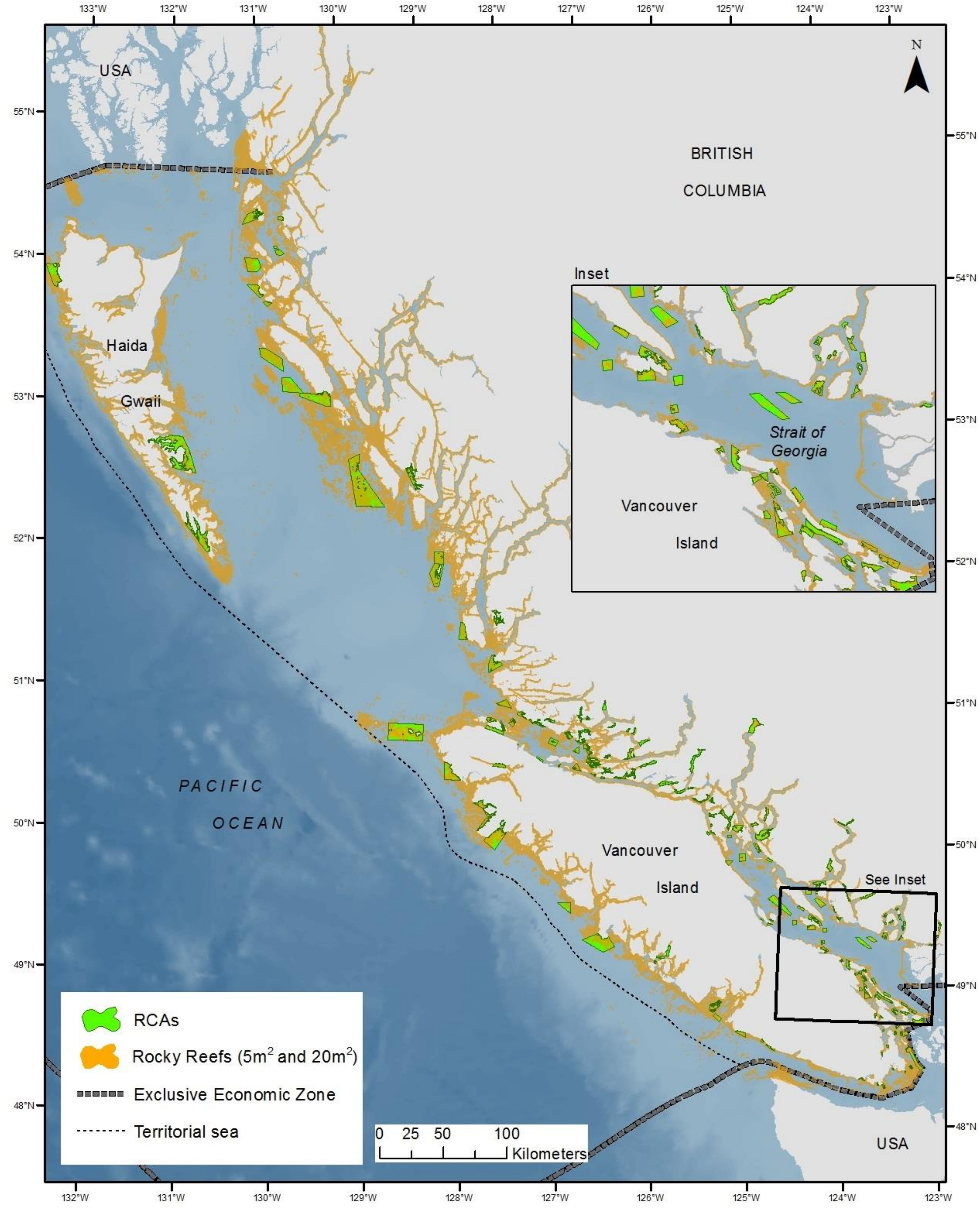


Figure 4: RCAs and modelled rocky reef habitat.

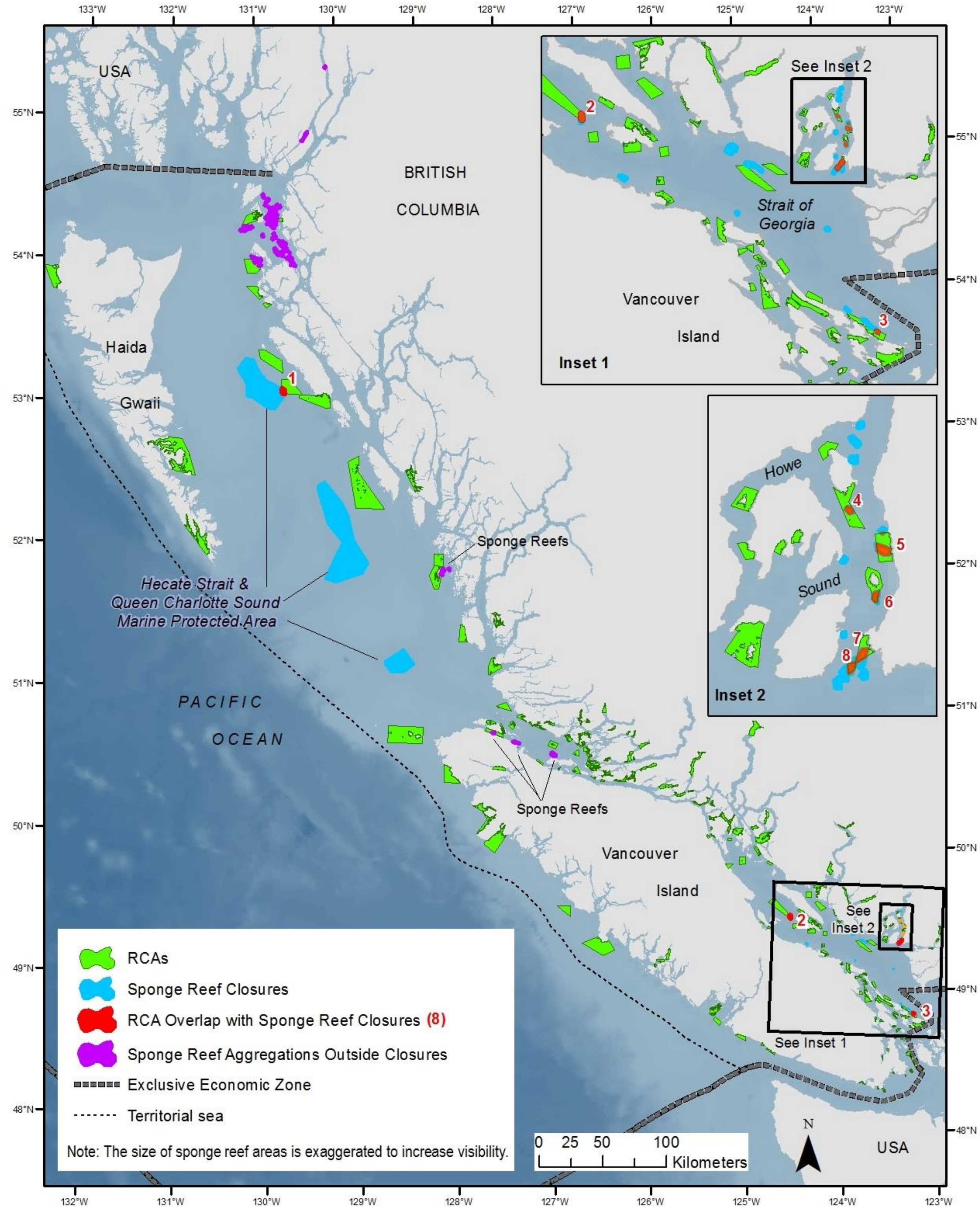
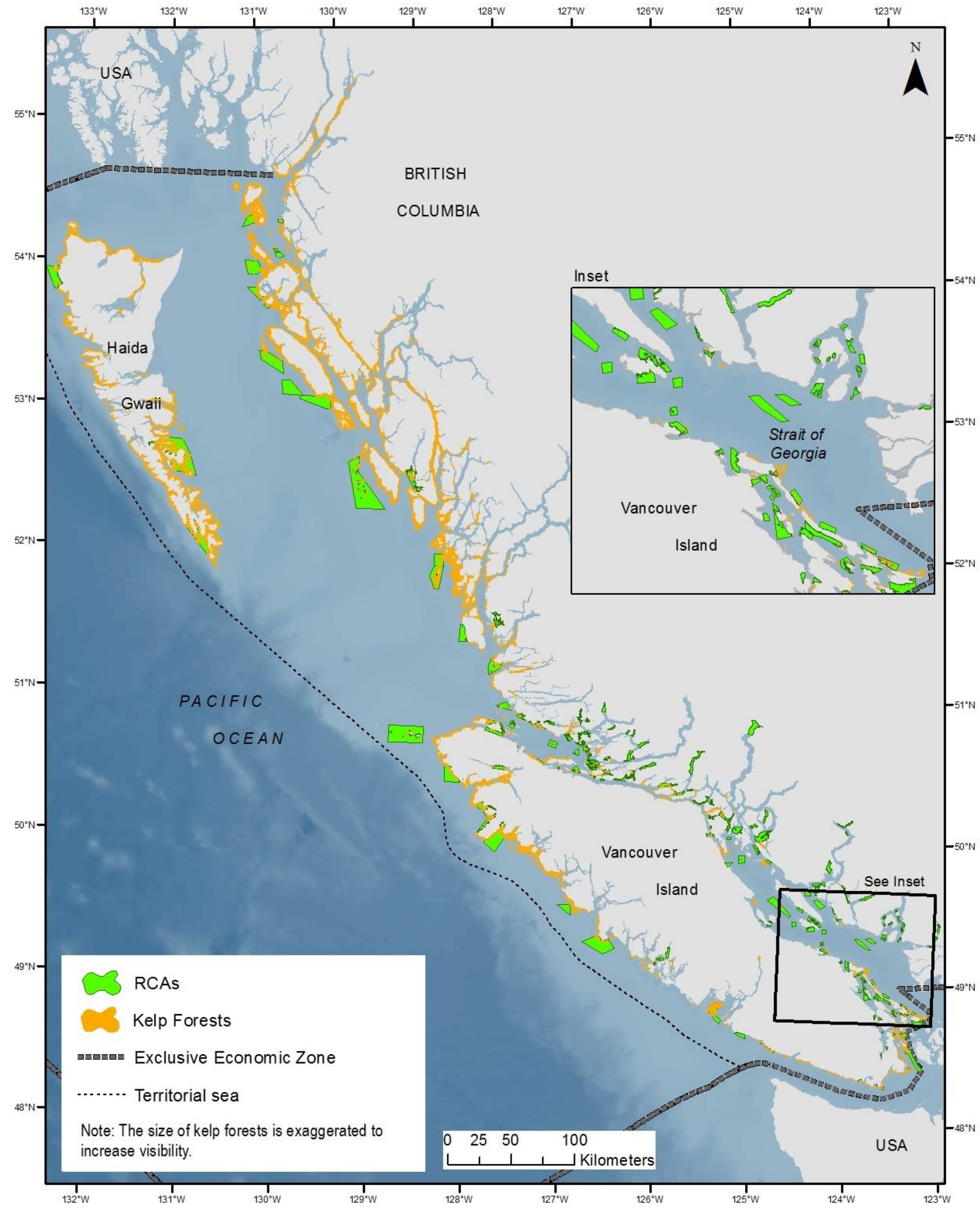


Figure 5: RCA overlap with glass sponge reef closures and unprotected sponge reef aggregations.



Note: The size of kelp forests is exaggerated to increase visibility.

Figure 6: RCAs and kelp forests.

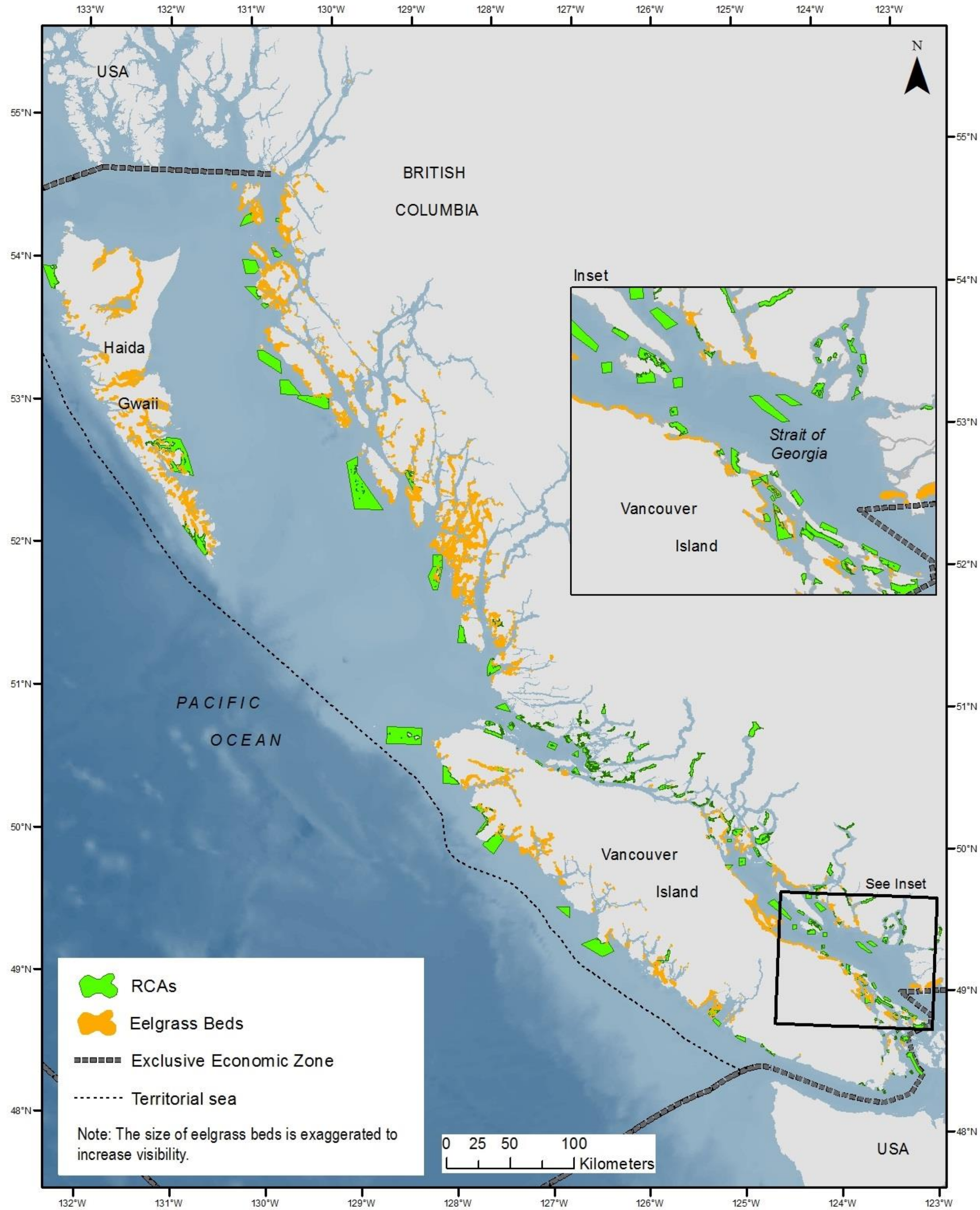


Figure 7: RCAs and eelgrass beds.

2.4 CRITERION 4: LONG-TERM DURATION OF IMPLEMENTATION

The fourth criterion states that the measure must either: be entrenched via legislation or regulation; or, if not entrenched via legislation or regulation, there must be clear evidence that the management measure is intended for the long-term (minimum of 25 years). Science advice from DFO (2016B) notes: “An ABMM is more likely to provide biodiversity conservation benefits if it has been in place over the long term and if one can reasonably expect that it will continue into the foreseeable future, or at least long enough to achieve its conservation objectives” (p. 5).

RCAs are fisheries closures established by variation order under the Fisheries Act, which are not considered to be entrenched by legislation or regulation. The science advice for RCA development cited the estimated rebuilding period for Yelloweye Rockfish populations, under no-fishing conditions, to be 25 years (Yamanaka and Lacko 2001). In a 2007 news release announcing that all 164 RCAs had been established, DFO anticipated that RCAs would be in place for “a number of years” to allow Inshore Rockfish and Lingcod stocks to rebuild. Further, other RCA documents suggest that monitoring of populations was intended to occur over at least a 10 to 25-year period before any decisions would be made on the future of RCAs (Fisheries and Oceans Canada, Pacific Region, unpublished data, 2002; MacKenzie 2004; Yamanaka and Lacko 2001).

2.5 DISCUSSION

2.5.1 Addressing OEABCM Criterion 1

RCAs meet criterion 1 as they have fixed boundaries that are clearly defined in publicly available sources, including the DFO website. The existence of well defined boundaries improve the likelihood of RCAs delivering conservation benefits to Inshore Rockfish and their habitat.

2.5.2 Addressing OEABCM Criterion 2

RCAs lack a single unifying DFO document that clearly outlines specific objectives. Nonetheless, publicly available documents do provide conservation and stock management objectives including the long-term protection of a portion of inshore rockfish populations and their habitat on inside (20 percent) and outside waters (30 percent) from fishing mortality to buffer against scientific uncertainty and rebuild stocks. Therefore, RCAs meet criterion 2.

2.5.3 Addressing OEABCM Criterion 3

Although RCAs would benefit from ground-truthing to improve our understanding of rockfish populations and habitats within their boundaries, there has been significant evidence gathered to date that suggests the presence of Inshore Rockfish and their habitat within each RCA. Therefore, criterion 3 is met. However, the size of rockfish populations and the quantity of habitat likely vary within each RCA, indicating that some RCAs may provide greater conservation benefits than others (see Dunham et al. 2019).

2.5.4 Addressing OEABCM Criterion 4

In the absence of legislation or regulation, there must be clear evidence that the management measure is intended for the long-term (minimum of 25 years) for RCAs to meet criterion 4. DFO science advice (Yamanaka and Lacko 2001) provides a biological explanation for why fishery closures need to be in place for multiple decades to effectively rebuild local rockfish populations. Further there is some evidence in DFO’s messaging to suggest that RCAs are intended as long-term management measures. However, there is no clearly stated long-term management objective in an official DFO publication, such as an Integrated Fisheries Management Plan. Therefore, RCAs currently do not meet criterion 4.

3 OEABCM CRITERION 5 AND ENFORCEMENT, EDUCATION, AND MONITORING

OEABCM criterion 5 states that no human activities that are incompatible with conservation of the ecological components of interest may occur or be foreseeable within the defined geographic location (DFO 2016A). In addition, it highlights that ecological monitoring, surveillance, and enforcement are important elements of adaptive management that are necessary to ensure effective conservation. While these elements are not precursors to meeting OEABCM criterion 5, the criterion does state that over time an area designated as an OEABCM must develop such management elements in the measure.

Therefore, before proceeding to the next section's assessment of the risks to Inshore Rockfish, this section highlights the areas where compliance improvement are most needed if RCAs are designated as OEABCMs. Anthropogenic activities that may adversely affect Inshore Rockfish populations and their habitats in RCAs must be managed to ensure conservation objectives are not compromised. This means management decisions should be closely linked to significant ecosystem components (SECs) identified in this risk assessment in the current paper (see Section 5. Although marine protected areas and fishery closures have become a popular tool for rebuilding and protecting marine areas and species (Marinesque et al. 2012), these tools depend upon high levels of compliance to rules and regulations to effectively protect species and habitats (Arias 2015; Edgar et al. 2014). Research has shown that even low levels of non-compliance can seriously impact protected area effectiveness (Graham et al. 2011; Little et al. 2005).

3.1 ENFORCEMENT

3.1.1 Marine and aerial patrol activity

In recent years, monitoring for compliance with regulations for RCAs and marine protected areas (MPAs) has been a priority for DFO's Conservation and Protection Program (C&P) in both air and marine patrols (A. Bussell, *pers. comm*., DFO, RHQ, Vancouver, Oct 2018). DFO's Fisheries Aerial Surveillance and Enforcement program conducts 154 to 166 one-day air patrol missions per year in the Pacific Region. On average, four flights per week are conducted. The goal of these aerial patrols is to fly the entire BC coast every week. The plane checks for fishing violations in all RCAs within a day's patrol mission area.

North Coast and South Coast Canadian Coast Guard (CCG) Marine Patrol Vessels each conduct approximately 286 to 309 operational days per year with two to three C&P Fishery Officers on each vessel. Each vessel has a rigid hull inflatable boat on board, which the Fishery Officers use for on-water patrols. All RCAs are checked in every area of the patrols. Separately, C&P Fishery Officers at field offices also conduct vessel patrols in their areas and check RCAs. The number of these latter patrols is more variable compared to the other two methods.

All the above mentioned C&P monitoring platforms have found and responded to violations within RCAs. Table 4 summarizes a review of fisheries violations files from 2002 to 2015 by C&P. There are 161 charges and 121 convictions related to RCAs (J. Fraser and A. Bussell, DFO, RHQ, Vancouver, unpublished data 2018).

Table 4: Fisheries violations in Rockfish Conservation Areas (2002-2015) (J. Fraser and A. Bussell, DFO, RHQ, Vancouver, unpublished data, 2018). Table excludes the outcome of some files including if ongoing after 2015, failures to appear in court or other reasons.

Year	Charges	Convictions	Stayed
2002	3	0	0
2003	1	1	0
2004	1	1	0
2005	5	5	0
2006	3	3	0
2007	4	4	0
2008	27	23	1
2009	49	40	9
2010	9	9	0
2011	14	11	1
2012	6	4	0
2013	9	9	0
2014	13	7	0
2015	17	4	0
Total	161	121	11

3.2 COMPLIANCE

3.2.1 Commercial Groundfish

Reducing and accounting for all catch of Inshore Rockfish by commercial groundfish fisheries was a central focus of the Inshore Rockfish Conservation Strategy and related integration initiatives within groundfish management (Yamanaka and Logan 2010). This section provides an overview of monitoring and enforcement within commercial groundfish fisheries, which are the largest group of fisheries prohibited within RCAs[13]. Data and capacity constraints prevented the analysis of compliance in other commercial fisheries (e.g. salmon trolling) prohibited in RCAs. We acknowledge that compliance by such fisheries should be assessed in future work.

The commercial groundfish fisheries in the Pacific Region now have extensive on-board, electronic, and dockside monitoring programs in place. Groundfish fisheries that catch large

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[13] With the exception of groundfish by mid-water trawl, all groundfish fisheries are prohibited within RCAs.

quantities of rockfish, such as the commercial groundfish bottom trawl fishery, have 100% on-board observer coverage. Each fishery is assessed individually, and an annual management plan is developed to outline monitoring of fishing locations, catches, and bycatch as necessary.

The commercial groundfish monitoring system is comprehensive, making enforcement of regulations easier for DFO (A. Bussell, *pers. comm.,* DFO, RHQ, Vancouver, Sept 2018). However, enforcement efforts are ongoing and a crucial part of effectively managing RCAs. For example, in 2017, there was a conviction with significant fines for a commercial groundfish vessel that was fishing in an RCA.

3.2.2 Recreational

Globally, recreational fishers take 12% of the annual fish catch, and recreational effort is typically concentrated in coastal areas (Marinesque et al. 2012; Cooke et al. 2004). Recreational non-compliance can have significant impacts on marine reserve effectiveness (Edgar et al. 2014). Many popular recreational fisheries (e.g. hook-and-line fishing for any species) are prohibited in RCAs. The only recreational fisheries permitted in BC are crab by trap, shrimp and prawn by trap, invertebrates by hand picking or dive, and smelt by gillnet. While DFO fisheries officers regularly patrol RCAs by air and on the water, with an average of 315,286 recreational tidal water licences issued annually between 2006-2017 to a very diverse group of fishers (from single-day to full-year licence holders) (Table 5), there are still challenges with respect to compliance in RCAs.

Table 5: Number of Tidal Water Licences Issued from 2006-2017 by Type and Duration (Source: Pacific Region Statistics from Tidal Waters Sportfishing Database and National Recreational Licensing System).

Licence Type & Duration	Resident	Non-Resident
Annual licence, Adult (16-64 years of age)	1,424,149	42,719
Annual licence, Senior (65 years of age and over)	298,967	0
Annual licence, Juvenile (under 16 years of age)	412,297	39,451
5 day licence	147,300	187,896
3 day licence	211,140	132,208
1 day licence	397,306	174,713
Total	**2,891,159**	**576,987**

A large portion of the directed and incidental catch of Inshore Rockfish by recreational fishers has traditionally been concentrated in the Strait of Georgia and west coast of Vancouver Island. For example, in 2011, recreational fishers caught 90% of the estimated total 35,000 Inshore Rockfish harvested in the Strait of Georgia, and 35% of an estimated 60,000 rockfish on the west coast of Vancouver Island versus 8% of 93,000 rockfish on the northeastern coast of Vancouver Island (Haggarty et al. 2016).

Recent research suggests that, in general, recreational fishers' compliance and knowledge of RCAs is low (Haggarty et al. 2016; Lancaster et al. 2015; Lancaster et al. 2017). Using DFO fly-over records' observations of recreational fishing activity in the Strait of Georgia from 2003 to 2011, Haggarty et al. (2016) found that in the years following the establishment of the 77 RCAs in the Strait, hook and line fishing effort continued to occur in 83% of them, and fishing effort in five RCAs had increased. Haggarty et al. (2016) also estimate that 1646 rockfish were removed from RCAs in the Strait of Georgia in 2011 based on a comparison of rockfish catch in PFMAs and aerial fly-over data on recreational non-compliance events. Lancaster et al. (2017) studied recreational effort in RCAs in the Southern Gulf Islands and Victoria area using shore mounted trail cameras. They found that 79% of RCAs in this area had fishing activity and there was no significant difference in fishing effort inside and outside RCAs. While, this study did not determine what portion of that effort was from restricted forms of recreational fishing versus permitted fishing activities (e.g. FSC purpose), a comparison of the fishing rates in RCAs and proximity to First Nation communities found no relationship (D. Haggarty, *pers. comm.,* Pacific Biological Station, Nov 2018). In a related study, Lancaster et al. (2015) surveyed 325 recreational fishers in the Southern Gulf Islands, Victoria, and Vancouver area where they found 25% of recreational fishers had never heard of RCAs, 60% were unsure of RCA locations, 16% had unintentionally fished in a RCA, and 7% knew someone who had intentionally fished in a RCA. The authors also found the recreational fishing sector lacks resources for identifying RCA boundaries since some boats are not equipped with navigation systems, hard copies of charts are difficult to obtain, there are very few highly visible charts in prominent locations such as boat launches and marinas, and there are no physical markers or reminders of RCA boundaries on the water (Chalifour 2012; Haggarty 2014). The research cited here raises concern that recreational fishers are removing rockfish from RCAs by using hook and line gear, whether intentionally or unintentionally.

3.2.3 First Nations Food, Social, and Ceremonial (FSC)

There are no prohibitions on fishing for Food, Social and Ceremonial (FSC) purposes in RCAs. For this reason, we limit our considerations to the monitoring and compliance systems that are in place for FSC fishing activity in RCAs. Groundfish FSC dual fishing is subject to the same monitoring conditions as commercial groundfish fishing (e.g. 100% electronic monitoring with video monitoring for hook and line catch) and catch must be verified at the offload site. FSC catch that is offloaded at the same location as commercial catch is subject to verification via the Dockside Monitoring Program (DMP), which is conducted by a company that has been designated by the Department. When the FSC portion of the catch is landed at a different location (split offloads), it is verified by independent First Nation observers and a copy of the catch record must be submitted to DFO.

The DFO-approved groundfish service provider audits 100% of commercial groundfish trips logs for accuracy, including all dual fishing trips. Discrepancies between logbook catch reporting and DMP or electronic monitoring data (i.e. sensors and video) are investigated by DFO groundfish fishery managers. When a trip has passed the audit, catch information is entered by set into DFO's catch data system by the groundfish service provider. DFO does not currently have the capacity to analyze groundfish FSC catch on a set-by-set basis. Enforcement of dual fishing conditions of licence is a priority for DFO (S. Petersen, *pers. comm*., DFO, RHQ, Vancouver, Mar 2018). There is anecdotal evidence suggesting FSC catches from inside RCAs may sometimes become mixed in with commercial catches from outside RCAs, which is then offloaded and sold as commercial catch (T. Johansson, DFO, Fisheries and Oceans Field Office, Port Hardy*, pers. comm*., Feb 2018).

First Nations' decisions about whether to permit fishing for FSC purposes in RCAs plays a role in the conservation effectiveness of RCAs. Such decisions, and the compliance by individual fishers, likely vary throughout the coast. Some First Nations access RCAs for dual fishing trips.

At the same time, other First Nations are known to restrict dual fishing in RCAs by including restrictions in their designation certificates.

3.2.4 Aquaculture

There are no RCA specific prohibitions on aquaculture. However, all aquaculture facilities must operate in compliance with key health and environmental legislation (e.g. *Species at Risk Act*). In addition, all finfish aquaculture facilities are required to record and report all species incidentally caught during aquaculture harvests and transfer events. Records are the responsibility of facility managers and are not monitored by third-party observers; however, DFO conducts occasional audits of harvests.

The aquaculture industry in BC is monitored and enforced by DFO's Aquaculture Environmental Operations (AEO) and by Fishery Officers. The AEO develop aquaculture licensing that require operators to submit numerous reports and permits to DFO, including information on anchoring suitability, fish transfers, Health Management Plans, Carcass Management Plans, Marine Mammal Interaction Management Plans, and incidental catch (K. Shaw, *pers. comm.,* Aquaculture Environmental Operations DFO, Jan 2019). AEO maintain a benthic monitoring data set from 2002 onward with information from sediment sampling at sites and ROV video data. Sea lice at finfish aquaculture sites are also monitored and, if licence-specific thresholds are exceeded action must be taken to reduce levels (K. Shaw, *pers. comm.,* Aquaculture Environmental Operations DFO, Jan 2019). These data are sent to DFO by operators. DFO publicly reports a large portion of aquaculture monitoring data[14].

Twelve DFO Conservation and Protection staff are dedicated to aquaculture enforcement specifically. Additionally, AEO experts conduct site audits and inspections to assess mortalities, fish health, and licence compliance. Benthic monitoring is conducted by AEO at ~20% of active sites every year (K. Shaw, *pers. comm.,* Aquaculture Environmental Operations DFO, Jan 2019).

3.3 EDUCATION AND OUTREACH

Education and outreach campaigns for RCAs were intended to be conducted during and after RCA implementation. RCA boundaries and regulations were provided online through the DFO website, fishery notices, and integrated fishery management plans. A hard copy RCA booklet[15] with regulations and charts was first printed in 2006 and then reprinted in 2013.

Recent years have seen an increase in education materials and outreach about RCAs and their regulations. In 2018, DFO produced brochures and posters about RCAs and Inshore Rockfish species. Approximately 1,000 posters and 5,000 brochures have been distributed to DFO offices, C&P officers, recreational licence vendors, aquariums, environmental groups, and other groups coast-wide. Digital copies are also available through the DFO website. At docks, marinas, and on the water, the North Coast and South Coast Marine Patrol Program Fishery Officers regularly educate fishers about RCAs and fishing regulations. On social media (e.g. Twitter), DFO occasionally posts messages about RCA regulations.

DFO has also provided external organizations with data and regulations for RCAs. In 2017, the Pacific Salmon Foundation and the Sport Fishing Institute released the free Fishing BC app for iPhones and Androids. This app outlines RCA regulations and provides a static, non-interactive

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[14] Aquaculture monitoring data can be found online.

[15] The booklet was also made available on a compact disc in 2007.

map of RCA locations by PFMA. However, the identification information for rockfishes in this app does not allow the distinction of species. In 2018, Navionics added the RCA boundaries and regulations to their navigation software.

Outside of the education and outreach work done by DFO, non-governmental organizations such as the Galiano Conservancy Association have been conducting education and signage campaigns since 2014 to raise awareness of RCAs. They have posted RCA signs at docks and marinas in the Southern Gulf Islands, Victoria, Nanaimo, and on the Sunshine Coast. They have also hosted RCA workshops to engage locals and conduct interviews with fishermen and shore-based monitoring of RCAs (J. Falke, *pers. comm.,* Galiano Conservancy Association, Feb 2018).

3.4 MONITORING

Although some research has been conducted by various researchers from different institutions using a variety of methods and tools in RCAs since they were first implemented (Haggarty 2014), a comprehensive management strategy and monitoring plan, has yet to be developed for RCAs. Such a monitoring plan could help improve an overall understanding of RCA effectiveness. Three important elements should be included:

- Ecological indicators - regular, long-term research is necessary to collect data on relevant ecological indicators that can detect both sudden shifts and longer-term trends in rockfish populations and habitat. Research should be conducted using non-invasive tools such as side-scan telemetry and visual survey methods (Remotely Operated Vehicles, SCUBA, towed cameras). Data will be compared to any available baseline data collected before RCAs and from the mid/late 2000s when RCAs were first established, and to areas outside RCAs with comparable habitats.
- Catch reporting - for permitted fishing activities; all rockfish removals will need to be accounted for.
- Compliance - due to the unique life history of Inshore Rockfish (e.g. long-lived, slow to mature and reproduce) it may take decades before biological indicators will conclusively show whether RCAs are effectively protecting rockfish and their habitats. Compliance in RCAs is critical and must be high to ensure meaningful protection to rockfish.

Monitoring information and new research findings should feed directly into the management of the RCA network. Consequently, a long-term adaptive management approach is desirable to incorporate new knowledge as it becomes available. Implementation of a successful monitoring plan will best ensure depleted Inshore Rockfish populations will recover and rebuild to the desired restoration targets.

4 LEVEL 1 QUALITATIVE RISK ASSESSMENT

To determine whether RCAs meet OEABCM criterion 5, an existing DFO risk assessment framework, in conjunction with expert opinion, was applied to assess whether currently permitted activities and their impacts are compatible with the conservation of the ecological components of interest (DFO 2016A). Systematic, science-based ecological risk assessments have been used by DFO Pacific Region as a tool to determine the linkages between specific anthropogenic activities and the marine environment. An ecological risk assessment framework (ERAF) was developed by DFO Pacific Region (O et al. 2015) to evaluate and prioritize the single and cumulative threats from multiple anthropogenic activities and their associated stressors on significant ecosystem components (SECs) and identify knowledge gaps. The key elements of this framework consist of an initial scoping phase, followed by the risk assessment phase. The scoping phase includes the identification of SECs, which can be a species, habitat, or community, and the identification of anthropogenic activities and stressors that have the potential to affect these SECs. A Level 1 qualitative risk assessment was applied to assess the risk of harm to Inshore Rockfish, their rocky reef habitat, and relevant prey species within RCAs from currently permitted activities.

The ERAF supports three levels of assessment: Level 1 qualitative; Level 2 semi-quantitative; and Level 3 quantitative. Level 1 and 2 ERAFs have been applied in the Pacific Region, including a Level 1 ERAF application to the Pacific North Coast Integrated Management Area (PNCIMA; Murray et al. 2016), and Level 2 ERAF applications to three MPAs in the Pacific Region: SGaan Kinghlas-Bowie Seamount Marine Protected Area (SK-B MPA; Rubidge et al. 2018), Endeavour Hydrothermal Vents MPA (EHV MPA; Thornborough et al. 2018), and Hecate Strait and Queen Charlotte Sound Marine Protected Area (HS/QCS MPA; Hannah et al. 2019). To date, a Level 3 quantitative ERAF has not been applied in the Pacific Region.

A Level 1 qualitative assessment application provides a comprehensive, but largely qualitative analysis of risk. A significant advantage of the ERAF is that it is scalable and adaptable to a range of different management needs (O et al. 2015). A Level 1 qualitative ERAF is the most appropriate tool to assess large areas with a multitude of anthropogenic activities, and as a rapid assessment tool, which can highlight gaps related to a lack of data (to direct monitoring effort) and to a lack of knowledge (which may require a longer research program to address).

4.1 RISK OBJECTIVE AND SCOPE

The objective of the risk assessment is to assess the risk of harm to Inshore Rockfish and their habitat from permitted activities within the RCAs, and in doing so, rank risk results on a relative scale and identify key knowledge gaps. As part of this assessment, the risk of harm is used to provide information required to determine whether the primary goal of RCAs (the long-term protection and conservation of a portion of Inshore Rockfish populations and their habitat) is being met, and therefore, OEABCM criterion 5.

With a particular focus on the primary goal of the RCAs and OEABCM criterion 5, this work assesses the risk of harm to the collective population of Inshore Rockfish within RCAs (i.e. all RCAs collectively) and does not assess the risk of harm on an individual RCA basis (and therefore if Individual RCAs meet criterion 5). This assessment considers currently permitted activities within RCAs. While some data analysis is provided for activities that are no longer permitted within the RCAs, these past and prohibited activities are not included in the risk analysis. Similarly, this assessment does not include illegal activities and non-compliance, which may prevent RCAs from meeting criterion 5. The primary goal of RCAs focuses on the risk of harm from fishing activities; however, this assessment also includes other human activities that currently occur within RCAs. This is consistent with criterion 5’s requirement that no human activities that are incompatible with conservation of the ecological components of interest may occur or be foreseeable within the OEABCM (Fisheries and Oceans 2016A).

The Level 1 ERAF does not identify acceptable levels of risk or set risk thresholds, but instead is used to rank risk on a relative scale. In doing so, the activities with the highest potential to prevent RCAs from collectively meeting criterion 5 and the ecological components most at risk can be identified, but does not specifically address if and how RCAs meet criterion 5.

4.2 METHODS

The Level 1 ERAF (O et al. 2015) consists of two key phases: scoping and risk assessment. A scoping phase and quantitative risk assessment were applied to RCAs, following the methods outlined by O et al. (2015), but with the inclusion of a revised risk scoring method recommended through the Canadian Science Advisory Secretariat (CSAS) regional peer review process (DFO 2016C) and the PNCIMA Level 1 assessment (Murray et al. 2016). All revisions to the original ERAF method (O et al. 2015) are detailed here, including any alterations that were made to accommodate the objective to assess the risk of harm to the collective population of Inshore Rockfish spread across all RCAs.

4.2.1 Scoping

The scoping phase identifies the key features or properties of the system (i.e. Significant Ecosystem Components (SECs)) and the activities and associated stressors that have the potential to affect these SECs.

Identifying Significant Ecosystem Components

A SEC in the context of this study is defined as an environmental element that has ecological importance to the ecosystem being studied. One of the benefits of using the ERAF is that it is adaptable to a range of different management needs (O et al. 2015). While the ERAF provides criteria that can be used as a guide to select SECs, it also allows for the inclusion of SECs that have been identified using other methods.

As the goal of the RCAs is specific to Inshore Rockfish and their habitat, and the operational guidance in OEABCM criterion 3 (DFO 2016A) specifies that “the measure must contain at least two ecological components of interest: a habitat that is important to biodiversity conservation AND a species of regional importance that uses the habitat”, the O et al. (2015) SEC selection criteria were not used in this assessment. As the primary focus of this work, Inshore Rockfish automatically became a SEC for this assessment. With the OEABCM requirement of a habitat important to biodiversity and conservation related to Inshore Rockfish and RCAs be included in the assessment, literature review and consultation with subject matter experts were used to identify Inshore Rockfish habitats and ecological communities essential to Inshore Rockfish health within RCAs. The habitat with the greatest relative significance to the RCA goal was then determined, giving consideration to the spatial overlap between identified Inshore Rockfish habitat and RCA boundaries.

The number of SECs included in the assessment does not impact the effectiveness of the ERAF. A Level 1 risk assessment could be conducted on a single SEC, and while risk would not be able to be ranked relative to other SECs in the assessment, the relative risk of harm from the activities and stressors included in the assessment would be useful and valid. To address the risk objective and determine which activities are potentially preventing RCAs from meeting their conservation goal, it is more useful to focus on a small number of SECs and a wide range of activities, and compare the relative risk of harm across activities.

Identifying Activities and Stressors

Expert guidance and a review of the literature, DFO archives, and other risk assessments conducted in the Pacific Region were used to identify permitted activities with the potential to harm RCA SECs. The RCA goal focuses on the protection and conservation of rockfish and their habitat from fishing, and the resulting list of activities was divided into permitted fisheries (including commercial, recreational, FSC fishing, aquaculture) and other permitted human activities affecting RCAs.

DFO experts (e.g. Fishery Managers, Scientists, Database Managers) were contacted to explain details of how specific fisheries operate (e.g. gear type, deployment style, fishing season, monitoring protocols, etc.), or to help locate and gather existing data from numerous databases (e.g. Groundfish Fisheries Fishery Observation System (GFFOS), Prawntrap_Bio, etc.). Some external experts also provided their data or guidance on where to locate data on various fisheries and stressor impacts. Experts were selected through snowball sampling.

As part of the identification of current activities and associated relevant data, the decision was made to exclude FSC fishing (except groundfish dual fishing[16]) and recreational fishing. The potential impacts of unrestricted activity within RCAs is a potential concern to achieving the RCA goal; however, the lack of reporting and data collected by DFO on these activities means that there is likely not enough data to assess risk on a relative scale with those activities currently occurring within RCAs that have available data.

This Level 1 risk assessment does not consider the potential impact of non-permitted RCA activities such as illegal fishing, non-compliance, or other illegal activities. The goal of this paper is to assess the potential negative impact from the permitted human activities within RCAs on Inshore Rockfish, and their habitat and; therefore, assessing non-compliant RCA activities is beyond the scope of this paper. However, enforcement and monitoring of illegal activities is an important part of designing effective marine reserves and is discussed in more detail in Section 3.

Stressors associated with each activity were identified through a combination of literature review, expert guidance, DFO and public data, and a review of existing Pathways of Effects (PoE) models (DFO 2014) and Pacific Region ecological risk assessments.

4.2.2 Level 1 Qualitative Risk Assessment

Risk assessment is an analytical approach for estimating the risk that, in this case, is defined as the likelihood that a SEC will experience unacceptable adverse consequences due to exposure to one or more identified stressors (O et al. 2015). Cumulative risk is a calculation of the risk to a SEC from more than one stressor and is a measure of the overall risk to a given SEC. The "potency" is the cumulative (additive) risk of an activity or stressor presented on a relative scale across all values in the assessment.

This assessment aims to analyze four types of risk by following methods outlined by O et al. (2015) and Pacific Region ERAF applications (Murray et al. 2016; Rubidge et al. 2018; Thornborough et al. 2018; Hannah et al. 2019):

1. Relative risk ($Risk_{sc}$) to a SEC (c) from the individual stressors (s) that affect it within RCAs,
2. Cumulative risk ($CRisk_c$) to a SEC from all of the different stressors that affect it within RCAs,
3. Potency ($Potency_s$) of stressors impacting the SECs within RCAs, and
4. Potency ($Potency_s$) of activities impacting the SECs within RCAs.

The scoring procedure for this risk assessment generally follows the method developed by O et al. (2015) and implemented by Murray et al. (2016) with minor variations. A brief overview is provided here, but readers are encouraged to refer to these sources for further information.

SEC-stressor matrix

An interaction matrix was used as a first rapid screening to identify any potential negative interactions between the identified SECs and activities/stressors. Interactions were scored using a binary system as either (1) potential interaction, or (0) no interaction based on the expertise of

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[16] See section 5.3.2 for definition of dual fishing.

the authors. SEC-stressor interactions noted as having no potential negative interaction are filtered out of the assessment process at this stage.

It should be noted that the ERAF scoring rubric only considers negative SEC-stressor interactions (i.e. where the stressor has a detrimental effect 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 SEC's overall health/integrity). While the framework could support both direct and indirect effects of a stressor on a SEC, only direct effects were scored for this iteration of risk assessment of RCAs (aligning with other applications of ERAF in the Pacific Region; Murray et al. 2016; Rubidge et al. 2018; Thornborough et al. 2018; Hannah et al. 2019). Examples of indirect effects include increased predation due to disturbances, increased competition for food sources as the result of disturbances, etc. This focus on direct effects creates a baseline unto which future risk assessments may further develop and ensures that risks results can be assessed on a relative scale.

Qualitative Risk Variables

Risk is a product of the SECs exposure to a stressor and the consequence of that exposure to the SEC. As part of the risk calculation, uncertainty is incorporated into this calculation. Risk is calculated according to the risk variables in the following equation:

$$Risk_{sc} = Exposure_{sc} \times Consequence_{sc}^{2} \qquad \text{Equation 1}$$

Where:

$Risk_{sc}$ to SEC (*c)* by stressor (*s)* is the product of the $Exposure_{c}$ of SEC (*c)* to stressor (*s)* and the $Consequence_{sc}$ to SEC (*c)* when exposed to stressor (*s*), where SEC (*c)* is one of the SECs selected for this analysis and stressor (*s)* is a stressor produced by one of the identified anthropogenic activities.

Risk scores are calculated using Equation 1 incorporated into R code by random sampling within a normal distribution, with the median defined by the risk variable score and the shape of the distribution defined by the uncertainty score, as described in Murray et al. (2016). In this method, $Consequence_{sc}$ (maximum of 6) is squared to make the scale of the score comparable to $Exposure_{sc}$, which is the product of three variables (maximum of 36). The R code used in this assessment has been updated with minor modifications to remove redundancies and fix bugs since the original application of the Level 1 R code in Murray et al. (2016). This updated code is published on DFO's Open Data Portal as part of the Appendices for Murray et al. (2016).

Scoring Exposure and Consequence

Qualitative scoring of $Exposure_{sc}$ and $Consequence_{sc}$ follow the method defined by O et al. (2015) and modified in Murray et al. (2016). $Exposure_{sc}$ of SEC (*c)* to stressor (*s)* is the product of three variables: *Temporal Scale* (TS_s)*, Spatial Scale* (SS_s)*, and Load* (L_s)*,* so that Equation 1 becomes:

$$Risk_{sc} = TS_s \times SS_s \times L_s \times Consequence_{sc}^{2} \qquad \text{Equation 2}$$

An uncertainty term is assigned for each variable in Equation 2 (detailed below).

Scoring Exposure

$Exposure_{sc}$ scoring follows the method used and recommended in the PNCIMA application of the Level 1 ERAF (Murray et al. 2016) with modifications to be able to score $Exposure_{sc}$ based on the activities being assessed and an assessment of risk at the scale of all RCAs (rather than each RCA individually). In this method, $Exposure_{sc}$ variables are scored on the overlap between the stressor and all RCAs and are independent of SECs. This means that $Exposure_{sc}$ scoring is common across all SECs that interact with the stressor. The interaction between the SECs and stressors is captured in the $Consequence_{sc}$ scoring. When detailed information is not available for temporal and spatial variables, scoring considers the likely exposure versus the maximum potential exposure. For example, the maximum potential temporal scale that an aquatic invasive species introduced by Crab by Trap could become established is >6 months of the year, but based on a lack of historical cases introduced by the Crab by Trap fishery in BC, the temporal scale is scored as low. In some cases where little to no information related to the potential versus actual exposure is available (particularly for fisheries open year round but thought to occur for only a fraction of that time), the exposure term is scored based on the likely exposure, and applying the precautionary principle, the score is inflated +1. Information to assist in scoring *temporal* and *spatial* overlap for fisheries within RCAs were provided by fisheries managers (provided in Appendix B). The information compiled in Appendix C was also used to score $Exposure_{sc}$.

Temporal scale (TS_s) refers to the incidence of the stressor, rather than its duration. Consideration is given to the proportion of the year that the stressor occurs (represented by days), rather than persistence of the stressor or how long the effect is felt by the SEC (which is in part captured by the *Load* and $Consequence_{sc}$ scores). Due to the focus on fishing activities in RCAs and the seasonal nature of many of these fisheries, the TS_s scoring rubric from O et al. (2015) and Murray et al. (2016) was adapted to represent the proportion of the year that the stressor occurs. The scoring bins were developed to capture stressors that only occur for a number of days to stressors that occur for more than six months of the year, indicating reduced recovery time potential. While it is unlikely that a stressor from an activity would occur in all RCAs equally, TS_s was scored using the precautionary principle and based on the temporal overlap with any RCA. For example, if a stressor was known to occur for >6 months of the year in two RCAs, the stressor is still scored high, even though it does not occur in all RCAs for that period. TS_s is scored on a scale of 1 (very low) to 4 (high), with scoring bins described in Table 6.

Table 6: Qualitative scoring bins for sub-terms of $Exposure_{sc}$ (Temporal Scale, Spatial Scale, and Load) (adapted from Murray et al. 2016 and O et al. 2015). (a) temporal scale, (b) spatial scale, and (c) load.

(a) Temporal Scale

Score	Description	Definition
1 (low)	Very low	<3.5 days (0.1-1% of the year)
2 (low / moderate)	Low	3.5 days to 2.5 months (1-20% of the year)
3 (moderate / high)	Medium	2.5-6 months (20-50% of the year)
4 (high)	High	>6 months (>50% of the year)

(b) Spatial Scale

Score	Description	Definition
1 (low)	Few restricted locations	1-24 RCAs (1-15% of total RCAs)
2 (moderate)	Localized	25-49 RCAs (15-30% of total RCAs)
3 (high)	Widespread	50> RCAs (>30% of total RCAs)

(c) Load

Score	Description	Definition
1 (low)	Low	Low density and low persistence
2 (moderate)	Moderate	High density or persistence
3 (high)	High	High density and persistence

Spatial Scale (SS_s) refers to the scale/extent of the stressor footprint, expressed as the proportion of RCAs with spatial overlap with a stressor. As the effectiveness of RCAs collectively at protecting Inshore Rockfish is being assessed in this work, the number of RCAs the stressor occurs in was used as a proxy to determine the spatial overlap. While in many cases there is information available on which RCAs an activity occurs in, detailed information is lacking to be able to state the proportion of each RCA that overlaps with a stressor. As a result, where an activity could be identified as occurring within an RCA, a precautionary approach assumed the stressor occurred throughout the RCA. SS_s is scored from 1 (few restricted locations) to 3 (widespread), described in Table 6.

Load (L_s) is a measure of the density and persistence of the stressor. Depending on the stressor/activity in question, L_s can refer to effort, density, amount of an activity, or the amount or strength of a stressor (e.g. quantity or concentration of a pollutant or harmful species) across the entire RCA area. Most frequently, L_s is scored considering these variables, but also assessing the load of the stressor on a relative scale against other activities that produce the same stressor. L_s is scored on a scale of 1 (low) to 3 (high), described in Table 6.

Scoring Consequence

$Consequence_{sc}$ is scored based on the stressor's risk to the particular SEC (i.e. consequence varies according to the SEC). $Consequence_{sc}$ is the effect of the stressor on the individual SEC and is scored for each SEC-stressor combination identified in the SEC-stressor interaction matrix as a potential direct negative effect. Scores range from 1 (negligible) to 6 (intolerable). Table 7 describes the general scoring rubric used along with the more detailed $Consequence_{sc}$ scoring rubric in O et al. (2015). The information compiled in Appendix C was used to score $Consequence_{sc}$.

Table 7: Qualitative scoring bins for scoring Consequence (adapted from O et al. 2015).

Score	Effect	Definition
1 (low)	Negligible	Negligible effect on population/habitat/ community
2 (low / moderate)	Minor	Minimal effect on population/habitat/ community structure or dynamics
3 (moderate)	Moderate	Maximum effect that still meets an objective (e.g. sustainable level of impact such as a full exploitation rate for a target species; maintaining levels of critical habitat)
4 (moderate / high)	Major	Wider and longer term effects (e.g. long-term decline in CPUE)
5 (high)	Severe	Very serious effects occurring, with a relatively long time period likely to be needed to restore to an acceptable level (e.g. serious decline in spawning biomass limiting population increase)
6 (very high)	Intolerable	Widespread and permanent/irreversible damage or loss will occur – unlikely to ever be fixed (e.g. local extinction)

Aligning with the risk objective and RCA goal, $Consequence_{sc}$ scoring is based on the potential effect on the collective population of SECs across RCAs generally, rather than the effect on SECs within a single RCA. $Consequence_{sc}$ scoring considers available information on the SEC, such as population size, geographic range, behaviour, etc., but is most commonly scored on the population size or geographic range of a SEC. When scoring SECs that include more than a single species or species group (e.g. habitat, community, etc.), scoring was based on the species within that SEC that is directly impacted by the stressor. However, if more than one species within that SEC is impacted by the stressor, scoring is based on the most sensitive ecological component.

Scoring Uncertainty

An uncertainty score between 1 and 5 is allocated for each risk variable, where 1 represents low uncertainty and 5 represents high uncertainty (Table 8). In some cases, data specific to the location was available but would be specific to the activity and not the stressor. This would increase the uncertainty score.

Table 8: Definitions of uncertainty scoring bins, based on categories outlined in Therriault and Herborg (2008) and Therriault et al. (2011) and adapted by O et al. (2015).

Score	Evidence	Description
1	Extensive	Extensive scientific information; peer-reviewed information; data specific to the location; supported by long-term datasets (10 years or more)
2	Substantial	Substantial scientific information; non-peer-reviewed information; data specific to the region; supported by recent data (within the last 10 years) or research
3	Moderate	Moderate level of information; data from comparable regions or older data (more than 10 years) 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: the amount of literature available and scientific consensus. This second type of uncertainty is not explicitly represented in Table 8. To implicitly assess this type of uncertainty, the uncertainty score is increased by one (n+1) when there is no scientific consensus.

The uncertainty associated with each scored variable is incorporated into the risk score using the method described as “Method 2” in Murray et al. (2016) where uncertainty in each risk variable is modelled from a truncated normal distribution with the median equal to the risk score and the standard deviation corresponding to the level of uncertainty assigned. The statistical program R was used to generate and run the code for estimating uncertainty (R Core Team 2016; the code is provided as an appendix to Murray et al. (2016)). The outputs of the code include 10% and 90% quantiles accompanying each risk score, indicating the uncertainty associated with that score.

Scoring Process

Literature reviews on the potential effects of human activities on Inshore Rockfish and their habitats were conducted covering studies in BC and internationally. Where available, data were compiled on the spatial extent of human activities in RCAs, and any additional data that could assist with assessing potential effects to Inshore Rockfish and their habitats. Current management, enforcement, education, and monitoring systems for RCAs were also examined and considered during scoring. DFO subject matter experts and fisheries managers were consulted to review the information compiled and feedback was incorporated. This information was compiled and summarised by activity to support scoring and is presented in Appendix C. Where information was not available for a specific SEC-stressor interaction, scoring of $Consequence_{sc}$ was supported by other Pacific Region ERAF applications that included an Inshore Rockfish component and/or a similar SEC (i.e. SK-B MPA (Rubidge et al. 2018), HS/QCS MPA (Hannah et al. 2019), and PNCIMA (Murray et al. 2016)). Scoring and scoring justifications for fisheries (including commercial, recreational, aquaculture, and groundfish FSC dual fishing) were reviewed in February 2019 by a small selection of DFO science staff and managers and feedback was incorporated into the final report where appropriate.

Calculating cumulative risk to SECs from multiple stressors ($CRisk_c$)

Estimation of $CRisk_c$ across SECs enables evaluation of the relative risk ($Risk_{sc}$) to SECs within the area assessed. This means that comparisons may be drawn between SECs based on $CRisk_c$. This method is additive and is calculated by summing the risk scores of all stressors that affect a SEC.

$CRisk_c$ is defined by the equation:

$$\boldsymbol{CRisk_c = \sum_{s=1}^{n}(Risk_{sc})} \qquad \text{Equation 3}$$

Where (*s)* is the stressor interacting with a SEC (*c*).

Calculating cumulative risk by stressor ($Potency_s$) and activity ($Potency_a$)

The $Potency_s$ of each stressor is calculated by summing the $Risk_{sc}$ scores of stressors for each SEC that the stressor interacts with. This allows comparison across all individual stressors impacting SECs.

$Potency_s$ is defined by the equation:

$$\boldsymbol{Potency_s = \sum_{c=1}^{n}(Risk_{sc})} \qquad \text{Equation 4}$$

Where (*c*) is the SECs that stressor (*s*) affects.

Similarly, $Potency_s$ of each broad category of stressor (e.g. entrapment/entanglement, removal of biological material, etc.) is calculated by summing all risk scores resulting from that stressor category. This allows comparison between broad category stressors (e.g. removal of biological material).

Finally, $Potency_a$ by activity is calculated by summing the risk scores resulting from all SEC-stressor interactions from that activity. This allows comparison between activities.

4.3 RESULTS

4.3.1 Identification of Significant Ecosystem Components

As the primary focus of RCAs, Inshore Rockfish were automatically selected as a SEC. This SEC includes the collective population of Inshore Rockfish species (see detailed description in Section 2.1) across all RCAs to be able to assess if RCAs are effectively conserving BC's Inshore Rockfish.

Literature review and consultation with subject matter experts identified four Inshore Rockfish habitats: rocky reefs, eelgrass beds, kelp beds, and glass sponge reefs. Spatial analysis of these habitats and the proportion of RCA area they cover found that 26% of the total RCA area is covered by these habitats (Table 3; see Section 3.3 for details). Rocky reefs are the primary habitat type in RCAs with significantly more spatial coverage in RCAs (23.58%) as compared to sponge reefs (0.16%), kelp forests (3.48%), and eelgrass (0.47%) (Table 3). When the low spatial overlap of eelgrass beds, kelp forests, and glass sponge reefs with RCAs is combined with the limited spatial information available on many of the activities that occur within RCAs (e.g. which RCA(s) the activity occurs in, how frequently it occurs within RCAs, etc.), inclusion of these habitat types would rely on precautionary scoring, and therefore likely inflate risk results that may not reflect the actual risk of harm. Preliminary scoring trials for these SECs found that terms of $\mathit{Exposure}_{sc}$ and $\mathit{Consequence}_{sc}$ could only be scored using a precautionary approach with high uncertainty, confirming that the risk scores would be artificially inflated and difficult to compare on a relative scale. Given the low spatial overlap of eelgrass beds, kelp forests, and glass sponge reefs with RCAs and that the OEABCM operational guidance requires a habitat that is important to biodiversity conservation, the decision was made to only select rocky reefs as a habitat SEC in this assessment. The rocky reef habitat includes both the substrate and the ecological communities inhabiting these areas, such as mobile invertebrate feeders, carnivores, omnivores, roving herbivores, territorial herbivores, piscivores, sessile invertebrate feeders, planktivores, cup corals, sponge, kelp and algae, etc.

As part of the literature review and consultation with subject matter experts, Inshore Rockfish prey was identified as a potential SEC. Studies have reported a wide array of prey items and sizes in the diets of each species of Inshore Rockfish (Murie 1991). Rockfish diet consists of marine invertebrates (e.g. caridean shrimp, crabs, squat lobsters, mysids, euphausiids, polychaete worms, amphipods, etc.), teleost fish (e.g. herring, sandlance), and algae (see Table 1 Table 1: Prey categories of each species of Inshore Rockfish.for a list of prey by Inshore Rockfish species). The inclusion of prey as a SEC informs the risks to Inshore Rockfish, including both the direct pathways of effects from stressors on Inshore Rockfish as a SEC, but also the indirect pathways of effects from a change in prey abundance, condition, and distribution as the result of interactions with anthropogenic stressors. Prey species were grouped for this purpose and defined as a species that is known to be consumed by Inshore Rockfish. The proportion of Inshore Rockfish diet the prey species makes up is not considered during scoring. This is discussed further in the discussion 5.4.1.

The final list of SECs selected for this assessment include:

1. Inshore Rockfish SEC
2. Rocky Reef SEC
3. Prey SEC

4.3.2 Identification of Activities and Associated Stressors

The primary goal of RCAs is the long-term protection and conservation of a portion of Inshore Rockfish populations and their habitat from the effects of fishing. There are three categories of fishing that occur within RCAs: commercial, recreational, and Food, Social, and Ceremonial (FSC). The decision was made to only include currently permitted commercial fishing activities in the assessment, as reporting and data required for scoring recreational and FSC fishing are generally not sufficient to assess risk on a relative scale. Without detailed information related to catch (use to score Load and Consequence), or data on the spatial and temporal extent of the activity, a precautionary approach to scoring would be employed, resulting in risk scores that may not accurately represent the actual risk of harm to RCA SECs. This would also make the interpretation of risk results difficult to assess at a relative scale.

There are two exceptions that were identified and included in the assessment: smelt by gillnet (recreational only), and FSC groundfish dual fishing by hook and line fishing. While the commercial fishery for smelt by gillnet is currently closed, the data available for recreational smelt by gillnet is detailed enough to be able to include in the assessment. With the possibility that the commercial smelt by gillnet fishery could reopen in a future year, the inclusion of this activity in the risk assessment will provide some information and guidance in determining the potential risk if the commercial fishery was to reopen.

Dual fishing occurs when commercial and FSC harvesting occurs during the same fishing trip. It is permitted in commercial groundfish and other fisheries. To authorize a vessel and vessel master, an aboriginal organization provides a dual fishing designation certificate to catch and retain groundfish for FSC purposes on their behalf. The FSC portion of dual fishing trips is permitted to occur in RCAs. However, an aboriginal organization may choose to prohibit fishing in RCAs by including a provision in their dual fishing designation certificate. In this assessment of FSC fishing activities within RCAs is limited to groundfish dual fishing by hook and line, as it has the most robust data collected by DFO.

Commercial fisheries include those that may have bottom contact (crab by trap, groundfish by mid-water trawl, prawn and shrimp by trap, scallop by trawl), pelagic fisheries (euphausiid (krill) by mid-water trawl, herring gillnet, herring spawn-on-kelp, herring seine net, salmon by gillnet, salmon by seine), handpicking of invertebrates (e.g. geoduck, sea urchin, sea cucumber), and aquaculture (finfish and shellfish). Some commercial fisheries were identified as previously occurring within RCAs, including opal squid by seine net, sardine seine net, and sardine gillnet. Information for these fisheries was compiled and analyzed (presented in Appendix C) but was not included in the assessment, as they do not currently occur within RCAs.

While the RCA goal focuses on the effects of fishing, the decision was made to extend the scope of the activities to include other anthropogenic activities, as this is consistent with the assessment requirements for OEABCM criterion 5. Other human activities were selected based on expert guidance, a review of previous ERAF processes on the BC coast, and data availability. Other activities/threats identified include; vessel use, land-use, petroleum tenures, log dumps and storage, extractive research surveys and existing coastal infrastructure. Data is available for each of these activities/threats and were included in the risk assessment, with the exception of petroleum tenures, as petroleum extraction is not a current activity within RCAs.

Illegal activities and fishing non-compliance were not included in this assessment. While these activities likely impact Inshore Rockfish in RCAs, these activities are considered outside the scope of the current assessment, in part because of a lack of information and in part because these activities cannot be managed at the scale of the RCAs. Similarly, activities considered to have minimal impacts on RCA SECs (e.g. scuba diving) and/or a lack of information were not included in the assessment. Long-range stressors and those that cannot be managed at the scale of RCAs, such as climate change, were not included in the assessment.

The activities identified for consideration in the risk assessment are presented in Table 9. A total of 21 activities were scored in the final assessment. To support the scoring of activities in the risk assessment, existing data and information were compiled and analyzed for each identified activity. This information is summarised by activity and is presented in Appendix C.

*Table 9: Permitted activities occurring within RCAs and assessed in this report. * denotes activities that are not currently permitted to occur that were not included in the risk assessment.*

Human Activity			**Appendix**
Fisheries	Bottom contact	Crab by trap	C.1
		Prawn and shrimp by trap	C.3,4
		Scallop by trawl	C.5
	Pelagic	Euphausiid (krill) by mid-water trawl	C.6
		Groundfish by mid-water trawl	C.2
		Herring gillnet	C.7
		Herring spawn-on-kelp	C.7
		Herring seine net	C.7
		Opal squid seine net*	C.8
		Salmon by gillnet	C.9
		Salmon by seine	C.9
		Sardine seine net*	C.7
		Sardine gillnet*	C.7
		Smelt by gillnet (recreational only)	C.7
	Handpicking of invertebrates	Geoduck, sea urchin, sea cucumber	C.10
	Recreational	General description	C.12
	FSC dual fishing	Groundfish by hook and line	C.13
	Aquaculture	Finfish	C.11
		Shellfish	C.11
Other Activities	Coastal infrastructure	Wharves, marinas, etc.	C.14
	Extractive Research	Invasive (bottom long-line) fishery surveys	C.15
	Land-use	Outfalls	C.16
	Log dumps	Movement and storage of logs	C.17
	Petroleum	Infrastructure and tenures*	C.18
	Vessel use	Vessel discharge	-
		Movement underway	-
		Oil spill	-

Ten standard stressors were identified in this assessment and attributed to the various activities identified. These include: disturbance (noise), removal of biological material, entrapment/entanglement, introduction (aquatic invasive species (AIS)), introductions (nutrients/biological material), contaminants, oil, substrate disturbance (crushing), substrate disturbance (foreign object), and substrate disturbance (sediment resuspension). Each is described in Table 10. Each of these stressors will have a similar pathway of effect on SECs; however, the level and type of effect will be specific to each activity to which the stressor is linked. For example, sediment resuspension from trap fishing will have a different load to that of sediment resuspension from the movement and storage of logs. However, it is important to differentiate between ‘current snap-shot stressors’ (i.e. stressors that are known to occur within the RCAs and can be predicted to a degree of accuracy) and ‘potential’ stressors (i.e. those stressors that occur infrequently and/or unpredictably). Two of the stressors are *potential* stressors: oil and introductions (AIS). The remaining eight stressors are considered *current snap-shot* stressors.

Seventy-nine unique stressors (activity-stressor) were included in the assessment, 62 of which were found to have a potential negative impact on a SEC(s). A full list of activities and associated stressors are presented in Appendix D.

*Table 10: Stressors described in this assessment (adapted from Hannah et al. 2019). *Denotes potential stressors.*

Stressor	Description
Disturbance (noise)	Artificial noise associated with vessels. Noise can range from pervasive low frequency sound from vessel engines to short-term noise from anchor deployment and retrieval. Also includes the vibration associated with sound. This stressor could potentially impact all SECs, but has a more significant impact on species SECs.
Removal of biological material	This stressor includes biological material (flora and fauna) that is removed as targeted catch, bycatch, sampling, etc. and other activities that remove biological material from the environment. This stressor can impact all SECs.
Entrapment/ entanglement	The entrapment or entanglement of organisms can occur from discarded or lost fishing gear. Ghost fishing is included as part of this stressor. This stressor is specific to species SECs.
Introductions (aquatic invasive species)*	An organism introduced to an area outside the natural range and distribution that can become established and have a negative impact on the native environment. This stressors refers to the establishment of an aquatic invasive species, rather than exposure to a vector, which may not become established This stressor is specific to all SECs
Introductions (nutrients/ biological material)	Biological material, including as nutrient rich sewage and bycatch/by-product from commercial vessels. This stressor is capable of impacting all SECs.
Contaminants	Contaminants are specific to the activity producing them. For example, the contaminants associated with operational discharge from vessels (ballast) are different from the contaminants associated with outfalls. This stressor is capable of impacting all SECs.
Oil*	This stressor is specific to oil spill and can consist of a range of oil types. This stressor is capable of impacting all SECs.
Substrate disturbance (crushing)	Crushing of benthic substrate and communities from traps, anchors, etc. This stressor is specific to habitat SECs only.
Substrate disturbance (foreign object)	An obstacle affecting or altering habitat that would not naturally occur. This stressor is specific to habitat SECs only.
Substrate disturbance (resuspension)	The resuspension of sediment particles into the water column from interaction with benthic substrates. The amount of sediment resuspended will be specific to the activity that produces the stressor. This stressor is capable of impacting all SECs.

4.3.3 Level 1 Qualitative Risk Assessment Results

SEC-Stressor Interaction Matrix

The SEC-stressor interaction matrix is presented in Appendix D showing potential negative interactions between identified stressors and selected SECs. A total of 127 potential negative SEC-stressor interactions were identified of a potential 237 interactions assessed by the matrix. While the matrix method filtered out 110 stressors, only one activity was removed from the assessment at this stage: handpicking of invertebrates. Some potential positive interactions (where the SEC benefits for a period of time from interaction with the stressor) were identified. However, these positive interactions were not included in the matrix, as this type of interaction is not accounted for in the ERAF scoring rubric.

Scoring Risk Variables

A review of available data and known gaps for each activity in relation to RCAs are presented in Appendix C. Select information from Appendix C is included in the scoring justifications presented in Appendices E and F. Where information was unavailable, other applications of the ERAF from the Pacific Region were used (Murray et al. 2016; Rubidge et al. 2018; Hannah et al. 2019) as a guide when scoring to reduce uncertainty, ensure consistency, and provide scoring justifications. Both the SK-B MPA and HS/QCS MPA risk assessments include Inshore Rockfish, various fish, invertebrates, and algal species, and reefs. A total of 644 risk terms were scored (including uncertainty scores). Scores and justifications are presented in Appendix E.

Uncertainty

Uncertainty was generally scored higher for $Exposure_{sc}$ than for $Consequence_{sc}$ for some stressors because there was more information available on the consequences of interactions between a stressor and a SEC. Exposure factor, $Load_s$, was associated with high uncertainty scores. Stressors that are difficult to predict and/or have rarely occurred in BC waters, such as potential stressors *introductions (aquatic invasive species) [various activities]* and *oil spill [oil spill],* had higher uncertainty scores than stressors known to continuously occur in RCAs.

Relative Risk ($Risk_{sc}$)

Median $Risk_{sc}$ scores and associated uncertainties were calculated for each SEC. The resultant plots highlight the uncertainty of each variable and the degree to which $Exposure_{sc}$ and/or $Consequence_{sc}$ drives the estimated $Risk_{sc}$ scores. The five stressors that have the highest estimated $Risk_{sc}$ scores for each SEC are presented in Table 11 along with the median $Exposure_{sc}$ and $Consequence_{sc}$ scores used to create the $Risk_{sc}$ score. The full results are presented in Appendix G.

Inshore Rockfish

The five stressors with the highest Risk_{sc} score affecting Inshore Rockfish are related to removal of biological material from FSC dual fishing groundfish hook and line (Dual-FSC fishing) and Crab by Trap, oil from oil spills, and contaminants from outfalls and log storage (Table 11). High uncertainty relative to the Risk_{sc} score is associated with each of theses stressors. The Risk_{sc} score for each of the top five stressors is driven by $\mathrm{Exposure}_{sc}$ with the exception of [oil spill] oil, which has low $\mathrm{Exposure}_{sc}$ (5.72) but high $\mathrm{Consequence}_{sc}$ (16.64). The $\mathrm{Exposure}_{sc}$ scores for Crab by Trap [removal of biological material] were more than five times higher than the $\mathrm{Consequence}_{sc}$ score (23.07 and 4.41, respectively). Overall, the highest uncertainties were associated with the stressors with the highest Risk_{sc} scores (e.g. oil from vessel oil spills; Figure 8). All $Risk_{sc}$ scores for Inshore Rockfish are presented in Appendix G1.

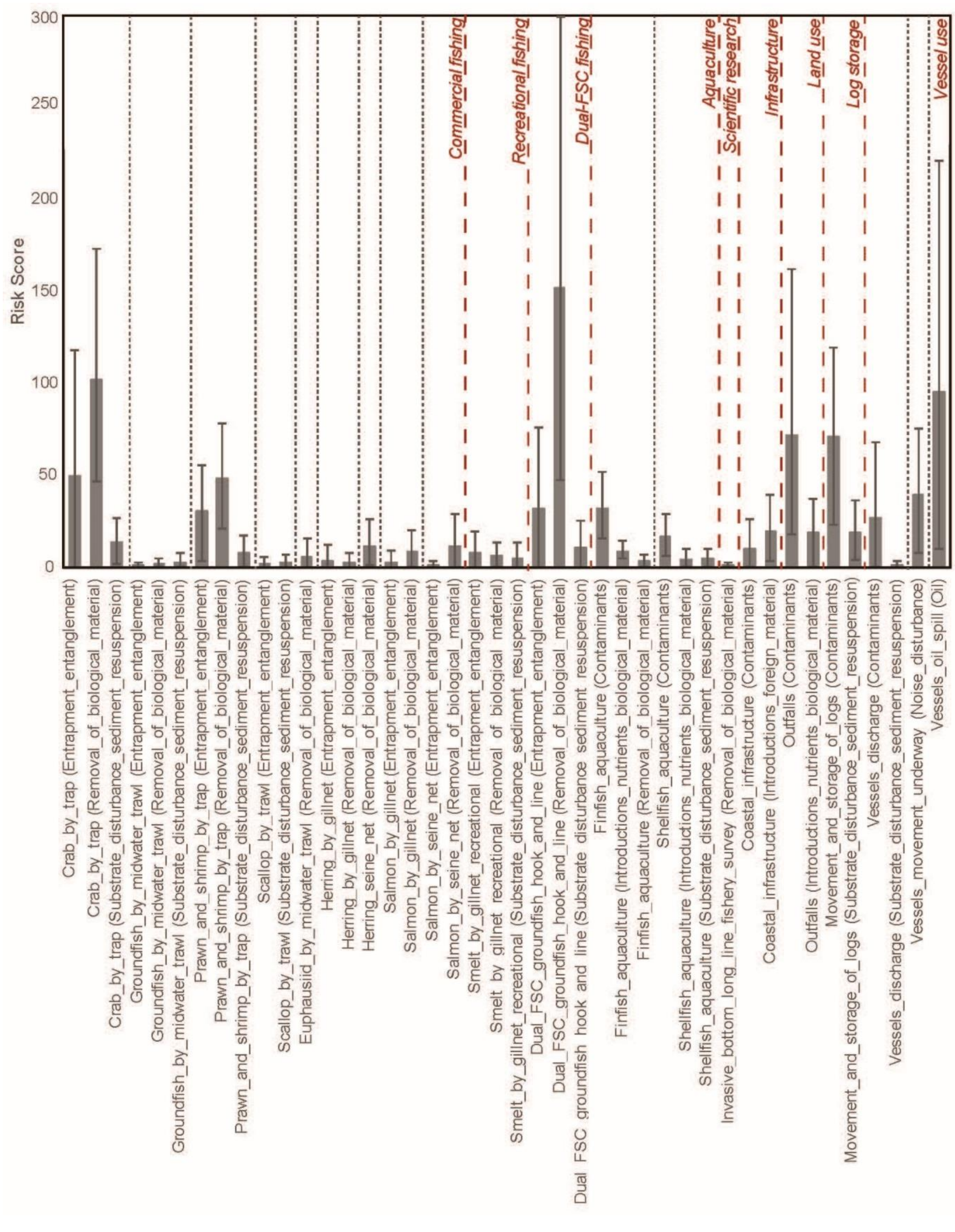

Figure 8: Median risk scores for Inshore Rockfish and 10/90% quantiles. Activities are grouped by type: commercial fishing, recreational fishing, Dual-FSC fishing, aquaculture, scientific research, infrastructure, land use, log storage, and vessel use. Black dotted lines represent divisions between sub-activities.

Rockfish Prey Species

The five stressors with the highest *$Risk_{sc}$* score affecting Prey are related to *removal of biological material* from *Prawn and Shrimp by Trap, Introductions (aquatic invasive species)* from *coastal infrastructure*, *oil* from *oil spill*, and *contaminants* from *outfalls* and *movement and storage of logs* (Figure 9; Table 11). The highest uncertainties are associated with each of the highest *$Risk_{sc}$* scores. The two highest stressors, *Prawn and Shrimp by Trap [removal of biological material]* and *coastal infrastructure [introductions AIS]*, have almost evenly weighted *$Exposure_{sc}$* and *$Consequence_{sc}$* scores (*$Exposure_{sc}$* of ~12 and *$Consequence_{sc}$* of ~9 for both) (Table 11). This is in contrast to *oil spill [oil],* which has a *$Consequence_{sc}$* score nearly four times higher than the *$Exposure_{sc}$* score (16.52 and 5.24, respectively), and *outfalls [contaminants]* and *movement and storage of logs [contaminants],* which both have *$Exposure_{sc}$* scores four times higher than *$Consequence_{sc}$* scores (*$Exposure_{sc}$* ~16, *$Consequence_{sc}$* ~4) (Table 11). All *$Risk_{sc}$* scores for Prey are presented in Appendix G2.

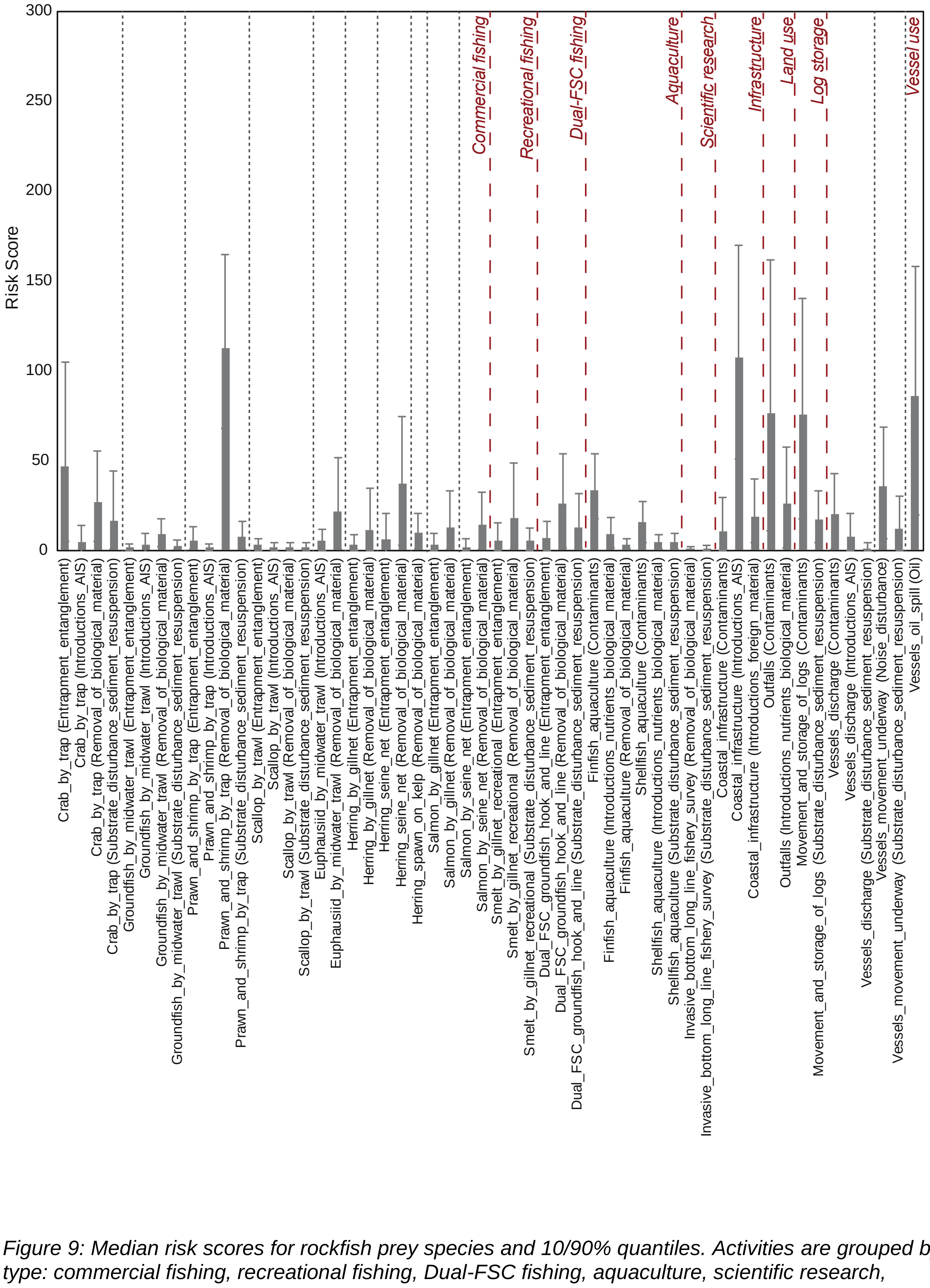

Figure 9: Median risk scores for rockfish prey species and 10/90% quantiles. Activities are grouped by type: commercial fishing, recreational fishing, Dual-FSC fishing, aquaculture, scientific research, infrastructure, land use, log storage, and vessel use. Black dotted lines represent divisions between sub-activities.

Rocky Reefs

The stressors with the highest *Risk$_{sc}$* score impacting Rocky Reefs include *outfalls* [*contaminants*], *coastal infrastructure [introductions of AIS]*, and *oil spill [oil]* (Figure 10; Table 11). The highest relative uncertainties are associated with these stressors. The next two highest stressors have approximately half the risk scores of the top three stressors: *Crab by Trap [substrate disturbance sediment resuspension]* and *coastal infrastructure [contaminants]* (Figure 10; Table 11). *Outfalls [contaminants]* and *coastal infrastructure [introductions AIS]* have slightly higher *Exposure$_{sc}$* scores than *Consequence$_{sc}$* scores (*Exposure$_{sc}$* 15.37 *Consequence$_{sc}$* 9.49 and *Exposure$_{sc}$* 11.86 and *Consequence$_{sc}$* 9.27, respectively) (Table 11). *Oil spill [oil]* has a *Consequence$_{sc}$* more than two times that of *Exposure$_{sc}$* (Table 11). Conversely, the fourth and fifth highest stressors *(Crab by Trap [substrate disturbance sediment resuspension]* and *coastal infrastructure [contaminants]*) have low *Consequence$_{sc}$* scores (4.79 and 4.69, respectively) and relatively high *Exposure$_{sc}$* scores (12.67 and 8.00, respectively) (Table 11). All *Risk$_{sc}$* scores for Rocky Reefs are presented in Appendix G3.

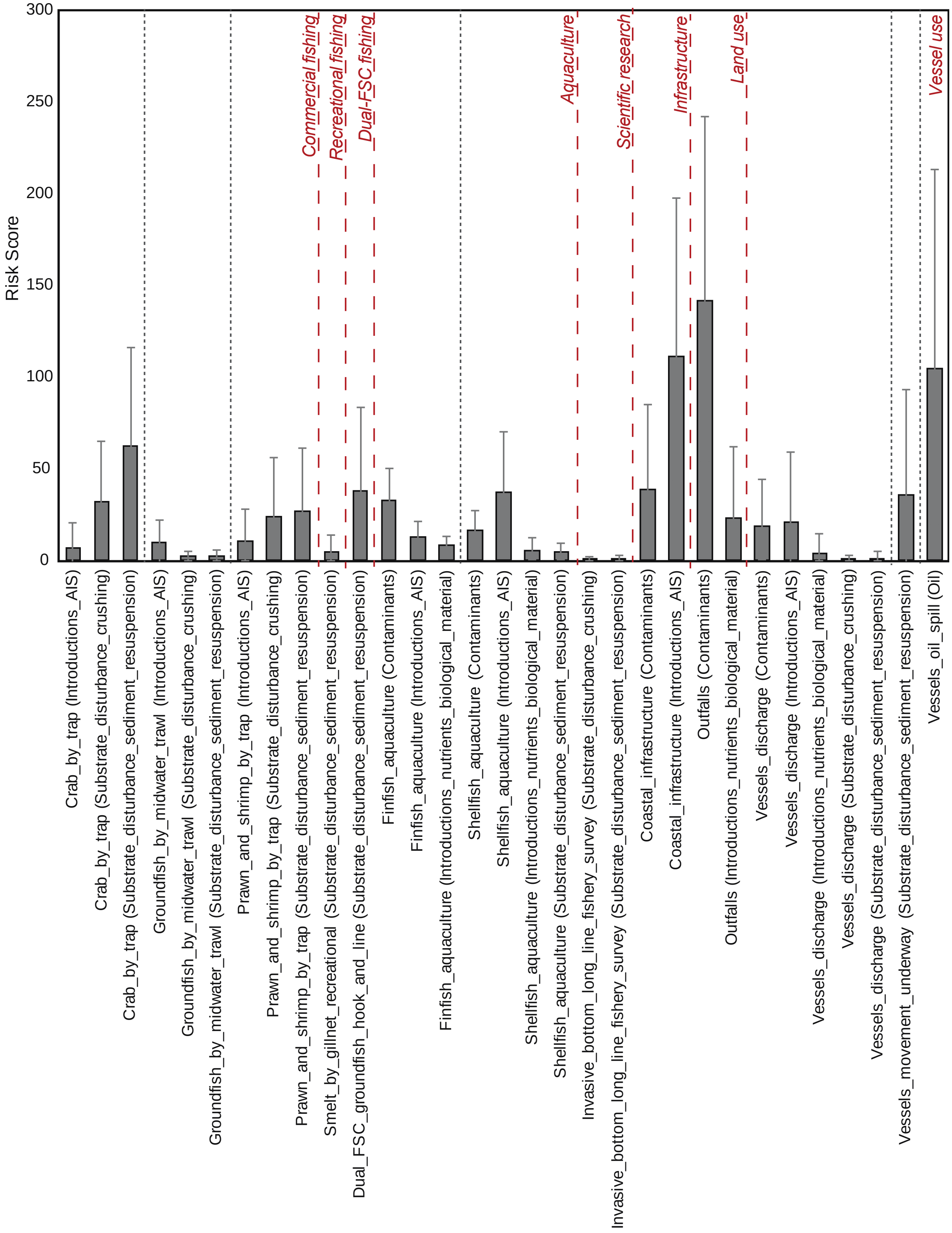

Figure 10: Median risk scores for rocky reef SEC and 10/90% quantiles. Activities are grouped by type: commercial fishing, recreational fishing, Dual-FSC fishing, aquaculture, scientific research, infrastructure, land use, log storage, and vessel use. Black dotted lines represent divisions between sub-activities.

Table 11: The five stressors with the highest estimated median Risk$_{sc}$ scores for each SEC showing 10/90% Quantiles, and the associated median Exposure$_{sc}$ and Consequence$_{sc}$. (a) Rockfish, (b) Rockfish prey, and (c) Rocky Reefs.

(a) Rockfish

Stressor	**Median Risk**	**10% Q**	**90% Q**	***Exposure$_{sc}$***	***Consequence$_{sc}$***
Dual-FSC groundfish hook and line (Removal of biological material)	151.99	47.48	301.27	17.01	8.92
Crab by trap (Removal of biological material)	101.91	46.43	172.90	23.07	4.41
Vessels oil spill (Oil)	95.60	10.17	220.76	5.72	16.64
Outfalls (Contaminants)	71.98	18.20	162.20	16.14	4.40
Movement and storage of logs (Contaminants)	71.18	23.53	119.60	16.40	4.44

(b) Rockfish prey

Stressor	**Median Risk**	**10% Q**	**90% Q**	***Exposure$_{sc}$***	***Consequence$_{sc}$***
Prawn and shrimp by trap (Removal of biological material)	112.16	67.90	164.46	12.40	9.10
Coastal infrastructure (Introductions AIS)	106.97	50.66	169.77	11.68	9.38
Vessels oil spill (Oil)	86.04	20.01	157.63	5.24	16.52
Outfalls (Contaminants)	76.02	10.78	161.82	16.29	4.50
Movement and storage of logs (Contaminants)	75.86	17.71	140.01	16.00	4.61

(c) Rocky Reefs

Stressor	Median Risk	10% Q	90% Q	*$Exposure_{sc}$*	*$Consequence_{sc}$*
Outfalls (Contaminants)	141.87	53.57	242.05	15.37	9.49
Coastal infrastructure (Introductions AIS)	111.21	43.26	197.62	11.86	9.27
Vessels oil spill (Oil)	104.32	20.00	213.34	6.29	16.16
Crab by trap (Substrate disturbance sediment resuspension)	62.03	7.41	115.73	12.67	4.79
Coastal infrastructure (Contaminants)	38.46	8.15	85.33	8.00	4.69

Summary

Overall, the highest estimated $Risk_{sc}$ scores were associated with the highest uncertainties and, similarly, the lowest estimated $Risk_{sc}$ scores were associated with the lowest uncertainties. Of the 127 SEC-stressor interactions scored, $Consequence_{sc}$ was scored as negligible (score=1) for 77 (60.6%) interactions. These specific SEC-stressor interactions resulted in the lowest risk scores for each SEC. However, the stressors that scored as negligible for one SEC were not necessarily scored as negligible for another SEC. For example, *Crab by Trap [removal of biological material]* was scored as minor (score=2) for Inshore Rockfish, but as having a negligible (score=1) effect on Prey.

All $Exposure_{sc}$ and $Consequence_{sc}$ scores are presented in Appendix G.5 and G.6. A ranking of all SEC-stressor interactions by first $Exposure_{sc}$ score, then by $Consequence_{sc}$ score highlighted the risk term ($Exposure_{sc}$, $Consequence_{sc}$, or both) driving the resulting risk scores. The stressors with the highest $Exposure_{sc}$ scores include *vessel movement underway [noise disturbance], Crab by Trap [removal of biological material], outfalls [contaminants], movement and storage of logs [substrate disturbance sediment resuspension],* and *outfalls [introductions nutrients/biological material]* (Appendix G.5). Each of these stressors have a high Temporal overlap (T_s) with RCAs (>6 months of the year) and most have a moderate or high Spatial overlap (S_s) with RCAs. The stressors with the highest $Consequence_{sc}$ scores include *oil spill [oil], vessel discharge [introductions AIS], Crab by Trap [introductions AIS], groundfish by mid-water trawl [introductions AIS],* and *coastal infrastructure [introductions AIS]* (Appendix G.6). All of these stressors are *potential* stressors.

Cumulative Risk *($CRisk_c$)*

Cumulative risk ($CRisk_c$) assesses the cumulative (additive) risk of harm, allowing comparison of SECs on a relative scale. Additionally, the number of SEC-stressor interactions contributing to the $CRisk_c$ score assist in determining the factors driving this score. Overall, the rockfish prey SEC received the highest $CRisk_c$ score (1019.76) and had the highest number of SEC-stressor interactions contributing to this score (54) (Figure 11). Rockfish received the second highest

CRisk$_c$ score (956.56), with 42 SEC-stressor interactions contributing to the score (Figure 11). The rocky reef SEC received the lowest *CRisk$_c$* score (836.35), with the lowest number of SEC-stressor interactions contributing to this score (31) (Figure 11). The 10 and 90% quantiles for each *CRisk$_c$* score overlap between SECs, indicating little differentiation on a relative scale.

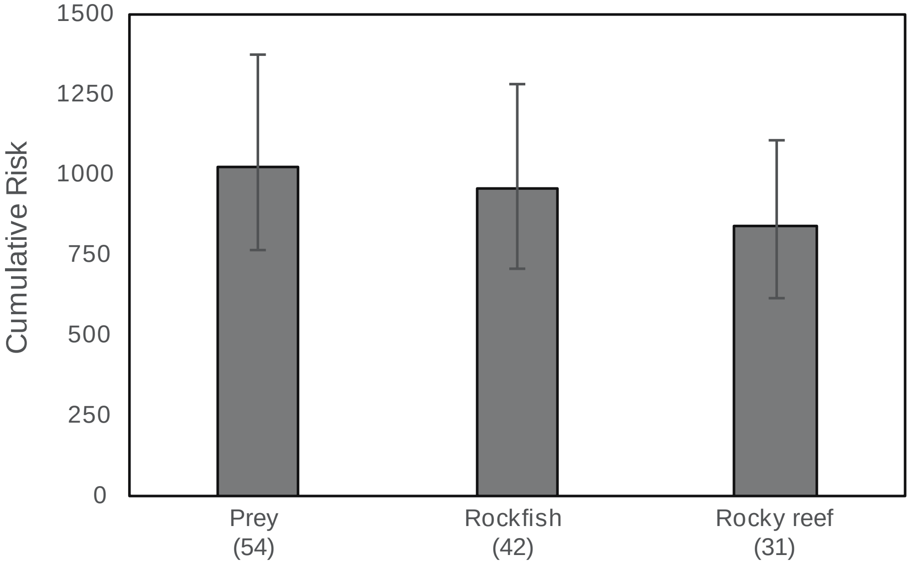

Figure 11: Estimated CRisk$_c$ for each SEC, ranked in descending order with 10/90% error bars.

Potency$_s$ - Cumulative Risk by Stressor

The 15 stressors with the highest *Potency$_s$* scores are displayed in Figure 12. The number of SECs contributing to the estimated *Potency$_s$* scores ranged between one and three (Figure 12). *Outfalls [contaminants]* and *oil spill [oil]* had the highest estimated *Potency$_s$* scores, with a score of 311.55 (all SECs) and 295.45 (all SECs), respectively (Figure 12). *Coastal infrastructure [AIS]* had the third highest *Potency$_s$* score (266.39), impacting Rocky Reefs and Prey (Figure 12). The fourth and fifth highest *Potency$_s$* scores were *dual-FSC groundfish (hook and line) [removal of biological material]* (166.20; Inshore Rockfish and Prey) and *Prawn and Shrimp by Trap [removal of biological material]* (161.41; Inshore Rockfish and Prey). While the highest uncertainty scores were associated with the highest *Potency$_s$* scores, the sixth and ninth stressors (*movement and storage of logs [contaminants]* and *Crab by Trap [entrapment/entanglement]*) had notably higher uncertainties associated with them relative to other lower ranked stressors (Figure 12).

While the top two stressors have all SECs contributing to their estimated *Potency$_s$* score, the number of SECs does not necessarily translate to the highest estimated *Potency$_s$* score. Seven of the top 15 stressors with the highest *Potency$_s$* score had only two SECs contributing to the overall *Potency$_s$* score. Of the 62 unique activity-stressor combinations, 52 (83.9% of total) scored less than a quarter of the stressor with the highest *Potency$_s$* score *outfalls [contaminants]*.

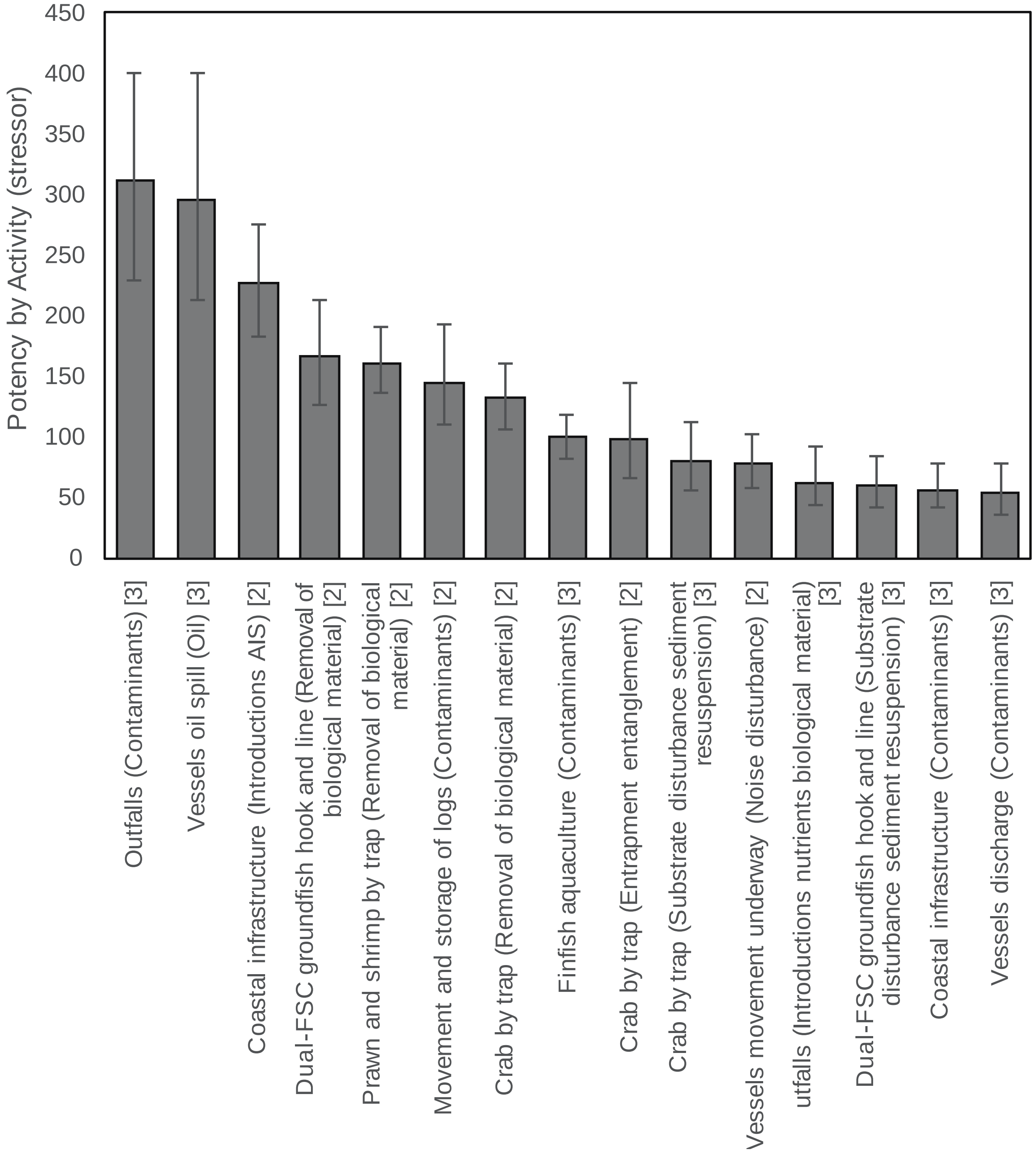

Figure 12: Estimated cumulative risk by stressor-activity (Potency$_S$) for the 15 stressors with the highest scores ranked in descending order with 10/90% quantiles. The number of SECs each stressor-activity impacts is denoted by square brackets.

Potency$_S$ **- Cumulative Risk by Stressor Category**

Ten stressor categories (described in Table 10) were considered in the risk assessment. The *Potency$_S$* analysis by stressor category identified *contaminants* as having the highest *Potency$_S$* (cumulative (additive) risk) score, with the highest associated uncertainty and 17 SEC-stressor interactions contributing to the score (Figure 13). The *removal of biological material* is the second highest stressor category, with high associated uncertainty and 26 SEC-stressor interactions (mostly related to fishery activities) contributing to the score. *AIS*, a *potential* stressor, had the third highest *Potency*$_s$ by stressor category, with 14 SEC-stressor combinations contributing to the score. Sediment resuspension had the fourth highest *Potency*$_s$ score, but the highest number of SEC-stressor interactions contributing to the score (Figure 13). Oil, a *potential* stressor, had the fifth highest *Potency*$_s$ score, with only three SEC-stressor interactions contributing to the score. *Entrapment/entanglement* had the sixth highest *Potency*$_s$ score, with 19 SEC-stressor interactions contributing to the score. *Nutrients/biological material, noise disturbance, crushing*, and *foreign material* have the lowest *Potency*$_s$ scores, with 10, 2, 5, and 2 SEC-stressor interactions contributing to the scores, respectively.

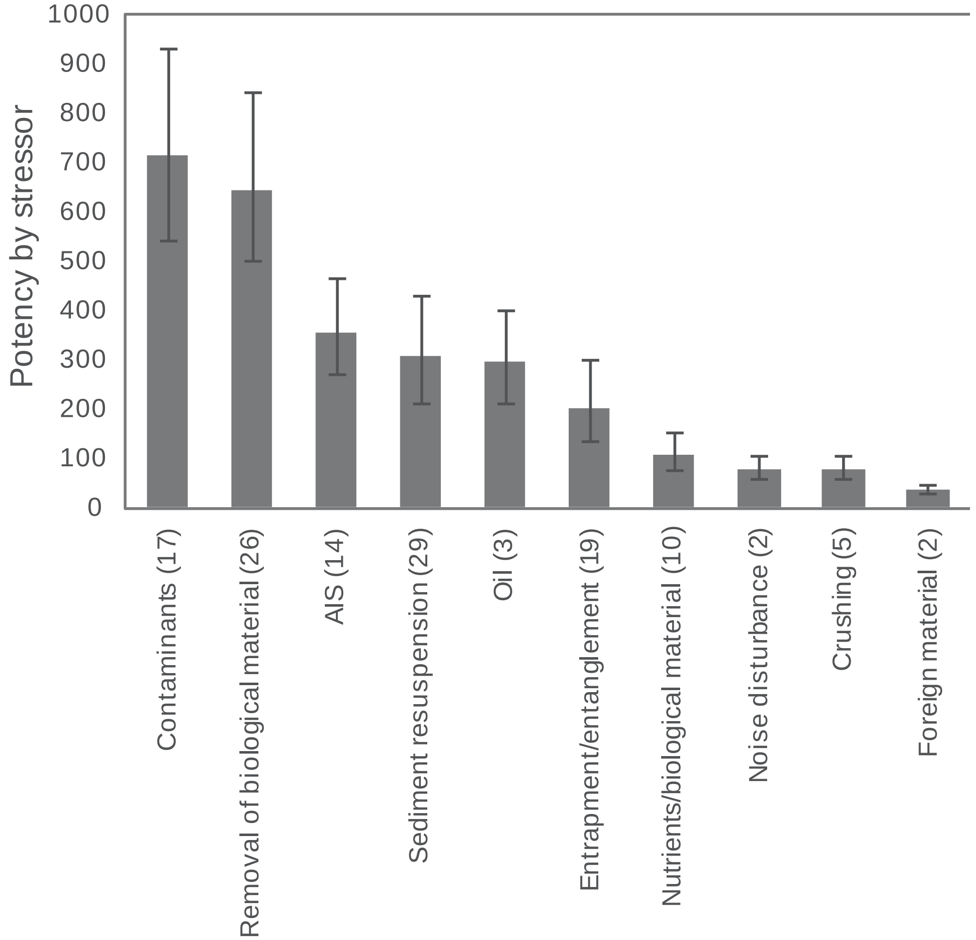

Figure 13: Estimated potency (cumulative risk) of stressors included in the risk assessment, ranked in descending order with 10/90% quantiles. The number of SEC-stressor interactions per stressor is denoted in brackets.

Potency$_a$ - Cumulative Risk by Activity

Outfalls had the highest *Potency*$_a$ by activity level, impacting all SECs but with only two stressors associated with the activity (Figure 14). *Crab by Trap* is the second *Potency*$_a$ score with the maximum number of SEC-stressor interactions per activity (10) contributing to the score. *Coastal infrastructure* (7 SEC-stressor interactions), *oil spill* (3 SEC-stressor interactions), *Prawn and Shrimp by Trap* (10 SEC-stressor interactions), and *Dual-FSC groundfish (hook and line)* (7 SEC-stressor interactions) had the third to seventh highest *Potency*$_a$ scores (Figure 13). The average *Potency*$_a$ score across the 21 activities assessed was

133.94. 48% of these activities had a $Potency_a$ score of less than half the average (score <99.96).

The $Potency_a$ by activity analysis results are linked to the number of SEC-stressor combinations the activity produced. A low number of SEC-stressor interactions were generally linked to a low $Potency_a$ score, with the activities ranked 15-21 all with less than seven SEC-stressor interactions. *Herring spawn-on-kelp* was found to have the second lowest $Potency_a$ score and produced a single SEC-stressor interaction. A notable outlier is *oil spill*, which ranked as the fourth highest activity and produced only three SEC-stressor interactions. Conversely, Groundfish by mid-water trawl are ranked fourteenth by $Potency_a$ score, but produced ten SEC-stressor interactions. Generally, higher uncertainty was associated with the highest ranked activities and the lowest uncertainties associated with the lowest ranked activities.

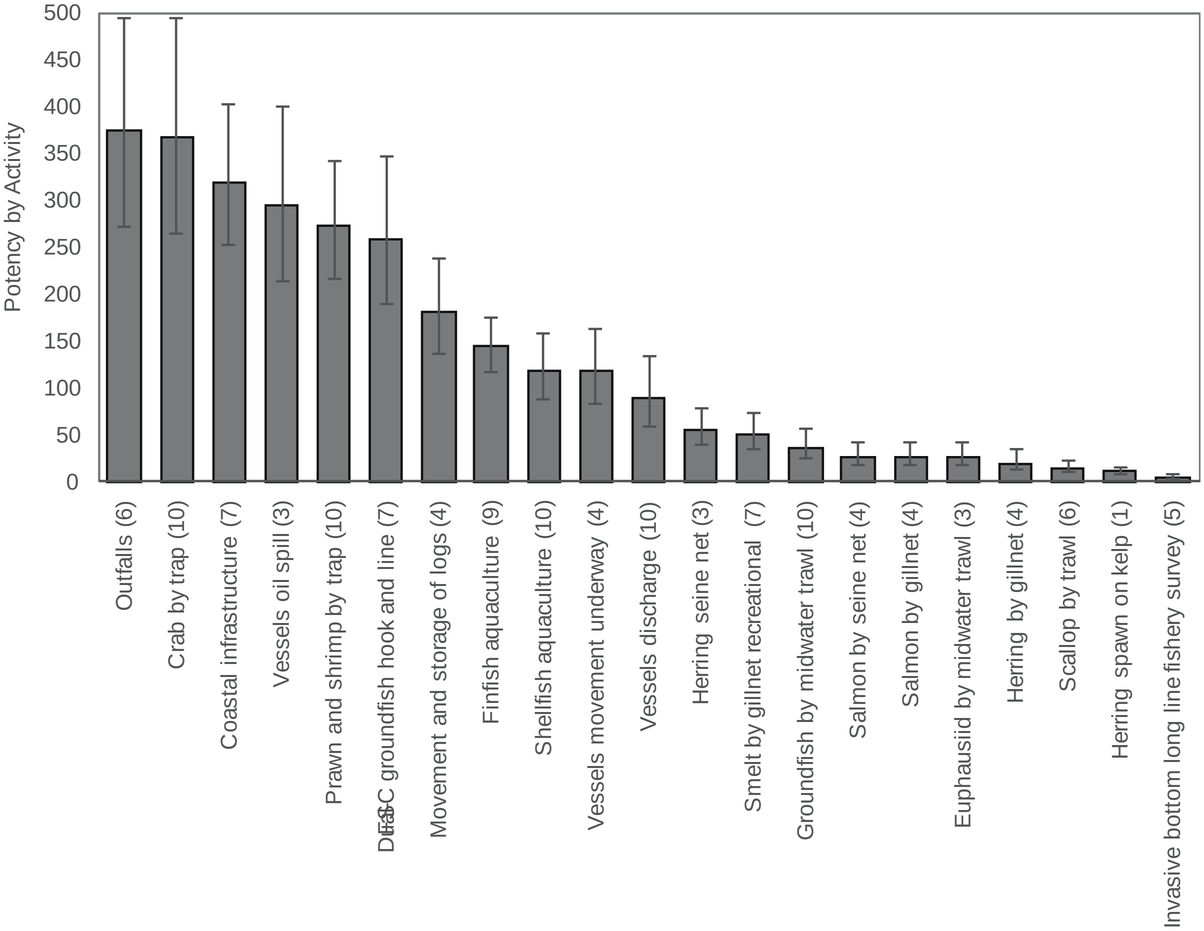

Figure 14: Estimated potency (cumulative risk) of activities included in the risk assessment, ranked in descending order with 10/90% quantiles. The number of SEC-stressor interactions that each activity produces is denoted in brackets.

4.4 DISCUSSION

4.4.1 Outcomes of the Level 1 Risk Assessment

$Risk_{sc}$ represents the relative estimated risk to SECs from anthropogenic activities and associated stressors. By summing the risk score across all SEC-stressor interactions by SEC (cumulative risk), comparisons can be drawn between SECs. While the cumulative risk score for Inshore Rockfish and Prey are similar, Prey has a slightly higher score and is impacted by 54 stressors, compared with 42 stressors impacting Inshore Rockfish. This indicates that stressors affecting Inshore Rockfish result in relatively higher effects (and $Risk_{sc}$ scores), but that Prey are at higher risk from multiple stressors occurring simultaneously. This difference can be further explained by examining the difference in stressors impacting the two SECs, the associated uncertainty, and how Prey were scored. The additional stressors impacting Prey contributes to the $CRisk_{c}$ (cumulative by SEC) score, many of which are related to *introductions [AIS]* and tend to have higher uncertainty scores associated with $Consequence_{sc}$. While this risk assessment included a range of activities, the majority of activities were related to fishing. With the exception of fisheries targeting groundfish, Prey are the target of most of the remaining fisheries. The Prey SEC comprises a range of species with differing sensitivities to disturbances and recovery times, and the species that are impacted by activities in this assessment tend to be invertebrates, which are particularly prone to stressors such as *oil* and *contaminants*. Scoring is based on the most sensitive species within the Prey SEC for that is being impacted by each stressor and, as a result, $Consequence_{sc}$ is scored higher more consistently than if a single prey species had been assessed. This method of scoring resulted in higher uncertainty scores for Prey than for Inshore Rockfish. While Inshore Rockfish are also made up of several species with different prey and habitat preferences, the consequences of being exposed to stressors are generally similar, and this factor does not inflate the uncertainty score.

Inshore Rockfish

The amount of information available for the Inshore Rockfish SEC, both for terms of $Exposure_{sc}$ and $Consequence_{sc}$, far outweighed the information available for Prey and Rocky Reef SECs. This helped to reduce uncertainty when scoring $Consequence_{sc}$ for some activities. However, because RCAs are designed to protect BC's Inshore Rockfish populations, and the risk objective focuses on effects at this scale (rather than at an individual RCA scale), uncertainty is increased for some stressors when scoring $Consequence_{sc}$. The stressors with the highest impact on Inshore Rockfish are related to *removal of biological material* from *Dual-FSC groundfish (hook and line)* and *Crab by Trap*, *oil* from *oil spills*, and *contaminants* from *outfalls* and *log storage. Dual-FSC groundfish (hook and line)* is one of two activities that targets groundfish included in the risk assessment; however, it is the $Exposure_{sc}$ score that is driving this result, as it is nearly double that of the $Consequence_{sc}$ score. While some catch data are available on the *dual-FSC groundfish hook and line* fishery, the full extent of catch in RCAs is not known. As a result, $Exposure_{sc}$ terms Load and Temporal were scored as moderate and moderate/high, respectively, with associated moderate to high uncertainty scores. Inshore Rockfish can be caught as both target and bycatch by *dual-FSC groundfish hook and line,* depending on the species being targeted. Conversely, Inshore Rockfish are impacted by *Crab by Trap [removal of biological material]* by being caught as bycatch. This stressor was identified as having the second highest $Exposure_{sc}$ score, mostly due to the fishery being open year-round in some areas. $Exposure_{sc}$ was almost six times higher than $Consequence_{sc}$ of this stressor, which was scored as having minimal impact on Inshore Rockfish in RCAs.

The third highest stressor impacting Inshore Rockfish, *oil spill [oil]*, is a *potential* stressor, meaning that occurrence (temporal and spatial) and volume and type of oil are difficult to predict (although model simulations based on automatic identification system data can provide guidance) driving uncertainty scores. A high $Consequence_{sc}$ score is driving the risk score for this stressor, based on the potential of a large-scale oil spill occurring in Inshore Waters impacting multiple RCAs and the toxicity of oil to rockfish.

Contaminants from *outfalls* and *log storage* were identified as the fourth and fifth highest ranked stressors impacting Inshore Rockfish, which both have $Exposure_{sc}$ scores four times that of $Consequence_{sc}$ scores. This is due to the year-round exposure to these stressors (high temporal overlap), a moderate load of contaminants relative to other activities included in this assessment, and the associated high uncertainties around the type and level of contaminants impacting RCAs, and therefore the *Consequence*$_{sc}$ on Inshore Rockfish.

Prey

Prey of Inshore Rockfish is most at risk from *Prawn and Shrimp by Trap [removal of biological material], coastal infrastructure [introductions (AIS)]*, *oil spill [oil]*, and *contaminants* from *outfalls* and *movement and storage of logs. Prawn and Shrimp by Trap [removal of biological material]* has almost evenly weighted *Exposure*$_{sc}$ and *Consequence*$_{sc}$ scores. Inshore Rockfish prey includes a range of species and sizes and includes prawn and shrimp species that are targeted by the *Prawn and Shrimp by Trap* fishery. While the sizes of the prawns removed as part of this fishery are generally too large to be Inshore Rockfish prey, smaller prawns and shrimp do make up a small proportion of Inshore Rockfish diet. The assessment considers the impacts of this stressor on the prawn and shrimp population (including those too large to be prey) as any reduction in population size of a prey species could impact Inshore Rockfish as a secondary effect. Secondary impacts on Inshore Rockfish and the result of this scoring approach are discussed in more detail below.

Coastal infrastructure [introductions (AIS)] is a *potential* stressor driven by almost equal *Exposure*$_{sc}$ and *Consequence*$_{sc}$ scores. As Prey comprise a range of species that include benthic communities, this stressor was scored based on the potential introduction of either a species such as Green Crab or an invasive tunicate becoming established and impacting these sensitive communities. Highly mobile Prey species (e.g. herring) are not expected to be impacted by this stressor. Another *potential* stressor identified as being high risk to Prey includes oil spill [oil], with a *Consequence*$_{sc}$ score more than three times higher than the *Exposure*$_{sc}$ score. This scoring was based on the sensitive invertebrate Prey species, assuming a large-scale oil spill. *Contaminants* from *outfalls* and *movement and storage of logs* are high risk stressors to Prey, both with *Consequence*$_{sc}$ scores four times higher than *Exposure*$_{sc}$ scores. While not a *potential* stressor, the *Consequence*$_{sc}$ score is (similar to *oil spill [oil]*) likely inflated due to unknown volumes, types and effects on a range of Prey species in RCAs.

Rocky Reefs

The Inshore Rockfish habitat SEC, Rock Reefs, is most at risk from *outfalls* [*contaminants*], *coastal infrastructure [introductions of AIS]*, and *oil spill [oil]*. The high scores associated with *outfalls [contaminants]* are associated with high *Exposure*$_{sc}$ scores (ranked as the stressor with the third highest *Exposure*$_{sc}$ score), as it is a year-round stressor that occurs in or near 29 RCAs. However, the *Consequence*$_{sc}$ scores are low/moderate, but with moderate uncertainty.

Both the establishment of AIS and oil from oil spills are considered *potential* stressors, meaning that predicting the exact temporal and spatial scale, as well as the load of the stressor, is reliant on historical events and predictive models. Without specific predictive model outputs that overlap with RCAs, the uncertainty associated with the temporal scale of these stressors is moderate to high. Not being able to accurately predict the potential load of these stressors results in precautionary scoring for this *Exposure*$_{sc}$ variable, with load for *oil spill [oil]* scored as the worst-case scenario of a large scale oil spill (high load with high moderate/high uncertainty). However, the *Consequence*$_{sc}$ score for *oil spill [oil]* is more than double that of the *Exposure*$_{sc}$ score. The *Consequence*$_{sc}$ of an oil spill impacting the Rocky Reef habitat was based on a potential high load, with a moderate/high score.

Similarly, *coastal infrastructure [introductions AIS]* was scored based on a scenario where an AIS becomes established and could impact multiple RCAs. However, a recent study of AIS in relation to coastal infrastructure in BC waters (Iacarella et al. 2018) helped to reduce the uncertainty scores associated with scoring terms of *Exposure*$_{sc}$. The potential *Consequence*$_{sc}$ of *coastal infrastructure [introductions AIS]* on Rocky Reef was scored as moderate.

The fourth highest stressor impacting Rocky Reefs was *Crab by Trap [substrate disturbance sediment resuspension],* which was driven by a high *Exposure*$_{sc}$ score, due to the high spatial and temporal overlap, and a moderate *Consequence*$_{sc}$ score. In other ERAF applications in Pacific Region MPAs (Rubidge et al. 2018; Hannah et al. 2019), the sensitive invertebrate communities associated with rocky reefs have been identified as the highest risk SECs. However, these assessments were conducted in MPAs where most fisheries were closed, and those that did occur within boundaries of the MPA were restricted by both temporal and spatial scales.

4.4.2 Addressing OEABCM Criterion 5

This Level 1 qualitative risk assessment was conducted to determine whether the current level of activities in RCAs meet OEABCM criterion 5, which states that “no human activities that are incompatible with conservation of the ecological components of interest may occur or be foreseeable within the defined geographic location”. The ERAF is designed to determine the interaction between selected SECs and the stressors, and prioritize SECs and stressors on a relative scale to inform decision-making. The ERAF does not identify levels of acceptable risk or set thresholds. To avoid selecting a risk threshold that would likely be subjective, the relative rankings are used to identify activities and stressors occurring in RCAs that may prevent the ecological components of interest from being effectively conserved (OEABCM criterion 5). Not all activities identified as high risk will require a management response. This analysis of relative ratings involves identifying both individual stressors and overall activities that pose the highest risk to Inshore Rockfish, their Prey, and Rocky Reef habitat.

It is unlikely that all 127 identified SEC-stressor interactions would individually affect RCAs in such a way that would prevent criterion 5 from being met. Examining risk across this broad distribution of risk levels, nine activity-specific stressors stand out as having more than two times (and in the most extreme case, 6.9 times) the average risk score. These include *outfalls [contaminants]*, *oil spill [oil]*, *coastal infrastructure [AIS], dual-FSC groundfish (hook and line) [removal of biological material], Prawn and Shrimp by Trap [removal of biological material]*, *movement and storage of logs [contaminants], Crab by Trap [removal of biological material], finfish aquaculture [contaminants],* and *Crab by Trap [entrapment/entanglement].* This list of the nine highest risk stressors aligns with the eight activities with the highest *Potency*$_a$ risk scores: *outfalls, Crab by Trap, coastal infrastructure, oil spill, Prawn and Shrimp by Trap, dual-FSC groundfish (hook and line), movement and storage of logs,* and *finfish aquaculture*. These activities have *Potency*$_a$ by activity scores higher than the average across all activities, and the top five activities have more than double this average. Similarly, the nine highest risk stressors align with the stressor categories with the highest *Potency*$_s$ scores: *contaminants, removal of biological material, Introductions (AIS), oil,* and *entrapment/entanglement* (with the exception of *substrate disturbance (sediment resuspension),* ranked the fourth highest stressor category by *Potency*$_s$ score). The eight highest risk activities with the potential to prevent OEABCM criterion 5 being met are discussed below.

Outfalls

The activity with the highest risk across analyses was *outfalls,* largely driven by the year-round exposure of RCAs and potentially high impact of *contaminants*, which is also the highest ranked stressor category. There are only two stressors linked to *outfalls* (*contaminants* and *introductions (nutrients/biological material)*), but these stressors affect all three SECs. Due to the fixed positions of the outfalls, it is expected that RCAs within the zone of influence for these outfalls are currently being negatively impacted. There is moderate uncertainty around the potential load of this stressor due to the unknown contaminant type, amount, and consequences on RCAs, but low uncertainty associated with temporal and spatial overlap. As more information becomes available about outfall volumes and contaminant type, load may be better quantified and uncertainty associated with scoring the consequence of this activity on SECs would be reduced.

Crab by Trap

Crab by Trap is the second highest activity identified by the cumulative analysis and produces the highest number of SEC-stressor interactions, as well as having two stressors (*removal of biological material* and *entrapment/entanglement*) listed in the top nine $Potency_s$ by stressor results risk results. *Crab by Trap* is considered a likely threat to the conservation of Inshore Rockfish, but it should be noted these risk scores are driven by high exposure scores across all RCAs as *Crab by Trap* is permitted year-round in some RCAs. As *Crab by Trap* does not occur in all RCAs year-round, it is likely that the risk to those RCAs that are not exposed to the activity year-round will be at lower risk.

Coastal infrastructure

Coastal infrastructure is the third highest risk activity impacting RCAs. This activity produces three stressors (*introductions [AIS], contaminants,* and *introduction of foreign material*) and seven SEC-stressor interactions. *Coastal infrastructure [AIS]* is ranked as the third highest stressor, largely driven by high exposure and consequence to benthic communities, if/when this stressor occurs. Additionally, AIS is a *potential* stressor and the consequence of impacts to SECs is likely inflated, as the precautionary approach was taken to scoring this stressor and moderate/high uncertainty is associated with the risk scores.

Oil spills

Oil spills from vessels are identified as the fourth highest risk activity impacting RCAs. Despite only having a single stressor associated with this activity, *oil spill* comes out high in the assessment because the consequence on Inshore Rockfish, Prey, and Rocky Reef habitat could be catastrophic. This lack of other stressors is why the cumulative risk by activity value is lower than the individual SEC-stressor interaction would otherwise indicate. This stressor was identified as the second highest risk stressor impacting RCAs through analysis of $Potency_s$. Oil spills are considered a *potential* stressor, which is a stressor where the terms of exposure cannot be accurately predicted and are therefore difficult to manage. There is moderate/high uncertainty associated with this activity, which further inflates risk scores. This activity is scored based on shipping vessels and the oil types that could be spilled from this kind of vessel. However, it should be noted that oil spills from smaller commercial vessels such as fishing vessels would likely be fuel spills at much smaller scales. Oil spills have been identified in other ERAF applications in the Pacific Region as one of the highest impact activities to occur in BC (Murray et al. 2016; Rubidge et al. 2018; Thornborough et al. 2018; Hannah et al. 2019). A large oil spill event would impact the conservation of Inshore Rockfish, their Prey, and Rocky Reef habitat.

Prawn and Shrimp by Trap

The activity with the fifth highest risk is *Prawn and Shrimp by Trap*, which produces ten SEC-stressor interactions. The risk from this activity is largely driven by a number of minimal or low interactions with SECs and moderate exposure scores, but also by the moderate consequence score to Prey, due to the direct targeting of Prey (in this case, prawns and shrimp). However, prawn and shrimp do not appear to make up a high proportion of Inshore Rockfish diet, and the secondary impacts on Inshore Rockfish are not expected to be high.

FSC dual fishing groundfish hook and line

Dual-FSC groundfish hook and line are the sixth highest risk to RCAs, producing seven SEC-stressor interactions. As one of the two targeted groundfish fisheries, this activity is considered a risk to Inshore Rockfish as both directed and incidental bycatch. While the effort (or load) is expected to be low to moderate, with a lack of reporting data for the locations and timing of fishing events and the potential to be able to operate for more than six months of the year in most areas, the risk from this activity is being driven by exposure scores. Additionally, there is potential for the gear used in this fishery to damage sensitive benthic communities of Rocky Reefs, but the full effects are not known. There are high uncertainties associated with this activity, indicating the need for increased reporting and data collection.

Movement and storage of logs

The seventh highest ranked activity impacting RCAs is movement and storage of logs. This activity only produces two stressors (*contaminants* and *sediment resuspension*) and four SEC-stressor interactions. The overall risk score for this activity is driven by high exposure scores (as this is a year-round activity) and associated uncertainty. The consequence of this activity on Inshore Rockfish and Prey is negligible from *sediment resuspension* and minor from *contaminants*, but the high exposure to these stressors likely results in reductions in health and changes in distribution of Inshore Rockfish and their Prey.

Finfish aquaculture

Finfish aquaculture was identified as the eighth highest risk to RCAs, producing nine SEC-stressor interactions, one of which, *finfish aquaculture [contaminants],* is also the eighth highest ranked stressor by $Potency_S$ score. All nine interactions between *finfish aquaculture* stressors and SECs were scored as having either a negligible or minor impact on the SECs. However, driving this risk score is the temporal overlap of this activity with RCAs (year-round) with low uncertainty. This activity is not currently considered a risk to the collective network of RCAs; however, it will likely contribute to the cumulative effects of multiple activities and stressors.

4.4.3 Risk across all RCAs

Application of the Level 1 qualitative ERAF focused on the assessment of RCAs collectively, rather than at an individual level, to be able to assess if the collective group of RCAs are effectively protecting Inshore Rockfish, their Prey, and Rocky Reef habitat. In taking this approach, a single risk score was given for each SEC-stressor interaction that represents the risk to the collective population/distribution of SECs. However, it is unlikely that all activities and stressors occur in all RCAs, and those that do occur within the same RCA may not occur simultaneously. Additionally, Rocky Reef has been found to occur in only 23.58% of total RCA area, and may not overlap with all stressors that occur within the bounds of RCAs. This approach, while necessary to assess the risk of harm to Inshore Rockfish across all RCAs and aligning with best practice by employing the precautionary approach, will likely inflate the risk score for some stressors. These stressors are generally associated with high uncertainty scores, acting as an indicator for to require more directed research and monitoring to help reduce uncertainties.

Conversely, there is a possibility that activities and stressors that scored very low in the risk assessment because they only occur in a small number of RCAs may be high risk stressors at the scale of an individual RCA. For example, *invasive bottom long-line fishery survey* has been permitted to occur in two RCAs in previous years. The benthic impacts on the scale of an individual RCA are anticipated to be moderate; however, scoring based on the impact to all RCAs is negligible. A further example is mid-water trawling in the Goletas Channel RCA, where approximately 83% of all trawl activity in RCAs occurred (269 fishing events). The potential of these stressors to be high risk at a local scale means that some individual RCAs may not meet the RCA goal. However, this does not impact the overall assessment if the collective network of RCAs is effective at conserving Inshore Rockfish, their prey, and habitat across these areas. Future assessments at the scale of an individual RCA would provide clarity.

4.4.4 Secondary effects and interactions between Inshore Rockfish, their Prey, and Rocky Reef habitat.

The ERAF considers direct interactions between SECs and stressors and does not include secondary or indirect interactions. This is a standard approach for both quantitative/semi-quantitative risk assessments and as the first application of an assessment framework to a location. The inclusion of secondary effects in these assessments reduces the effectiveness of using the cumulative risk or potency analysis to identify the activities and stressors that are preventing the RCA goal from being met, as these analyses assume equal-weighted, additive scores. The inclusion of secondary effects in an impact assessment context is usually reserved for more quantitative cumulative effects assessments and modelling that identify additive, synergistic, compensatory, and masking effects.

This assessment was designed around assessing whether Inshore Rockfish are being effectively conserved by RCAs. The additional SECs (Prey and Rocky Reefs) were selected as SECs that support Inshore Rockfish health within RCAs. As a result, the risks to these SECs are expected to have secondary effects on Inshore Rockfish, where a reduction in the health or distribution of crucial Rocky Reef habitat or a reduction in abundance or condition of Inshore Rockfish Prey could result in impacts to Inshore Rockfish distribution, health, and abundance. However, when examining the impacts of reductions in Prey on Inshore Rockfish, several factors need to be taken into consideration. The first is that the species of Prey scoring is based on changes between stressors and activities. For example, prawn and shrimp are impacted by *Prawn and Shrimp by Trap (removal of biological material),* but herring are the prey species impacted by *Herring by Seine (removal of biological material).* This scoring approach focuses on whether an activity reduces any Inshore Rockfish food sources, and indirectly, whether there would be any potential secondary effect by prey reduction on Inshore Rockfish. The second factor to consider with Prey is that while a species (from juvenile to adult) could be consumed by Inshore Rockfish, the secondary effects on prey reduction on Inshore Rockfish would not be equal across Prey species. For example, herring are a significant proportion of Inshore Rockfish diet, and large scale impacts to herring population could have a significant impact on Inshore Rockfish. Alternatively, prawn and shrimp make up a smaller proportion of Inshore Rockfish diet, and large scale impacts to prawn and shrimp populations may not significantly impact Inshore Rockfish. However, this approach was necessary for this first ERAF application to be able to consider the cumulative effects of all stressors (and activities) on the Prey SEC. Any future semi-quantitative assessment of risk in RCAs should use the outputs of this assessment and consider the stressors identified as having a high impact on Prey, identify Prey species that could be impacted by the activity, and separate these species into individual SECs.

4.4.5 Other activities not included in this assessment

Due to the scope of this Level 1 qualitative risk assessment, not all currently permitted activities were assessed through the formal risk assessment. However, it is important to highlight other activities that could impact, to an unknown degree, the ability of RCAs to effectively protect Inshore Rockfish, their Prey and Rocky Reef habitat.

While impacts for a specific gear type may be similar across commercial, recreational, and FSC fishing, the terms of exposure are different. Relatively fewer restrictions imposed on recreational and FSC fisheries and a lack of compulsory reporting data could result in artificially high exposure scores if they were to be included in the assessment. When little information is available, the scoring of exposure relies on the assumed level of activity and the allowed spatial and temporal extent of the activity. When the only information available is that the spatial and temporal extent of a fishery is unlimited or has very few restrictions, scoring considers the likely exposure level versus the maximum potential exposure and is often scored based on the likely exposure +1, and with high uncertainty to take a precautionary approach.

Most types of FSC fishing was scoped out of the assessment due to a lack of comprehensive data availability during the writing of this report. Many First Nations do collect information on RCA fishing activity, and this is an important area for further research. DFO receives reports on FSC catch for some of the fisheries, but often the information has been aggregated to the larger management areas, often larger than individual PFMAs. FSC fishing can use a wide variety of gear types (e.g. traps, nets, hook and line). Hook and line gear in particular can pose a direct threat of rockfish removals in addition to other indirect threats. If FSC fishing effort is high in RCAs, this could seriously impact the ability of RCAs to protect Inshore Rockfish stocks. Without detailed information on fishing effort, gear types, and catches within RCAs we are unable to determine the scale of impact FSC fishing could pose to RCA effectiveness. Given the current information, impacts could range from negligible to high. This fishery requires further consideration before its impact on RCA effectiveness can be accurately determined.

Additionally, non-compliant activities within RCAs could impact RCA effectiveness but were not considered in this assessment. Research has shown that recreational non-compliance occurs throughout the Strait of Georgia (Haggarty et al. 2016; Lancaster et al. 2017). Recreational fishing activity within RCAs could impact RCA effectiveness. Continued and enhanced monitoring efforts and fisher education could help address these concerns.

DFO actively monitors commercial fisheries, FSC dual fishing fisheries, aquaculture, and recreational fisheries (see section 4 for more detail). Additional non-compliance events such as garbage or chemical dumping could impact RCA effectiveness but are beyond the scope of this assessment. However, monitoring and enforcement are a crucial part of designing and maintaining effective marine reserves (Arias 2015; Edgar et al. 2014), and managers should continue to develop and enhance existing programs.

While not included in this assessment, future consideration should be given to activities (and therefore associated stressors) that occur outside of RCA boundaries, but which may still impact Inshore Rockfish, their Prey, and Rocky Reef habitat. As part of this consideration, buffer zones for specific stressors (e.g. *contaminants*, *sediment resuspension*) should be examined to determine the actual impact inside of RCA boundaries. While this assessment focused on activities that could be managed at the scale of RCAs, there are additional long-range stressors that could impact the long-term conservation and preservation of Inshore Rockfish, including contamination and debris resulting from the 2011 Japan earthquake and tsunami, microplastics, additional vessel noise, and climate change stressors. While outside the scope of this assessment, the addition of long-range impacts as stressors may add value to future risk assessments and any inclusion of long-range stressors should be noted in the results analysis and discussed separately.

4.4.6 Other habitats not included in this assessment

Due to the low spatial overlap between eelgrass beds, kelp forests, and glass sponge reefs and the OEABCM guidance that the inclusion of a single habitat satisfies the assessment requirements, these Inshore Rockfish habitats were not included in the scope of this assessment. Each of these habitats is highly sensitive to disturbance, and degradation or reduction in these habitats could result in negative secondary effects on Inshore Rockfish populations across RCAs. However, without detailed information on the spatial extent of the activities (and associated stressors) within RCAs, the potential consequence to these habitats would be scored using a precautionary approach, inflating risk scores and making comparisons to the SECs included in the current assessment uninformative. The exclusion of these habitats allowed for the effective assessment of relative risk and identification of activities and stressors that may prevent the RCAs from meeting OEABCM criterion 5. However, any assessment of the impacts of activities to individual RCAs should include these habitats in the assessment.

5 RECOMMENDATIONS

1. Clearly outline the specific conservation and/or stock management objectives for RCAs in a single unifying DFO document.
2. Modelled and catch data provide significant evidence to suggest the presence of Inshore Rockfish and their habitat within each RCA. However, the collection of empirical observations in each RCA would further inform the assessment of whether all or individual RCAs meet OEABCM criterion 3 (presence of ecological component of interest).
3. Although there is evidence that the intent was for RCAs to be in place for a long-term duration, to meet OEABCM criterion 4, either a clearly stated long-term management objective in an official DFO publication is required or RCAs must be be entrenched via legislation or regulation. A management objective should take into consideration the biological characteristics (longevity, variability in juvenile recruitment, and sedentary behaviour) that effect the rebuilding of Inshore Rockfish.
4. In order for the network of RCAs to meet OEABCM criterion 5:
   a) Review the spatial extent of permitted activities with the highest relative risk scores in relation to RCA boundaries that directly impact Inshore Rockfish (FSC dual fishing groundfish hook and line, oil spill), their Prey (Crab by Trap, Prawn and Shrimp by Trap, movement of coastal infrastructure through RCAs, oil spill), and Rocky Reef habitat (log dumps, movement of coastal infrastructure, oil spill).
   b) Focus research and monitoring effort to reduce uncertainties, particularly related to outfalls, log dumps, and FSC dual fishing groundfish, and their effects on Inshore Rockfish, rockfish prey, rocky reef habitat. Data availability has been identified throughout this assessment as a factor linked to uncertainty that can impact the final risk results and, in some instances, dictated the inclusion and/or presentation of SECs and activities/stressors in the assessment.
5. Future assessments at the scale of an individual RCA would provide clarity on the impacts of stressors at an individual RCA level. Consideration should be given to assessing the cumulative effects in an individual RCA.
6. Related to the intentions to introduce further management elements stated in criterion 5, consider developing a monitoring plan for the RCA network that includes ecological indicators, baseline monitoring (of rockfish, their prey and habitat), catch reporting, and compliance metrics. Consideration should also be given to the monitoring in RCAs for stressors and activities identified with highest relative risk scores from the risk assessment (contaminants/pollution from outfalls, oil spills, and log storage, the presence of aquatic invasive species, vessel traffic), and long-range stressors that were not evaluated in the risk assessment such as the effects of climate change.

7. Consider improving data collected in RCAs on permitted commercial fishing activities. Such data should include fishing locations, gear use, bycatch, and trap loss.
8. Consider improving fishery monitoring and catch reporting in recreational and First Nations fisheries occurring in RCAs.
9. Consider conducting the following fisheries-related research to improve our understanding of the effects of fishing activities in RCAs:
   a. Rockfish encounter rates in fishing gear, and the potential utility of bycatch reduction devices.
   b. The relationships between rockfish and their prey, and the effects of localized prey depletion.
   c. Impacts to rockfish habitats when fishing gear contacts the seafloor, including mid-water trawls.
   d. The prevalence of lost gear and subsequent capture rates of rockfish and their prey species.
   e. The prevalence of non-compliance within the various prohibited fishing activities.

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APPENDIX A: RCA CONSERVATION, GOALS, OBJECTIVES, AND INTENTS

The primary goal for RCAs is the long-term protection and conservation of a portion of Inshore Rockfish populations (and Lingcod) and their habitat from the effects of fishing (Fisheries and Oceans 2007). As part of this goal, the aim of RCAs is to contribute to coast-wide rebuilding and sustainability of Inshore Rockfish populations, and provide a buffer against scientific uncertainty and gaps in fisheries catch data.

During the RCA planning and implementation process, broad conservation goals and objectives were discussed, both internally and publicly, and were loosely defined in public documents and communication materials. Conservation objectives were described in a 2002 discussion paper used for consultation at that time (DFO 2002B). However, what the document lists as conservation objectives more closely resemble broad goals or vision statements than specific and measureable statements of action needed to meet the goal of RCAs (i.e. objectives). Many of the details relevant to objectives development are provided in later sections of the 2002 discussion paper or in other DFO documents. Unfortunately, a unifying document (e.g. management plan) that outlines specific details of the objectives for RCAs was never developed.

To gain a better understanding of the specific intentions behind the conservation objectives RCAs, we reviewed a collection of internal unpublished dataand public DFO documents (DFO 2000A; 2000B; 2001; 2002A; 2002B; 2002C; 2004A; 2004B; 2007; MacKenzie 2004; Yamanaka and Lacko 2001; Yamanaka and Logan 2010). Based on these documents, the intentions of RCA were:

- Long-term protection and conservation of a portion of juvenile and adult Inshore Rockfish (and Lingcod) populations from fishing activities (DFO 2000A; 2001; 2002C; 2004B; 2007; MacKenzie 2004) that pose a moderate to high risk of causing directed and incidental rockfish mortality (DFO 2004B; Fisheries and Oceans Canada, Pacific Region, unpublished data, 2002). Target areas are within the 0 to 200 m depth range and include locations where there was evidence of depleted populations, abundant rockfish, the presence of juvenile rockfish, and/or viable rockfish habitat (DFO 2000B; 2002B; Fisheries and Oceans Canada, Pacific Region, unpublished data, 2003).
- To establish spatial management in the form of area closures that provide a buffer against scientific uncertainty and gaps in catch data. These closures are developed to specifically address the concern of serial depletion of Inshore Rockfish as a precautionary fisheries management measure that is independent of biomass estimates, target exploitation rates, and quota management (DFO 2001; 2002B; 2002C; Yamanaka and Logan 2010). Decisions about the total percentage of rockfish habitat requiring protection were based on recommendations from DFO Science (Yamanaka and Lacko 2001; Yamanaka and Logan 2010):
  - A 20% closed area was recommended as a precautionary measure to ensure against fishery management shortcomings in meeting fishing mortality targets. The 20% target was applied in situations, such as outside waters, where there was evidence of relatively good stock abundance and confidence that management measures (TAC and catch monitoring) were limiting fishing mortality to within set targets.
  - A 50% closed area was recommended for a management unit where little or no effective management was in place outside of closures. Due to extensive allowable catch reductions within the Strait of Georgia, and an increase in monitoring and catch accountability in the early 2000s, DFO modified this target to 30% in inside waters.

- To provide the opportunity for the natural enhancement and dispersal of Inshore Rockfish production over the long-term through a return to a natural size and age structure and increase in population densities of Inshore Rockfish within RCAs, thereby providing spillover of rockfish into adjacent areas (DFO 2000A; 2002B). Multiple RCAs were implemented to promote the spillover of rockfish at all life stages (larval to adult) into adjacent areas (DFO 2002B; MacKenzie 2004).
- To establish control and reference sites for scientific research and fishery assessment. Over 10 to 25 years, rockfish populations in RCAs were to be monitored, using non-lethal techniques, to gain an understanding of the effects of the protection measures on rockfish populations (Fisheries and Oceans Canada, Pacific Region, unpublished data, 2002; MacKenzie 2004; Yamanaka and Lacko 2001).
- To take a species-by-species and adaptive management approach to conservation in RCAs (MacKenzie 2004). DFO may explore the possibility of using an ecosystem-based approach in the future, recognizing that RCAs also contribute to the protection of other species and their habitats (e.g. groundfish species such as Lingcod, Kelp Greenling), as well as marine ecosystem structure and function (Fisheries and Oceans Canada, Pacific Region, unpublished data, 2001; MacKenzie 2004).

APPENDIX B: FISHERY TEMPORAL INFORMATION

Summary information on the location and timing of fisheries were compiled through a review of Pacific Region's IFMPs and input gathered from various DFO fishery staff (L. Barton for invertebrates; A. Dobko for salmon; V. Postlethwaite for recreational, F. Markevicius for recreational salmon and urchins, and R. Tadey for mid-water trawl). Information on salmon are general timings only and not species-specific.

This information was used to inform the *Exposure*$_{sc}$ scoring (temporal and spatial) for commercial fisheries.

Fishery	Commercial	Recreational	First Nations	Comments
Invertebrates by hand picking or dive: Geoduck, sea cucumber, red and green urchins	*Geoduck and horse clam:* rotational fishery with portions of the coast open on a 3-year rotation. Subject to in-season sanitary and biotoxin contamination closures. Schedule of openings and closures varies from year to year, but the goal is to allow for a year-round supply of geoducks to the market. *Sea cucumber:* Fishery commences in October and scheduled for 8 weeks (majority of total allowable catch usually harvested within first 3-4 weeks of opening). Limited entry licencing (currently 85 licence eligibilities) distributed across 4 licence areas (north coast, central coast, east coast of Vancouver Island and west coast of Vancouver Island).	*Geoduck and horse clam:* open coastwide and year round subject to testing for sanitary or biotoxin contamination. Limited to hand digging methods. *Sea cucumber:* Open year round in all area A sport fishing licence is required for harvest. *Red sea urchin:* Harvest may occur coastwide year-round (except for areas closed to fishing), where appropriately licenced. *Green sea urchin:* Harvest may occur coastwide year-round with a sport fishing licence except in areas closed to fishing. Fishing effort by recreational harvesters is	*Geoduck and horse clam:* FSC harvest or domestic use under a treaty is open coastwide throughout the year and area is not closed as a result of sanitary or biotoxin contamination. *Sea cucumber:* FSC harvest is open coastwide throughout the year. No limits have been placed on FSC harvest. *Red sea urchin:* Harvest may occur coastwide throughout the year, where authorized by an Aboriginal communal licence or a harvest document if under treaty. *Green sea urchin:* With exception for areas closed to fishing, FSC harvest may occur coastwide and year-round	*Geoduck and horse clam:* There are an unknown number of Aboriginal harvesters for geoduck and horse clam, however, fishing effort for FSC purposes is thought to be minimal, due to general inaccessibility of these deep-water clams. Areas 1-11 closed for harvest. Commercial fishery operates under a 3-year area rotation. There are 55 commercial licences. *Sea cucumber:* Amount of FSC harvest coastwide is unknown. *Red sea urchin:* Number of Aboriginal harvesters is unknown. Number of recreational harvesters is unknown, however, it is thought to be minimal. Commercial fishery is a limited entry fishery with 110 licence eligibilities, of these 30 area designated communal commercial licences for FNs to participate

Fishery	Commercial	Recreational	First Nations	Comments
	Red sea urchin: Licence year runs from August to July of the following year. Fishery may open/close based on market demand and completion of area quotas. Harvest is by hand picking while diving. *Green sea urchin:* Licence year is from September to August of the following year. With exception of permanent closures, current fishery occurs only on east coast of Vancouver Island in quota management areas. Other areas of the coast may be considered for openings if sustainable harvest quota can be established. Majority of landings occur between Oct-Feb when roe quality is at its best. Harvest is by hand picking while diving.	thought to be minimal.	where authorized by a communal licence or, under treaty, or a harvest document.	in the commercial fishery. *Green sea urchin:* 54 Aboriginal communal (FSC) licences and 3 harvest documents may be issued annually. Number of Aboriginal harvesters is unknown. Number of rec harvesters is unknown, however catch is limited to 12 per day (all urchin species combined).There are 49 commercial licences, of these, 1 is designated communal commercial (FZC) licence for FN participation in the commercial fishery.
Crab by trap	4 areas open all year, 3 areas have seasonal closures (3-6 months)	All year	All year	-
Shrimp/prawn by trap	Open coastwide starting in May for about 40 days (6 weeks) depending on in-season sampling. Fall Humpback shrimp by trap fishery in	Open coastwide (except for permanent and seasonal closures) throughout the	Open coastwide throughout the year (April-March annually).	-

Fishery	Commercial	Recreational	First Nations	Comments
	PFMA 4-10; potential for Nov/Dec Coonstripe shrimp trap fishery in Sooke area.	year (April-March).		
Scallop by trawl	Open May-April annually. Seven participants have been eligible and less than five have been active in recent years. Occurs in southern BC (PFMAs 13 and 14) subject to biotoxin and sewage contamination closures.	Use of scallop trawl gear is not permitted.	May occur coastwide where authorized by an Aboriginal communal licence, or under treaty, a harvest document for domestic purposes. Currently no communal licences or harvest documents issued for use of scallop trawl gear.	-
Salmon by seine or gillnet	June to end of October	Not applicable. Restricted to hook and line as per the BC Sport Fishing Regulations.	June to November	This is the general salmon timing when fisheries could occur coastwide. As they are migratory and run at different times it isn't very accurate and would need to be done at a more detailed level.
Herring by gillnet (roe), seine (roe and food & bait) and spawn-on-kelp	Food & Bait and Special Use (by seine): Nov 7-Feb 12 Roe seine and gillnet: late February-early April Spawn-on-kelp: early March – late April	Minimal and only allowed by dip net, herring jig, herring rake, and cast net – open year round	Year round but most fishing November-March	-
Sardine by gillnet, seine, and trap	June 1-October (when open)	Minimal to no catch and only allowed by dip	Year round (but mainly June 1-October)	Fishery not likely to open in the next couple years but

Fishery	Commercial	Recreational	First Nations	Comments
(commercial fishery closed since 2015 - may reopen)		net, herring jig, herring rake, and cast net – open year round		possible in this decade.
Smelt by gillnet (commercial fishery closed since 2012 officially but no directed commercial fishery since 1999 - may reopen)	April – December (when open)	Year round by gillnet and dip net only; closed June 15-August 15 in Area 28 and 29	Year round (but April-December mostly)	The chance the commercial fishery will reopen is unlikely in the next decade.
Euphausiid (krill) by mid-water trawl	November to March (to minimize incidental catch of larval and juvenile fish). Inlets with quota remaining may re-open in August until October. Small limited entry fishery with seasonal and area closures. Occurs in upper Strait of Georgia and a few mainland inlets in the south coast of BC. Most of catch comes from Jervis Inlet and Strait of Georgia. TAC is 500 tonnes.	Generally not harvested recreationally. Daily limit under a sport fishing licence for "other shellfish" is 20 individual animals by dip net.	FSC harvest may occur where authorized by a communal licence. Species are generally not harvested by First Nations for FSC purposes.	-
Groundfish by mid-water trawl	Open all year and coastwide under Option A licences only.	Not applicable. Trawl is not a permitted gear type for recreational fishing.	Open all year round.	R. Tadey noted that to his knowledge there has been no First Nations fishing with trawl gear in RCAs.

APPENDIX C: DATA AND ASSESSMENT OF ANTHROPOGENIC ACTIVITIES

This section provides an overview of activities discussed in this paper, analysis of relevant datasets, the state of knowledge, and the potential impacts of the activities on the Inshore Rockfish population. This information was used to support risk assessment scoring, including terms of exposure (temporal scale, spatial scale, load), consequence, and uncertainty scoring. The risk assessment scoring presented in Appendix E includes summaries of the information provided in this section, divided into relevant risk terms.

C.1. CRAB BY TRAP

Dungeness Crab (*Cancer magister*), and three other crab species (Red Rock (*Cancer productus*), Red King (*Paralithodes camtschatic*) and Golden King (*Lithodes aequispinus*)), are harvested with baited traps coast-wide in BC in commercial, recreational, and FSC fisheries (DFO 2017b). Dungeness and Red Rock Crabs are part of the *Brachyura* infraorder, referred to as true crabs. Red and Golden King Crabs are part of the *Anomura* infraorder, referred to as king crabs.

The main management measure for all sectors is the minimum size limit, and non-retention of females in the commercial and recreational fisheries; consequently, fisheries target only large male crabs. In the commercial fishery there are 221 licences (DFO 2017b). The coast is divided into seven Crab Management Areas (CMAs), four of which have seasonal closures during the winter/spring to protect soft shell males. CMAs without seasonal closures are open all year to commercial harvesting. Recreational and First Nations fisheries generally are open all year (DFO 2017B).

C.1.1. Reporting Data and Methods

Commercial Crab Trap Effort

Commercial crab trapping effort in RCAs was assessed using commercial logbook data. Commercial fishers are required to fill out logbooks into which they record general fishing locations and estimates of their daily catches. Fishing event records from 2007 to 2017 were extracted from crab logbooks in DFO database CrabLogs. A buffer was not applied to GPS points because traps are fished individually or on ground lines depending on the CMA. Logbook GPS coordinates were mapped in ArcGIS as point locations and overlaid with RCA boundaries to determine the number of fishing events that have occurred in RCAs. The number of trap days ([*number of traps* × *hours soaked*]/*24 hours*) was used as a measure of fishing effort. Descriptive statistics for the number of trap days per year were calculated for all RCAs coast-wide and for each geographic region (Queen Charlottes, North Coast, Central Coast, West Coast Vancouver Island, Inside Waters) since RCA implementation in 2007.

Locations of commercial vessels are continuously tracked via electronic monitoring (EM), and these data are more spatially accurate compared to logbook data. Furthermore, traps have electronic tags that are scanned during hauling; therefore, trap scans can be used to identify locations of fishing activity. Coast-wide EM records were accessed from 2010 to 2016. Trap scan records were mapped in GIS as point locations and then overlaid with RCA boundaries to determine which fishing events occurred in RCAs.

Rockfish Bycatch in Commercial Crab Traps

Rockfish bycatch in commercial traps is not recorded in logbooks. However, crab biological sampling is done in the commercial fleet by certified observers hired by industry. Fishery-dependent crab biological data from DFO database Crab_Bio were used to assess the frequency of rockfish bycatch in commercial crab traps from 2007-2017. The following data points were extracted: Research LF, Commercial LF, DFO Observer on Commercial Boats, First Nation LF, Green Crab Studies, Soft Shell Crab studies, Box Crab Studies, Other LF, and Unknown Source. Sampling point data were overlaid with RCA boundaries in GIS and bycatch composition examined to determine potential rockfish impact. No buffers were applied to sampling point data.

Commercial Crab Trap Ghost Fishing

Commercial logbook data were used to determine the number of crab traps lost each year coast-wide from 2000 to 2014. Crab trap losses were not recorded in logbooks after 2014 due to changes in reporting requirements.

C.1.2. Data Assessment

Commercial Crab Trap Effort

According to logbook data, 17,000 commercial crab fishing events occurred in 103 RCAs (63%) between 2007 and 2017, and total fishing effort in RCAs represented approximately 4% of the coast-wide effort (5,681,118 out of 141,592,560 trap days occurring coast-wide inside and outside of RCAs) (Table 12).

Table 12: Coast-wide commercial crab trap effort in RCAs by year as determined from logbook data, 2007-2017. (Source: CrabLogs, extracted on October 25, 2018).

Year	Fishing Events	Weight (kg)	Trap Days in RCAs (Inside and Outside Waters)	Trap Days in RCAs (Inside Waters)	Traps Days in RCAs (Outside Waters)	Trap Days Coastwide Total
2007	1,497	108,922	559,937	465,676	94,261	14,028,102
2008	1,226	92,795	464,349	420,373	43,976	13,332,782
2009	1,410	90,032	410,706	364,524	46,182	12,676,957
2010	1,138	112,868	421,666	339,038	82,627	12,450,774
2011	1,184	89,011	424,959	371,626	53,333	10,817,539
2012	1,242	92,042	462,696	407,956	54,740	11,317,411
2013	1,349	101,733	436,278	370,290	65,988	12,768,886
2014	1,715	137,690	620,190	579,746	40,443	13,463,594
2015	2,200	211,179	698,609	654,605	44,004	13,596,686
2016	2,081	123,500	618,209	560,749	57,460	13,160,860
2017	1,960	111,083	563,520	512,446	51,074	13,978,970
Total	**17,002**	**1,270,853**	**5,681,118**	**5,047,031**	**634,088**	**141,592,560**

Crab EM data showed fishing occurred in 106 RCAs (65%) between 2010 and 2016. Crab trap fishing effort in RCAs was 38% higher after 2013 (Table 12). Inside waters had, by far, the greatest commercial crab trap effort in RCAs (5,047,031 trap days). The West Coast of Vancouver Island had the second highest commercial crab trapping intensity with 440,343 trap days, followed by the North Coast with 156,883 trap days, Central Coast with 23,609 trap days, and Queen Charlotte Islands with 13,253 trap days.

The number of commercial fishing events in RCAs may be underestimated. Unfortunately, GPS locations for all traps/ground lines, or the exact locations where traps are deployed, are not always recorded in logbooks (S. Humble, *pers. comm.*, Fisheries Management South Coast, Mar 2018). Not applying a buffer to GPS points means some ground lines fished near RCAs may have extended inside boundaries. Finally, not all trap tags are consistently scanned so some fishing events would not have been recognized when analyzing EM data.

Future analysis at the RCA level can incorporate overlaying modelled rockfish habitat layers (rocky reefs, eelgrass beds, kelp forests and sponge reefs) with crab fishing effort data to improve the assessment of interaction and potential risks that crab trapping may have on inshore rockfish species and their habitat.

Rockfish Bycatch in Commercial Crab Traps

Coast-wide, there were three rockfish recorded during 2,756 fishing events from 2007-2017. These rockfish were caught outside RCAs - one China Rockfish was caught in 2008 in Hecate Strait and two Copper Rockfish were caught in 2017 in the Strait of Georgia. Approximately 15% of sampling of commercial gear occurred in RCAs.

Commercial Crab Trap Ghost Fishing

Coast-wide between 2000 and 2014, 35,825 lost commercial crab traps were reported in logbooks (Table 13).

Table 13: Commercial crab trap losses per year coast-wide as determined from logbook data, 2000-2014.

Year	Count of Lost Traps
2000	2,614
2001	2,821
2002	2,520
2003	2,411
2004	2,429
2005	3,159
2006	2,172
2007	2,095
2008	2,341
2009	2,208
2010	2,375
2011	2,292
2012	2,036
2013	2,018
2014	2,334
Total	**35,825**

Trap losses were relatively consistent each year, with an average of 2,388 losses (SE=78.5). Although the number of lost commercial traps in RCAs is unknown, an estimate based on available data is 1,445 traps (5.5% of fishing events occurred in RCAs between 2007 and 2017, and 26,268 traps may have been lost coast-wide during this time period [determined using the mean number of traps lost per year]).

C.1.3. Discussion

Direct mortality of rockfish as bycatch in commercial crab traps appears to be low. These numbers may be underestimated if rockfish are caught in traps and consumed by crabs before traps are hauled to the surface. However, crab traps are typically deployed in subprime rockfish habitat preferred by Dungeness Crab (e.g. sandy or muddy substrates) (Harding et al. 2014). Prey species reduction and disturbance is also likely low in RCAs from crab traps. Crab fisheries primarily target large male Dungeness Crabs (DFO 2017B). Crab traps have a large mesh size and normally catch crabs larger than approximately 100 mm carapace notch width. In prey studies, most of the true crabs that inshore rockfish consume have been identified at the *Brachyura* infraorder and *Cancridae* family (Bizzarro et al. 2017; Murie 1995; Olson 2017; Lea et al. 1999; Rosenthal et al. 1988; Steiner 1978), which include a wide array of species, many of which are not harvested commercially. Of the two commercially harvested *Brachyura* species, Red Rock Crabs have been specifically identified in Copper Rockfish diets (Lea et al. 1999; Murie 1995), but Dungeness Crabs have not. The mean carapace width of four Red Rock Crabs from Copper and Quillback Rockfish stomachs was 26.2 mm (±19.7 mm within one standard deviation) (Murie 1991), well below the 115 mm minimum size limit for harvesting Red Rock Crab. Studies have not specifically identified Red or Golden King Crabs in inshore rockfish diets. The *Anomura* infraorder is the taxonomic level at which the king crabs that inshore rockfish consume have been identified (Bizzarro et al. 2017; Rosenthal et al. 1988). Crab larvae are frequently observed in rockfish diet studies (e.g. Dick et al. 2018; Murie 1995; Rosenthal et al. 1988; Steiner 1978). Dungeness and Red Rock Crab populations are currently considered to be healthy in the Pacific Region. Moreover, crab larvae can disperse over large distances due to their lengthy pelagic phase and therefore have the ability to replenish depleted populations (DFO 2017B).

The commercial crab trap fishery may affect rockfish recovery in RCAs through the secondary effects of bottom contact gear on rockfish habitats. Habitat impacts from crab trapping in rocky areas can be similar to concerns from the commercial prawn trapping assessment (see section 10.3), although crab traps are typically deployed in muddy/sandy habitats. However, commercial fishers may deploy approximately 25 to 50 traps per ground line and, although they may be targeting sandy and muddy substrates, some traps may drift into rocky areas and contact sessile organisms and sponge reefs and the resulting sediment plume could reach nearby reefs. Traps can cause irreversible damage to delicate sponges that provide important habitat to rockfish species and their prey. Traps can also drag while soaking, especially in bad weather, and during retrieval. Specific information on how often and how far crab traps are dragged during wind and storm events was unavailable. A study of bottom contact lobster traps in the Florida Keys, USA showed traps can be dragged 3.6 m during wind events exceeding 15 knots for more than two days. Dragging traps reduced sessile organism coverage by up to 41% (Lewis et al. 2009). These results are not directly comparable to crab trapping in BC due to different gear, habitat, and depth; however, they do highlight the ability of bottom contact, surface-buoyed fishing gear to damage benthic habitats.

Coast-wide, 35,857 lost commercial crab traps were recorded in logbooks between 2000 and 2014 (L. Barton, *pers. comm.*, Shellfish Data Unit, Feb 2018). Breen (1987) found 11% of crab traps from the Dungeness Crab fishery were lost each year in the Fraser River Estuary. The proportion of lost traps may have ghost-fished approximately 7% of annual commercial landings. Antonelis et al. (2011) estimated over 12,000 crab traps become derelict each year in the American waters, causing mortality of more than 178,000 Dungeness Crabs annually. The commercial fishery is required to use rot cord to facilitate escapements in case traps are lost. However, a study of the Dungeness Crab fishery in the USA found that, although rot cord is expected to take 90 to 130 days to disintegrate, it often takes much longer (up to 2.5 years in Washington and over 6 years in Alaskan fisheries. Marine growth and metal fatigue often inhibit escape panels from opening (Arthur et al. 2014). In BC, rot cord is required by all three sectors (DFO 2017B).

C.2. GROUNDFISH MID-WATER TRAWL

Commercial mid-water trawling for groundfish is permitted in RCAs. Subject to fishery closures and individual vessel quota holdings, vessels holding a valid Option A trawl licence may fish with mid-water trawl gear in all areas of the Pacific Coast (DFO 2017A). Fisheries data were assessed to determine the amount of commercial fishing effort by mid-water trawl that has occurred in RCAs.

C.2.1. Reporting Data

Data on mid-water trawling from DFO’s groundfish view of the Fisheries Operations System (GFFOS) were used to assess mid-water trawl effort in RCAs. GFFOS contains harvest information that includes data from the Dockside Monitoring Program, fisher logbooks, observer logbooks, and Electronic Monitoring logbooks. Trawl fishing events are logged in the database with a start or endpoint, or a combination of the two points. Not all fishing events have a reported set of coordinates, and not all events have a reported end point. Mid points are available for some of the logs but these were not used as they have not been validated. For this analysis, all groundfish trawl records from 2007 to 2017 were extracted from GFFOS. All available start or end points of fishing events were plotted as point locations in ArcGIS. Points that fell outside BC waters or located on land were removed. The dataset was filtered to extract only mid-water trawl events (using the field “sub-gear type” = mid-water trawl). Mid-water trawl points were overlaid with RCA boundaries to determine those fishing events which occurred in RCAs.

Detailed track line data are captured by the Electronic Monitoring System; however, this information is not reported to the Department unless it is required for part of an investigation. Generally speaking, positional data collected by the EM system is not retained in any database and the data stored on the hard drives is deleted if not required for an investigation (R. Tadey, DFO, Regional Head Quarters, Vancouver, *pers. comm*., January 2019). As a result, we were only able to assess fishing effort based on overlapping start/end data points in RCAs which may have underestimated the amount of fishing effort occurring in RCAs.

In those RCAs where there was mid-water trawl activity, the magnitude of the fishing effort was assessed. In addition, we also examined the species caught by mid-water trawl coast-wide from data in GFFOS. Most catch records originated from at-sea observer data (27 records came from fishing logs). Given the available data, we were only able to report on species caught based on logs where the start and/or end points fell within the RCAs.

C.2.2. Data Assessment

There were 325 mid-water trawl data points recorded in 17 RCAs (10%) between 2007 and 2017 (Table 14).

Table 14: Commercial mid-water trawl activity by number of fishing events in RCAs, 2007-2017 (Source: GFFOS, extracted January 2, 2019)

RCA	**Pacific Fisheries Management Area**	**Year**											
		2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**Count [%]**
Goletas Channel	12	31	4	10	9	10	19	24	23	17	45	77	269 [83%]
Goose Island	7/107	-	3	12	1	-	1	-	-	-	-	-	17 [5%]
Ajax / Achilles Bank	14	-	-	-	-	-	-	10	-	-	3	-	13 [4%]
Scott Islands	111/127	-	-	2	-	-	-	2	1	-	-	1	6 [2%]
Broken Group Islands	23	-	-	2	-	-	1	-	-	-	-	-	3 [1%]
Estevan Point	124/125	-	-	-	1	-	-	1	-	-	1	-	3 [1%]
Bolivar Passage	12	-	-	-	-	1	-	-	-	1	-	-	2 [1%]
Checleset Bay	26	-	-	1	1	-	-	-	-	-	-	-	2 [1%]
North Danger Rocks	105	-	2	-	-	-	-	-	-	-	-	-	2 [1%]
Browning Passage - Hunt Rock	12	-	-	-	1	-	-	-	-	-	-	-	1 [0%]
Eden-Bonwick-Midsummer-Swanson Islands	12	-	-	-	-	-	-	-	-	1	-	-	1 [0%]
Galiano Island North	29	-	-	-	1	-	-	-	-	-	-	-	1 [0%]
Hotham Sound	16	-	-	-	-	-	-	-	-	1	-	-	1 [0%]
Mayne Island North	18	-	-	-	-	-	-	-	-	-	1	-	1 [0%]
Nowell Channel	12	-	-	-	-	-	-	-	-	-	1	-	1 [0%]
Otter Passage	106	-	1	-	-	-	-	-	-	-	-	-	1 [0%]
Trincomali Channel	17	-	-	-	-	1	-	-	-	-	-	-	1 [0%]
Total	**-**	**31**	**10**	**27**	**14**	**12**	**21**	**37**	**24**	**20**	**51**	**78**	**325 [100%]**

Approximately one percent of the reported 35,108 (8,057 trips) mid-water trawl fishing events that occurred coast-wide from 2007 to 2017 were in RCAs. Trawl activity was highest in 2017 in RCAs when 78 fishing events were recorded. Mid-water trawling was concentrated in the

Goletas Channel RCA where approximately 83% of all trawl activity occurred (269 fishing events). The Goose Island RCA received approximately 5% (17 events) while Ajax/Achilles Bank received approximately 4% (13 events) of the fishing effort. The remaining 12 RCAs received six or fewer events.

None of the rockfish species listed in mid-water trawl records were any of the Inshore Rockfish species that RCAs protect. It is possible that Inshore Rockfish may have been captured by mid-water trawl gear and recorded as “rockfish complexes” or “unknown fish” in species catch records. However, it is unlikely that Fishery Observers would be unable to correctly identify Inshore Rockfish species as they are trained to recognize common rockfish species, which include all inshore species (R. Tadey, DFO, Regional Head Quarters, Vancouver, *pers. comm.,* December 2018).

Some of the species caught in commercial mid-water trawl gear are prey species of Inshore Rockfish. Unspecified rockfish (*Sebastes*) have been reported in the diets of Black, Copper, Tiger, and Yelloweye Rockfish (Bizzarro et al. 2017; Rosenthal et al. 1988; Steiner 1978; Turner et al. 2017). While further research is required, it is possible that at least some of the 17 rockfish species listed in the mid-water trawl records are Inshore Rockfish prey.

Table 15: Species caught in commercial mid-water trawl gear coast-wide, 2007-2017. Rockfish species are in bold.

Species common name
American Shad
Arrowtooth Flounder
Bank Rockfish
Big Skate
Bigfin Eelpout
Blackgill Rockfish
Blackmouth Eelpout
Boccaccio
Brown Cat Shark
Canary Rockfish
Cat Sharks
Chinook Salmon
Chum Salmon
Coho Salmon
Darkblotched Rockfish
Dover Sole
Dusky Rockfish
Eelpouts
English Sole
Eulachon
Flatfishes
Flathead Sole
Giant Wrymouth
Glass Shrimp
Greenlings
Greenstriped Rockfish
Herrings
Humboldt Squid
Jack Mackerel
Jellyfish
Longnose Skate
Northern Anchovy
Northern Rockfish
Pacific Cod
Pacific Hake
Pacific Herring
Pacific Ocean Perch
Pacific Sanddab
Petrale Sole
Pink Salmon
Pink Shrimp (Smooth)
Prawn
Prowfish
Rainbow Smelt
Redbanded Rockfish
Pacific Salmon and Native Trout
Redstripe Rockfish
Rex Sole
Rougheye/Blackspotted Rockfish Complex
Sablefish
Salmonids
Sauries
Schoolmaster Gonate Squid
Sharpchin Rockfish
Shortraker Rockfish
Showy Snailfish
Shrimp
Silvergray Rockfish
Sockeye Salmon
Spiny Dogfish
Splitnose Rockfish
Spotted Ratfish
Squids
Starry Flounder
Tope Shark
Unknown Fish
Walleye Pollock
Wattled Eelpout
Widow Rockfish
Yellowmouth Rockfish
Yellowtail Rockfish

C.2.3. Discussion

With the exception of a few RCAs, mid-water trawling has generally been an infrequent activity in RCAs. Catches of Inshore Rockfish species in trawl gear are very rare. An ERAF assessment of the Hecate Strait and Queen Charlotte Sound Glass Sponge Reef MPA found mid-water trawl gear caught 6.24 kg of Yelloweye Rockfish within the MPA footprint between 2007 and 2013 (Hannah et al. 2019). Many other species of finfish, including rockfish species like Canary Rockfish and Yellowtail Rockfish, which RCAs were not designed to protect, are regularly removed by mid-water trawls.

Damage to rockfish habitat in RCAs from mid-water trawl bottom contact is unknown. The Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs MPA ERAF found that mid-water trawl gear can contact the bottom during fishing. When bottom contact does occur, the effect on habitats is similar to bottom trawling (Hannah et al. 2019), and trawls can temporarily resuspend bottom sediment (Leys 2013). Mid-water trawling was identified as the third greatest human stressor to glass sponge reefs, sponge species, and motile indicator species (i.e. Squat Lobster and Boccaccio Rockfish) after vessel activities like oil spills and bottom trawling (Hannah et al. 2019). According to the Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs MPA ERAF, death of trapped organisms from entanglement in derelict mid-water trawl gear could occur quickly from injury or predation and entangled fish may die from predation, starvation, and suffocation (Laist 1997). It is not known what the incidence of lost gear is but would be expected to be low and lost gear is likely to be speedily recovered as it is expensive (*pers. obs.* L. Yamanaka, DFO, Pacific Biological Station, Nanaimo). It is unlikely that enough gear would be lost to have a population scale impact. Mid-water trawling has been excluded from the Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs MPA due to the risk of damage to sponge habitat when nets contact the seafloor.

C.3. COMMERCIAL PRAWN AND SHRIMP BY TRAP

The Pacific Region's fisheries for prawns and shrimp by trap gear take place along the BC coastline in rocky near-shore areas in depths of 40 to 100 m. There are commercial, recreational and FSC prawn and shrimp by trap fisheries. Most of the catch (>60%) comes from the Strait of Georgia and inside of Vancouver Island. The target species is Spot Prawn (*Pandalus platyceros*), with a small incidental catch of other shrimp species and small commercial fisheries directed at Coonstripe Shrimp (*P. danae*) and Humpback Shrimp (*P. hypsinotus*) (DFO 2018D). All three species are part of the *Caridea* infraorder, *Pandalidae* family, and *Pandalus* genus.

There are 246 commercial licences. The commercial fishery is managed by seasonal closures, in-season area closures, gear limits, gear marking requirements, trap mesh size requirements, minimum size limit (*P. platyceros* only), daily fishing time restrictions, and a daily single haul limit. The commercial prawn fishery is generally open for two months in early summer. The directed Humpback Shrimp and Coonstripe Shrimp fisheries take place in Prince Rupert and Sooke, respectively, in the fall to the end of December (DFO 2018D).

C.3.1. Reporting Data

Prawn Trap Fishing Effort

Commercial prawn trap logbook data were extracted from the DFO database *PrawnLogs* from 2007 to 2017 were used to assess coast-wide Spot Prawn fishing effort in RCAs by year. Coordinates for each fishing event were mapped as point locations using ArcGIS. Any points located outside BC waters or on land were removed. A data point represents a reported vessel position along a prawn string that can be up to 1,100 m. For estimating fishing effort, we did not apply a buffer around each data point to account for this positional uncertainty and as a result, fishing effort may have been underestimated in RCAs. Conversely, applying a buffer may also overestimate the amount of fishing effort in RCAs. RCA boundaries were then overlaid with fishing events to determine how many events fall within RCAs per year. Fishing effort was calculated based on the number of strings fished coast-wide and in RCAs, the proportion of RCAs fished, and the total commercial prawn catch in RCAs. We also reported soak time, which is the amount of time (in days) the gear was set, for those data points landing in RCAs and coast-wide between 2007 to 2017. This report includes an assessment of the targeted commercial fisheries for Coonstripe and Humpback Shrimp. These species can be retained during the open season for Spot Prawns (generally during May and June).

Rockfish Bycatch sampling program

In 2002, a rockfish bycatch sampling program was implemented for the commercial Spot Prawn trap fishery. The sampling program is conducted by third party on-board observers who also collect data for in-season management based on a spawner index (Rutherford et al. 2010). In 2002, every third trap per string was examined for rockfish bycatch (most strings consist of approximately 50 traps). Since 2004, all traps per string have been examined for rockfish bycatch. Bycatch sampling occurs throughout the duration of the commercial fishing season (approximately 60 to 70 days per year). Sampling effort was spatially dispersed across the coast to follow commercial fishing patterns. Total commercial fishing effort by year (2002-2008) and bycatch monitoring program sample rates can be found in Appendix 1 of Rutherford et al. (2010).

All rockfish bycatch sampling data for the prawn trap fishery were extracted from DFO's internal database (PrawnTrap_Bio), from 2002 to 2015. Using latitude and longitude fields, data were mapped in ArcGIS. For the data analysed in the bycatch sampling data, each string is represented by a single point at the midpoint. The maximum length of a prawn string is 1,100 m, so the study included a buffer with a 1,100 m diameter was applied around each point. Sampling locations and buffers were overlaid with RCA locations.

Bycatch composition inside and outside RCAs in the five regions were analysed: Haida Gwaii (Queen Charlottes), North Coast, Central Coast, West Coast of Vancouver Island, and the Inside waters (water between Vancouver Island and the mainland). Rockfish encounter rates (total rockfish on all sampled strings/total number of strings sampled) were calculated by year, inside and outside RCAs for each region.

C.3.2. Data Assessment

Prawn Trap Fishing Effort

From 2007 to 2017, on average approximately 17% of commercial prawn and shrimp trap fishing, representing 8,675 strings (9,940 days), occurred in RCAs annually (Table 16). On average, 103 RCAs (63%) have been fished annually since RCA implementation.

Table 16: Commercial prawn trap fishing effort coast-wide and in RCAs as well as incidental catches since their implementation in 2007. Mean ± SE. (Source: 2007-2014 K.Fong, DFO, unpublished data 2018; 2015-2017 extracted January 21, 2019 from PrawnLogs)

Year	Number of strings fished coast-wide	Number of strings fished in RCAs [% of strings fished in RCAs	Total prawn catch coast-wide (lb)	Total prawn catch in RCAs (lb) [% of catch landed in RCAs	Total incidental catch of coonstripe shrimp in RCAs (lb)	Total incidental catch of humpback shrimp in RCAs (lb)	Total number of RCAs fished [% of RCAs fished]	Soak-time (days) coast-wide	Soak-time in RCAs [% of soak-time in RCAs]
2007	71,823	12,505 [17.4%]	6,091,520	1,096,169 [18.0%]	1,195	3,559	101 [61.6%]	75,973	13,461 [17.7%]
2008	66,895	11,065 [16.5%]	5,162,345	871,191 [16.9%]	628	727	100 [61.0%]	70,872	11,651 [16.4%]
2009	75,352	13,077 [17.4%]	7,445,192	1,332,032 [17.9%]	278	1,123	94 [57.3%]	79,322	13,705 [17.3%]
2010	56,553	9,230 [16.3%]	4,754,455	741,823 [15.6%]	18	480	104 [63.4%]	58,973	9,621 [16.3%]
2011	69,208	11,612 [16.8%]	6,048,364	947,987 [15.7%]	264	681	104 [63.4%]	72,086	12,271 [17.0%]

Year	Number of strings fished coast-wide	Number of strings fished in RCAs [% of strings fished in RCAs	Total prawn catch coast-wide (lb)	Total prawn catch in RCAs (lb) [% of catch landed in RCAs	Total incidental catch of coonstripe shrimp in RCAs (lb)	Total incidental catch of humpback shrimp in RCAs (lb)	Total number of RCAs fished [% of RCAs fished]	Soak-time (days) coast-wide	Soak-time in RCAs [% of soak-time in RCAs]
2012	52,384	9,432 [18.0%]	3,916,985	664,301 [17.0%]	34	1,313	106 [64.6%]	53,668	9,635 [18.0%]
2013	53,321	8,277 [15.5%]	3,671,825	539,295 [14.7%]	363	480	108 [65.9%]	54,601	8,447 [15.5%]
2014	48,630	7,341 [15.1%]	3,553,812	528,339 [14.9%]	41	417	105 [64.0%]	49,484	7,532 [15.2%]
2015	55,617	9.664 [17.4%]	3,972,429	702,587 [17.7%]	250	317	108 [65.9%]	57,032	9,958 [17.5%]
2016	42,511	6,804 [16.0%]	2,629,908	410,153 [15.6%]	144	1,050	100 [61.0%]	43,309	6,823 [15.8%]
2017	38,999	6,077 [15.6%]	2,536,501	392,338 [15.6%]	23	578	98 [59.8%]	39,669	6,234 [15.7%]
-	57,390 ± 3,622	8,675 ± 1,114 [16.5 ± 0.3%]	4,525,758 ± 463,707	747,838 ± 88,371 [16.3 ± 0.4%]	294 ± 106	975 ± 276	103 ± 1.3 [62.5 ± 0.8%]	59,544 ± 4,014	9,940 ± 778 [16.6 ± 0.3%]

Please note that commercial logbook data can have location errors if fishing locations are misreported. Furthermore, often one GPS location is entered per string; therefore, some spatial variation in actual trap locations will not always be captured in the data.

Rockfish Bycatch in Prawn Traps

Between 2004 and 2016, 21,083 rockfish were caught per year coast-wide in the commercial Spot Prawn fishery (Table 17).

*Table 17: Inshore rockfish coast-wide bycatch totals from commercial prawn traps. K. Fong (DFO, Unpublished data 2018).*denotes official RCA implementation.*

Year	Mean Rockfish Bycatch Estimate Coast-wide (pieces)	Upper 95% CI
2004	16,687	23,108
2005	14,401	20,354
2006	16,428	22,612
2007*	18,109	25,009
2008	18,856	25,030
2009	28,691	35,246
2010	29,390	36,268
2011	32,011	39,761
2012	25,786	32,673
2013	21,555	27,210

Year	Mean Rockfish Bycatch Estimate Coast-wide (pieces)	Upper 95% CI
2014	13,564	18,131
2015	21,257	27,427
2016	17,346	22,235
Total	**274,081**	**355,064**
Total since RCA implementation	**226,565**	**288,990**

The total estimated rockfish bycatch (all species) coast-wide from 2007 to 2016 is 226,565 with an upper 95% confidence interval of 288,990 (K. Fong, DFO, unpublished data; Table 18). Rockfish were encountered at a rate of 0.36 (SE 0.02) rockfish per string in RCAs (Table 18).

Table 18: Number of rockfish caught by species in Spot Prawn trap bycatch monitoring program coast-wide in RCAs (2007-2015). Data from internal DFO database (PrawnTrap_Bio) in the Shellfish Data Unit. Bolded species belong to the inshore rockfish group.

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total Rockfish	Proportion (%)
Brown Rockfish	**-**	**-**	**-**	**-**	**-**	**-**	**1**	**-**	**1**	**2**	**0.17**
Canary Rockfish	-	4	-	-	1	-	-	1	-	6	0.52
China Rockfish	**1**	**-**	**4**	**-**	**1**	**2**	**-**	**1**	**1**	**10**	**0.86**
Copper Rockfish	**11**	**12**	**6**	**9**	**34**	**17**	**14**	**4**	**14**	**121**	**10.43**
Dusky Rockfish	1	-	-	-	-	-	-	-	-	1	0.09
Greenstriped Rockfish	4	16	13	14	9	23	18	14	9	120	10.34
Pygmy Rockfish	-	-	-	-	-	-	1	-	-	1	0.09
Quillback Rockfish	**59**	**58**	**125**	**107**	**114**	**80**	**110**	**73**	**90**	**816**	**70.34**
Redbanded Rockfish	-	-	-	-	-	3	1	-	-	4	0.34
Redstripe Rockfish	-	-	-	-	-	1	-	-	1	2	0.17
Stripetail Rockfish	-	-	-	-	-	-	-	-	2	2	0.17
Tiger Rockfish	**-**	**-**	**-**	**-**	**-**	**1**	**-**	**-**	**1**	**2**	**0.17**
Widow Rockfish	-	-	-	-	-	1	-	-	-	1	0.09
Yelloweye Rockfish	**3**	**9**	**6**	**10**	**12**	**6**	**14**	**5**	**4**	**69**	**5.95**
Yellowmouth Rockfish	-	-	-	-	-	-	-	-	1	1	0.09
Yellowtail Rockfish	-	-	2	-	-	-	-	-	-	2	0.17
TOTAL	**79**	**99**	**156**	**140**	**171**	**134**	**159**	**98**	**124**	**1160**	**100**

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total Rockfish	Proportion (%)
Number of strings sampled	316	275	373	358	416	343	362	330	432	3205	N/A
Encounter rate	0.25	0.36	0.42	0.39	0.41	0.39	0.44	0.30	0.29	0.36	N/A

The encounter rate of Inshore Rockfish species (bolded) in RCAs (2007-2015) in the commercial prawn fishery is 0.32 (SE 0.02) fish per string. Quillback Rockfish was the predominant bycatch species, making up 70.3% of incidentally caught rockfish in RCAs, followed by Copper Rockfish (10.4%). Greenstripe Rockfish were caught in a similar amount to Copper Rockfish (10.3%). Overall, Inshore Rockfish species comprised 88% of rockfish caught incidentally in RCAs.

The number of rockfish caught in prawn traps in RCAs was relatively low, with the highest numbers occurring in inside waters where commercial fishing is concentrated (Figure 15).

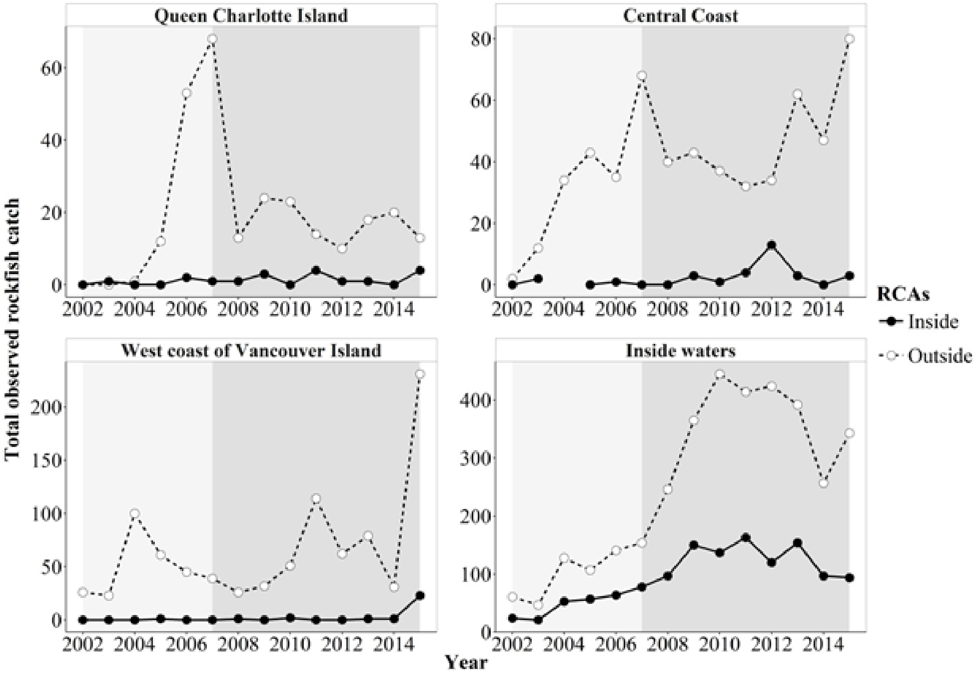

Figure 15: Summary of total rockfish caught during the rockfish bycatch sampling program for the commercial Spot Prawn trap fishery over the years (2002-2015), for each region, outside and inside RCAs. The light gray area represents the implementation phase of RCAs, the dark grey area represents the period when RCAs were established.

Similarly, Inside waters (between Vancouver Island and the Mainland) had the highest Inshore Rockfish encounter rates both inside (0.34, SE 0.03) and outside (0.37, SE 0.04) RCAs (Figure 16). Encounter rates by region were generally always higher outside than inside RCAs except on the central coast where the Inshore Rockfish encounter rate was 0.29 (SE 0.08) inside compared to 0.12 (SE 0.02) outside. However, sampling rates are not standardized inside and outside RCAs, and the number of strings sampled per year can vary. RCAs on the North Coast were not sampled during the prawn bycatch monitoring program.

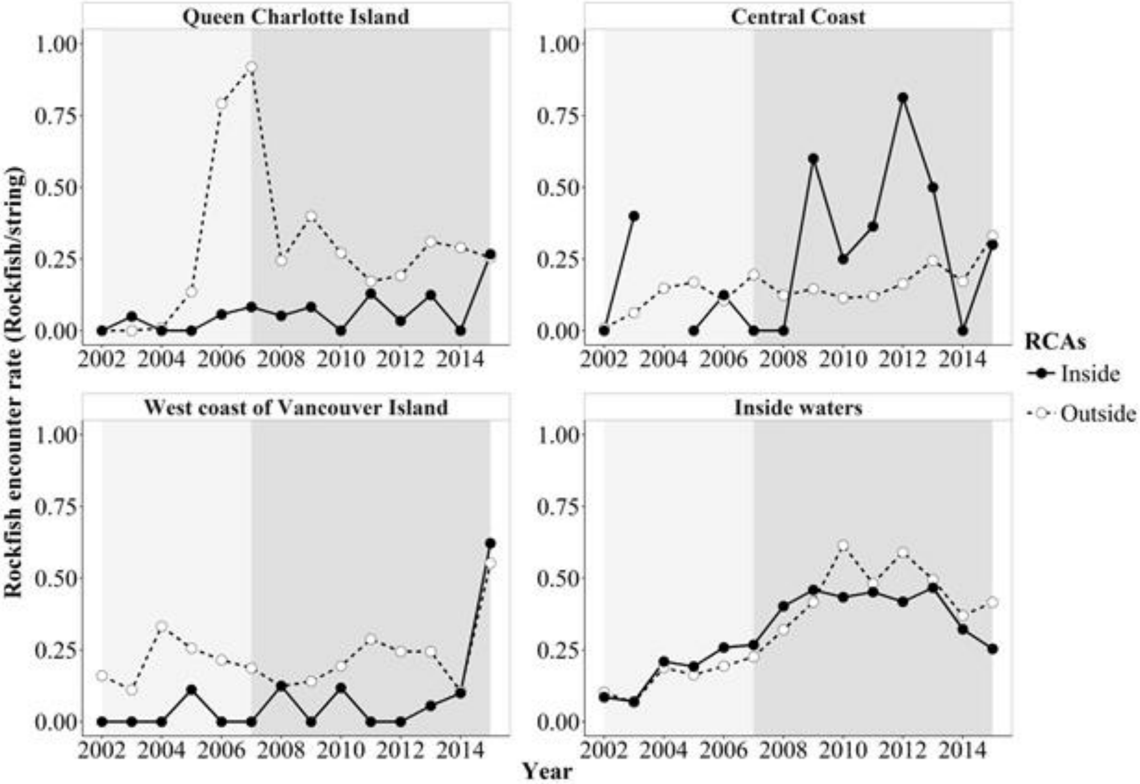

Figure 16: Rockfish encounter rate (Rockfish/strings) in the commercial Spot Prawn trap fishery, by regions, inside and outside RCAs from 2002 to 2015. The light gray area represents the implementation phase of RCAs, the dark grey area represents the period when RCAs were established.

C.3.4. Discussion

Commercial Spot Prawn fishing in RCAs could negatively affect rockfish in several ways. The direct removal of juvenile rockfish in traps as bycatch is a documented occurrence coast-wide. Rockfish caught in prawn traps are mostly juveniles (typically year three or four) (Rutherford et al. 2010). In Howe Sound, from 1999 to 2008, the overall rockfish catch rate in research traps (similar to commercial traps) was 0.015 rockfish per trap (Favaro et al. 2010). In Puget Sound, from 2004-2013, the overall rockfish catch rate (mostly Copper and Quillback) in prawn traps was 0.023 rockfish per trap drop. Rockfish bycatch was higher in the fall compared to the spring. The number of rockfish estimated to be caught in prawn traps by all fishing sectors in Puget Sound is approximately 2,600 fish each year (Antonelis et al. 2018).

Caridean shrimp are documented prey of Brown Rockfish (Bizzarro et al. 2017), China Rockfish (Rosenthal et al. 1988), Copper Rockfish (Rosenthal et al. 1988; Murie 1995; Olson 2017; Bizzaro et al. 2017), Quillback Rockfish (Rosenthal et al. 1988), Tiger Rockfish (Rosenthal et al. 1988), and Yelloweye Rockfish (Rosenthal et al. 1988; Bizzaro et al. 2017). *Pandalidae* are documented prey of Copper Rockfish (Olson 2017) and Tiger Rockfish (Rosenthal et al. 1988). *Pandalus* are documented prey of China Rockfish (Rosenthal et al. 1988), Copper Rockfish (Rosenthal et al. 1988; Murie 1995; Olson 2017; Turner et al. 2017), Quillback Rockfish (Murie 1995; Olson 2017; Rosenthal et al. 1988), Tiger Rockfish (Rosenthal et al. 1988), and Yelloweye Rockfish. Some studies have identified *Pandalus* specimens in the diets of various inshore rockfish species to the species level, including the three commercially harvested species. *P. danae* have been identified in the diets of Copper Rockfish (Murie 1995; Turner et al. 2017), Quillback Rockfish (Murie 1995), and Yelloweye Rockfish (AFSC 2011). *P. hypsinotus* have been identified in the diets of Quillback Rockfish (Olson et al. in prep.[17]). *P. platyceros* have been specifically identified in the diets of Copper Rockfish (Murie 1995), Quillback Rockfish (Olson et al. in prep), and Yelloweye Rockfish (AFSC 2011).

The contribution of shrimp and prawn reported inshore rockfish diets varies across studies. In Saanich Inlet, BC, a spearfishing study in depths to 40 metres reported *P. danae* were 6.8 percent and 9.4 percent of the mass of prey items in Quillback Rockfish and Copper Rockfish, respectively (Murie 1995). Whereas, a study of thirty-seven Copper Rockfish at shallow depths (<18 m) in the San Juan Channel, Washington, reported *P. danae* were dominant prey items (26% of mass of prey items) (Turner et al. 2017). Murie (1995) identified 3.3 percent of the mass of prey items in Copper Rockfish to be *P. Platyceros*. Turner et al. (2017) did not identify *P. platyceros* in Copper Rockfish diets in the San Juan Channel, but in the ecological community surveys conducted at these study locations Turner (2015) notes that *P. platyceros* were only observed in a few isolated instances.

The multiple factors that make it difficult for researchers to completely describe the food habits of rockfish (see section 2.1), also limit the data available on the sizes of shrimp and prawn consumed by inshore rockfish. Murie (1991) estimates mean flexed body length[18] of *P. danae* from Copper and Quillback Rockfish stomachs as 18.8 mm (±5.7 mm within one standard deviation), which is notably smaller than the average 7.5 to 10 cm total length of *P. danae* females and the minimum mesh size of traps. Five *P. platyceros* consumed by Copper Rockfish had a mean flexed body length of 32.4 mm (±2.6 mm within one standard deviation) (Murie 1991), which is smaller than the 33 mm carapace length minimum legal size limit for prawn in the commercial trap fishery. In a rockfish diet study on BC's Central Coast, two small *P. platyceros* (63 mm and 73 mm in total length) were measured in two of the 14 Quillback Rockfish specimens collected (Olson et al. in prep). North Pacific groundfish diet time series conducted by AFSC (2011) lists a carapace length of 47 mm for one of the *P. platyceros* found in a Yelloweye Rockfish stomach. While further research is required, this single case suggests that Yelloweye Rockfish are capable of consuming *P. platyceros* that are above the minimum legal size limit for prawn in the commercial trap fishery.

Reduction in inshore rockfish prey species in RCAs could increase food competition and decrease ecosystem carrying capacity. However, there is currently no data to assess this potential effect on rockfish recovery in RCAs.

Prawn traps are a bottom contact fishing method that can damage benthic habitats such as delicate sponges and corals, which are prime rockfish habitat. Some RCAs overlap with unprotected glass sponge reefs (Dunham et al. 2019). Prawn traps can drag along rocky habitat and cause damage to sessile organisms such as anemones, which are important habitats for many demersal crustaceans (Lewis et al. 2009). Damage to sessile benthic organisms could further affect prey availability and decrease habitat features that protect rockfish from predation.

Lost trap gear can continue to catch and kill marine species until they become disabled by disintegration of escape (rot) cord, or lose their structural integrity (NRC 2008). There is no

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[17] Findings from Olson et al. (in prep) were provided to the authors of the present paper by Angeleen Olson and Alejandro Frid. Specimen collection for Olson et al. (in prep) are part of: Frid, A., McGreer, M., Haggarty, D.R., Beaumont, J., and Gregr, E.J. 2016. Rockfish size and age: The crossroads of spatial protection, central place fisheries and indigenous rights, Global Ecology and Conservation, 8: 170-182.

[18] The distance from the back of the eye orbit to the posterior edge of the flexed, third abdominal segment (Murie 1991).

information available on annual commercial prawn trap losses in BC. However, lost prawn traps have been located with submersibles (Breen 1989). In Puget Sound, prawn trap loss from commercial sectors is believed to be very low (<0.1% of traps fished). The overall estimated density of derelict prawn traps was 14 traps per square kilometer in an average depth of 59 m (Antonelis et al. 2018). The commercial fishery is required to use rot cord to facilitate escapements in the case of ghost fishing. Rot cord is designed to take 90-130 days to disintegrate, but research has shown it can take much longer for cords to break and marine growth and rust can prevent some cages from opening for years (Arthur et al. 2014).

C.4. TOTAL ROCKFISH BYCATCH COASTWIDE (BY REGION) INSIDE AND OUTSIDE RCAS IN PRAWN TRAPS (ALL ROCKFISH AND INSHORE ROCKFISH).

Table C.4: Total rockfish bycatch in commercial prawn by trap presented by region (Queen Charlottes/Haida Gwaii, North Coast, Central Coast, West Coast of Vancouver Island, and Inside Waters). Regional bycatch tables are divided by rockfish caught outside RCAs and inside RCAs. No RCAs were sampled in the North Coast region. Bycatch data were extracted from DFO database (PrawnTrap_Bio).

Queen Charlottes/Haida Gwaii – Total number of Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Outside RCAs

Species	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
Black	2	2	-	-	-	-	-	-	-	4
Bocaccio	1	-	-	-	-	-	-	-	-	1
Brown	-	-	-	-	-	-	1	-	-	1
Canary	4	-	-	-	-	-	-	-	-	4
Copper	16	3	7	14	1	-	2	5	3	51
Darkblotched	1	-	-	-	-	-	-	-	-	1
Greenstriped	1	-	-	-	-	-	-	-	-	1
Harlequin	-	-	-	-	-	-	-	-	-	0
Quillback	39	8	12	9	13	10	14	15	7	127
Redbanded	1	-	-	-	-	-	-	-	-	1
Rosethorn	2	-	-	-	-	-	-	-	-	2
Tiger	1	-	2	-	-	-	-	-	-	3
Yelloweye	-	-	3	-	-	-	-	-	3	6
Yellowtail	-	-	-	-	-	-	1	-	-	1
TOTAL Rockfish caught per year	68	13	24	23	14	10	18	20	13	203
Number of strings sampled	74	53	60	85	81	52	58	69	51	583
Encounter rate	0.92	0.25	0.40	0.27	0.17	0.19	0.31	0.29	0.25	0.35

Queen Charlottes/Haida Gwaii - Total Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Inside RCAs

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Black	-	-	-	-	-	-	-	-	-	0
Bocaccio	-	-	-	-	-	-	-	-	-	0
Brown	-	-	-	-	-	-	-	-	-	0
Canary	-	-	-	-	-	-	-	-	-	0
Copper	1	1	-	-	1	1	-	-	-	4
Darkblotched	-	-	-	-	-	-	-	-	-	0
Greenstriped	-	-	-	-	-	-	-	-	-	0
Harlequin	-	-	-	-	-	-	-	-	-	0
Quillback	-	-	3	-	3	-	1	-	4	11
Redbanded	-	-	-	-	-	-	-	-	-	0
Rosethorn	-	-	-	-	-	-	-	-	-	0
Tiger	-	-	-	-	-	-	-	-	-	0
Yelloweye	-	-	-	-	-	-	-	-	-	0
Yellowtail	-	-	-	-	-	-	-	-	-	0
TOTAL	1	1	3	0	4	1	1	0	4	15
Number of strings sampled	12	19	36	21	31	29	8	15	15	186
Encounter rate	0.08	0.05	0.08	0.00	0.13	0.03	0.13	0.00	0.27	0.08

North Coast - Total Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Outside RCAs

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOT
Black	-	-	-	-	-	-	-	1	-	1
Bocaccio	-	1	-	-	-	-	-	-	-	1
Chilipepper	2	-	-	-	-	-	-	-	-	2
China	-	-	-	-	-	-	-	-	1	1
Copper	-	-	-	-	1	2	2	-	9	14
Darkblotched	-	-	-	-	-	-	-	-	2	2
Greenstriped	-	1	-	-	-	-	-	-	-	1

North Coast - Total Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Outside RCAs										
Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOT
Harlequin	1	-	-	-	-	-	-	-	1	2
Pacific ocean perch	-	-	-	-	-	-	-	-	-	0
Quillback	10	5	8	8	7	10	16	17	34	115
Rougheye	1	-	-	5	-	-	-	-	8	14
Stripetail	-	-	-	-	-	-	-	-	1	1
Tiger	-	-	-	-	-	-	-	-	-	0
Vermilion	-	-	-	-	-	-	-	-	-	0
Yelloweye	1	-	3	4	1	-	4	3	1	17
Yellowmouth	-	-	-	-	-	-	-	-	-	0
TOTAL	15	7	11	17	9	12	22	21	57	171
Number of strings sampled	93	85	99	47	61	85	69	46	122	707
Encounter rate	0.16	0.08	0.11	0.36	0.15	0.14	0.32	0.46	0.47	0.24
North Coast – No RCAs Sampled										

Central Coast - Total Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Outside RCAs										
Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOT
Central Coast	-	-	-	-	-	-	-	-	-	0
Black	-	-	-	-	-	-	-	1	1	2
Brown	-	-	-	-	-	-	5	-	-	5
Canary	1	-	-	-	-	-	-	-	-	1
Chilipepper	-	-	-	-	-	-	-	-	-	0
China	-	-	-	-	-	-	-	-	-	0
Copper	-	-	3	5	4	3	22	-	8	45
Darkblotched	1	-	-	-	-	-	-	-	-	1
Greenstriped	7	20	21	7	3	3	5	16	4	86
Harlequin	4	1	1	-	-	-	-	-	-	6
Pacific ocean perch	2	-	-	-	-	-	-	-	-	2
Puget sound	2	-	-	-	-	-	-	-	-	2
Quillback	43	13	13	22	22	25	26	26	47	237

Central Coast - Total Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Outside RCAs										
Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOT
Redbanded	3	-	1	-	-	1	-	-	-	5
Redstripe	1	-	-	-	-	-	-	-	9	10
Rockfishes	-	-	-	-	-	-	-	1	-	1
Rosethorn	1	-	-	-	-	-	-	-	-	1
Rougheye	-	2	-	1	-	-	-	-	-	3
Sharpchin	-	-	1	-	-	-	-	-	-	1
Shortraker	-	-	-	-	-	-	1	-	-	1
Splitnose	2	-	-	-	-	-	-	-	-	2
Stripetail	-	-	-	1	3	-	-	-	-	4
Tiger	-	-	-	-	-	-	-	-	2	2
Widow	-	-	-	-	-	-	2	-	-	2
Yelloweye	1	4	3	1	-	-	1	2	9	21
Yellowtail	-	-	-	-	-	2	-	1	-	3
TOTAL	68	40	43	37	32	34	62	47	80	443
Number of strings sampled	348	323	295	323	266	207	253	274	242	2531
Encounter rate	0.20	0.12	0.15	0.11	0.12	0.16	0.25	0.17	0.33	0.18

Central Coast - Total Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Inside RCAs										
Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOT
Central Coast	-	-	-	-	-	-	-	-	-	-
Black	-	-	-	-	-	-	-	-	-	0
Brown	-	-	-	-	-	-	-	-	-	0
Canary	-	-	-	-	-	-	-	-	-	0
Chilipepper	-	-	-	-	-	-	-	-	-	0
China	-	-	-	-	-	-	-	-	-	0
Copper	-	-	-	-	-	1	1	-	-	2
Darkblotched	-	-	-	-	-	-	-	-	-	0
Greenstriped	-	-	-	-	-	1	-	-	-	1
Harlequin	-	-	-	-	-	-	-	-	-	0

Central Coast - Total Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Inside RCAs

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOT
Pacific ocean perch	-	-	-	-	-	-	-	-	-	0
Puget sound	-	-	-	-	-	-	-	-	-	0
Quillback	-	-	3	1	4	9	2	-	3	22
Redbanded	-	-	-	-	-	2	-	-	-	2
Redstripe	-	-	-	-	-	-	-	-	-	0
Rockfishes	-	-	-	-	-	-	-	-	-	0
Rosethorn	-	-	-	-	-	-	-	-	-	0
Rougheye	-	-	-	-	-	-	-	-	-	0
Sharpchin	-	-	-	-	-	-	-	-	-	0
Shortraker	-	-	-	-	-	-	-	-	-	0
Splitnose	-	-	-	-	-	-	-	-	-	0
Stripetail	-	-	-	-	-	-	-	-	-	0
Tiger	-	-	-	-	-	-	-	-	-	0
Widow	-	-	-	-	-	-	-	-	-	0
Yelloweye	-	-	-	-	-	-	-	-	-	0
Yellowtail	-	-	-	-	-	-	-	-	-	0
TOTAL	0	0	3	1	4	13	3	0	3	27
Number of strings sampled	4	7	5	4	11	16	6	4	10	67
Encounter rate	0.00	0.00	0.60	0.25	0.36	0.81	0.50	0.00	0.30	0.40

West Coast - Total Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Outside RCAs

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOT
Black	-	-	1	2	-	2	-	2	1	8
Bocaccio	4	-	-	1	-	-	-	-	4	9
Canary	-	-	-	-	3	-	-	-	2	5
Copper	8	9	-	8	26	19	18	3	120	211
Darkblotched	1	1	-	-	-	-	-	-	1	3
Greenstriped	3	-	1	1	3	5	1	2	6	22
Harlequin	-	-	-	-	1	-	-	-	1	2

West Coast - Total Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Outside RCAs

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOT
Quillback	21	13	27	32	76	35	47	18	82	351
Redbanded	-	-	-	1	-	-	-	-	-	1
Redstripe	2	-	-	-	-	-	-	-	8	10
Silvergray	-	-	-	1	-	-	-	-	-	1
Widow	-	-	-	-	-	-	-	-	-	0
Yelloweye	-	3	2	4	5	1	13	6	4	38
Yellowtail	-	-	1	1	-	-	-	-	2	4
TOTAL	39	26	32	51	114	62	79	31	231	665
Number of strings sampled	209	210	228	263	396	254	323	291	418	2592
Encounter rate	0.19	0.12	0.14	0.19	0.29	0.24	0.24	0.11	0.55	0.26

West Coast - Total Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Inside RCAs

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOT
Black	-	-	-	-	-	-	-	-	-	0
Bocaccio	-	-	-	-	-	-	-	-	-	0
Canary	-	-	-	-	-	-	-	-	-	0
Copper	-	-	-	-	-	-	-	1	8	9
Darkblotched	-	-	-	-	-	-	-	-	-	0
Greenstriped	-	-	-	-	-	-	-	-	-	0
Harlequin	-	-	-	-	-	-	-	-	-	0
Quillback	-	1	-	2	-	-	1	-	14	18
Redbanded	-	-	-	-	-	-	-	-	-	0
Redstripe	-	-	-	-	-	-	-	-	1	1
Silvergray	-	-	-	-	-	-	-	-	-	0
Widow	-	-	-	-	-	-	-	-	-	0
Yelloweye	-	-	-	-	-	-	-	-	-	0
Yellowtail	-	-	-	-	-	-	-	-	-	0
TOTAL	0	1	0	2	0	0	1	1	23	28
Number of strings sampled	9	8	5	17	13	11	18	10	37	128
Encounter rate	0.00	0.13	0.00	0.12	0.00	0.00	0.06	0.10	0.62	0.22

Inside Waters - Total Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Outside RCAs

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOT
Black	-	-	-	1	3	1	-	-	-	5
Blackgill	-	-	-	-	-	1	-	-	-	1
Brown	-	-	-	-	-	-	-	1	-	1
Canary	-	8	-	-	8	-	-	2	2	20
Chilipepper	-	-	-	-	1	-	-	-	-	1
China	-	-	7	9	2	1	-	-	-	19
Copper	33	57	28	39	62	67	32	15	12	345
Dusky	-	-	-	1	-	-	-	1	-	2
Greenstriped	5	9	12	33	18	57	64	42	65	305
Pygmy	-	-	-	-	-	-	1	-	-	1
Quillback	97	150	295	329	307	253	251	176	240	2098
Redbanded	1	-	-	-	1	-	-	-	-	2
Redstripe	-	-	-	-	-	-	-	-	-	0
Sharpchin	1	-	-	-	-	-	-	-	-	1
Shortbelly	-	-	-	-	-	-	1	-	1	2
Silvergray	-	-	-	-	-	-	-	-	-	0
Splitnose	-	-	-	-	-	3	-	-	-	3
Tiger	1	-	2	-	-	-	-	2	-	5
Widow	-	-	-	-	-	1	-	-	-	1
Yelloweye	14	22	19	33	12	39	44	17	23	223
Yellowtail	2	-	2	-	-	1	-	1	-	6
TOTAL	154	246	365	445	414	424	393	257	343	3041
Number of strings sampled	681	767	877	724	859	718	792	695	825	6938
Encounter rate	0.23	0.32	0.42	0.61	0.48	0.59	0.50	0.37	0.42	0.44

Inside Waters - Total Rockfish (ALL SPECIES) caught by Spot Prawn trap in bycatch monitoring program - Inside RCAs									
Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOT
Brown	-	-	-	-	-	-	1	-	1	2
Canary	-	4	-	-	1	-	-	1	-	6
China	1	-	4	-	1	2	-	1	1	10
Copper	10	11	6	9	33	15	13	3	6	106
Dusky	1	-	-	-	-	-	-	-	-	1
Greenstriped	4	16	13	14	9	22	18	14	9	119
Pygmy	-	-	-	-	-	-	1	-	-	0
Quillback	59	57	119	104	107	71	106	73	69	765
Redbanded	-	-	-	-	-	1	1	-	-	2
Redstripe	-	-	-	-	-	1	-	-	-	1
Stripetail	-	-	-	-	-	-	-	-	2	2
Tiger	-	-	-	-	-	1	-	-	1	2
Widow	-	-	-	-	-	1	-	-	-	1
Yelloweye	3	9	6	10	12	6	14	5	4	69
Yellowmouth	-	-	-	-	-	-	-	-	1	1
Yellowtail	-	-	2	-	-	-	-	-	-	2
TOTAL	78	97	150	137	163	120	153	97	94	1089
Number of strings sampled	291	241	327	316	361	287	330	301	370	2824
Encounter rate	0.27	0.40	0.46	0.43	0.45	0.42	0.46	0.32	0.25	0.39

C.5. SCALLOP TRAWL

Two species of scallops, Pink Scallop (*Chlamys rubida*) and Spiny Scallop (*Chlamys hastata*) are harvested from in-shore waters in the trawl fishery. Since 2000, up to seven licences have been issued annually, with three licences active. Landings have been in the order of 11,340 to 15,876 kg per year. Between 2007 and 2017, five vessels fished mainly in the Campbell River/Quadra Island area (DFO 2018F).

C.5.1. Reporting Data

Commercial scallop trawl logbook data (ScallopTrawlLogs) were examined and fishing records from 2007 to 2017 were extracted to determine rockfish bycatch and fishing effort in RCAs. Coordinates for recorded fishing events were plotted in ArcGIS as point locations. The layer was examined and points located outside BC waters or on land were removed. This layer was then overlaid with RCA boundaries to determine those points that fell inside RCAs. A count of the number of fishing events, sum of time fished in hours, as well as the number of tows for all RCAs per year were determined to measure the amount of fishing effort in RCAs.

C.5.2. Data Assessment

Coast-wide between 2007 and 2017 the scallop trawl fishery made 3,012 tows and their effort was 3004 hours or 125.2 fishing days (hours fished/24) (Table 19).

Table 19: Scallop trawl fishery fishing effort coast-wide, 2007-2017 (Source: ScallopTrawlLogs, data extracted March 6, 2018).

Year	Fishing Events	Time Fished (hours)	Number of Tows
2007	101	573	588
2008	121	729	742
2009	80	499	485
2010	45	295	274
2011	70	459	454
2012	26	159	174
2013	20	142	148
2014	14	81	92
2017	10	67	55
Total	**487**	**3004**	**3012**

Two RCAs were fished in 2008 and 2009, respectively, for a total of 63 tows and 2.04 fishing days. No rockfish bycatch was recorded in RCAs. One China Rockfish was caught outside RCAs.

C.5.3. Discussion

Fishing activity in the scallop trawl fishery in RCAs is limited and rockfish bycatch could possibly be non-existent. The slow towing speed of scallop butterfly trawl nets (0.5 to 0.7 knots) allows most mobile organisms to avoid capture (DFO 2018F). This type of net is designed to remain approximately 20 cm off the bottom to catch swimming scallops, although occasional net contact can occur. This fishery is considered a bottom contact fishery because the net sits on several steel runners which roll across the bottom during tows. As a bottom contact fishery, commercial scallop trawling is prohibited in glass sponge reef closures; the steel runners and occasional net contact from this fishery are a concern for important rockfish habitat like glass sponges. Although this fishery is limited in its spatial scale and overall effort, repeated activity in a particular RCA could damage rockfish habitats and affect rockfish recovery.

A portion of a scallop identified to the Pectinidae family was documented in the stomach content of Quillback Rockfish (n = 67) off southeast Alaska, indicating scallops may be a prey species of low relative importance (Rosenthal et al. 1988).

C.6. KRILL BY MID-WATER TRAWL

Euphausiid (or krill) by mid-water trawl is a permitted fishery in RCAs. The commercial fishery is limited entry and managed through area-based quotas, seasonal openings, and a precautionary total allowable catch (DFO 2018l). The fishery occurs in the south coast of BC, in the upper Strait of Georgia, Jervis Inlet, and in several other mainland inlets. Most of the inlets are open to the fishery annually from January 5 until either the individual inlet area quota is caught or March 31, whichever occurs first. If there is quota remaining, an inlet may re-open August 16 quota is caught or October 31. Areas of the Strait of Georgia are open annually from November 1 until either quota is caught or December 31. From 2007 to 2015, three to six vessels per year have participated in the fishery (DFO 2018l).

In BC waters but Euphausiid biomass is dominated by five species: *Euphausia pacifica, Thysanoessa spinifera, T. inspinata, T. longipes* and *T. raschii* (DFO 2018l). *E. pacifica* typically accounts for 70 – 100 percent of the Euphausiid biomass in the Strait of Georgia (DFO 2018l).

C.6.1. Reporting Data

In order to assess effects of the krill trawl fishery on rockfish and their habitats in RCAs, DFO Fishery Managers and the krill IFMP were consulted. Since there are no logbook data for bycatch and GPS coordinates for fishing locations, rockfish bycatch and fishing effort in RCAs could not be assessed. The fishery has 100% dockside validation; however, it is unlikely small quantities of rockfish are noticed in large amounts of krill.

C.6.2. Data Assessment

Plankton trawl nets only fish the upper few metres of the water column. Due to slow towing speeds that are a requirement for fine mesh planktonic nets, larger marine organisms can generally avoid nets during tows. Between 2007 and 2015, total landings in the fishery were less than half of the 500 tonnes set as the total allowable catch, except in 2012 when 260 tonnes were landed (DFO 2018l). Bycatch typically consists of hake, herring, and dogfish. Juvenile rockfish are encountered on rare occasions (DFO 2018l; J. Johansson, DFO, Regional Head Quarters, Vancouver, *pers. comm*., January 2018).

C.6.3. Discussion

Rockfish bycatch is presumed to be low in the krill trawl fishery due to shallow fishing depths, slow tow speeds, and limited nature of the fishery. Bottom contact is also presumed to be an uncommon occurrence. Concerns about the removal of rockfish prey species are minimal since the krill fishery removes less than 1% of the estimated total krill biomass per year. Nevertheless, in low abundance years, localized depletions of krill could affect their availability to rockfish.

Concerns about the removal of rockfish prey species are minimal since the krill fishery removes less than 1% of the estimated total krill biomass per year. Nevertheless, in low abundance years, localized depletions of krill could affect their availability to rockfish. *Euphausiidae* krill are documented prey of Black Rockfish (Bizzarro et al. 2017), Brown Rockfish (Bizzarro et al. 2017), and Copper Rockfish (Lea et al. 1999). Murie (1995) found *E. pacifica* represent 0.9 percent and 7.9 percent of the mass of prey items diets of Copper Rockfish and Quillback Rockfish, respectively. *T. raschii* have also been identified as 2.8 percent of the total volume of prey in the diet of 67 Quillback Rockfish specimens (Rosenthal et al. 1988).

C.7. SARDINE, SMELT, AND HERRING BY SEINE, GILLNET, AND SPAWN-ON-KELP

Commercial fishing for smelt, sardine, and herring by gillnet, seine, and spawn-on-kelp are permitted in RCAs.

C.7.1. Reporting Data

Available catch monitoring data for smelt, sardine, and herring seine and gillnet fisheries did not allow for a formal RCA impact assessment to be conducted (e.g. there are no location data and limited bycatch monitoring); consequently, fishery managers employed by Fisheries and Oceans Canada were consulted to determine how these fisheries may affect RCAs.

C.7.2. Discussion

Smelt gillnet and seine net commercial fisheries have been closed since 2012. These fisheries were relatively small and occurred primarily near beaches and river mouths where smelt congregate. There was no catch monitoring program for this fishery when it was operational. Due to the small scale and location of this fishery, it probably did not encounter large quantities of rockfish. However, potential fishing in shallow eelgrass environments may affect juvenile rockfish. If the fishery reopens, it will be reassessed under the New Emerging Fisheries Policy (B. Spence, DFO, Regional Head Quarters, Vancouver, *pers. comm.*, February 2018).

The sardine seine net fishery has been closed since 2015. When the fishery was open, there were logbook records with GPS fishing coordinates, partial on-board observer coverage, and 100% dockside validation. Records of incidentally caught species indicate rockfish encounters were minimal; bycatch of salmon and dogfish was more common. Since the fishery is currently closed, rockfish bycatch from logbooks and sardine fishing effort in RCAs were not assessed. The fishery could reopen when stock assessments indicate sardine populations and migration patterns can support harvesting (DFO 2015; B. Spence, DFO, Regional Head Quarters, Vancouver, *pers. comm.*, February 2018).

The commercial Herring seine net fishery has 100% dockside validation. Rockfish bycatch and ghost fishing are not considered a major concern in the fishery. However, it is difficult to see rockfish bycatch in large quantities of Herring (V. Postlethwaite, DFO, Regional Head Quarters, Vancouver, *pers. comm.*, February 2018). Comprehensive assessments of rockfish bycatch in seine nets are not available. Vessels fish in deep water only and avoid bottom contact to prevent gear entanglement. There is no location specific logbook information available to assess fishing effort in RCAs (B. Spence, DFO, Regional Head Quarters, Vancouver, *pers. comm.*, February 2018).

The commercial herring gillnet fishery has 100% dockside validation, but it is difficult to see bycatch in large offloads of Herring. There is concern about rockfish bycatch in certain RCAs that overlap with Herring spawning and gillnet fishing locations, specifically gillnet fishing in Area 17 RCAs and Area 14 (Savoie Rocks - Maude Reef and Chrome Island RCAs). Areas 17 and 14 are significant gillnet fishing locations and consultations on any proposed changes would be required. Ghost fishing from lost nets is of concern in RCAs that overlap with gillnet fishing locations. There is no location specific logbook information for the Herring gillnet fishery to assess fishing effort in RCAs. Anchors are used when gillnetting Herring so benthic habitat damage is a possibility (B. Spence, DFO, Regional Head Quarters, Vancouver, *pers. comm.*, February 2018).

The herring spawn-on-kelp fishery is permitted in RCAs; however, this fishery is highly selective and there is no bottom contact as kelp is harvested from the surface by hand with a knife (S.

Groves, DFO, Fisheries and Oceans Field Office, Prince Rupert, *pers. comm.*, September 2017).

Although direct effects on rockfish appear to be small for Herring fisheries, herring are documented as prey for Black Rockfish (Bizzarro et al. 2017; Steiner 1978), Brown Rockfish (Bizzarro et al. 2017; Steiner 1978), Copper Rockfish (Murie 1995), Quillback Rockfish (Murie 1995; Rosenthal et al. 1988), Tiger Rockfish (Rosenthal et al. 1988) and Yelloweye Rockfish (Bizzarro et al. 2017; Rosenthal et al. 1988). Juvenile herring are a major component of some inshore rockfish species' diets. One study found juvenile herring made up 59.2 percent of Copper Rockfish diets and 65.1 percent of Quillback Rockfish diets by mass (Murie 1995). Effects of localized prey removals (e.g. removing herring spawn) to rockfish populations are unknown.

C.8. OPAL SQUID BY SEINE NET

The Opal Squid fishery was closed in 2012 and there are currently no plans to reopen this fishery in the future. There was little concern about rockfish bycatch in the fishery when it was operational; however, there were no available data to assess potential rockfish bycatch and fishing effort in RCAs before the fishery was closed (J. Johansen, DFO, Regional Head Quarters, Vancouver, *pers. comm.*, January 2018).

C.9. SALMON BY SEINE AND GILLNET

Pacific salmon species managed by DFO include Sockeye, Coho, Pink, Chum, and Chinook. These species occur in approximately 1300 to 1500 rivers and streams throughout the Pacific Region, notably in the Skeena, Nass, and Fraser Rivers, which account for approximately 75% of the total salmon production in Canada (DFO 2018H). Commercial salmon licences are issued for three gear types: seine, gillnet, and troll. Only fishing by seine and gillnet gear types are permitted in RCAs.

C.9.1. Reporting Data

Salmon gillnet and seine net fishers are required to report incidental rockfish catch in their harvest log books by Pacific Fisheries Management Area (PFMA). In some fisheries, incidental rockfish catch is reported by sub-area or area (G. Hornby, DFO, Fisheries and Oceans Field Office, Campbell River, *pers. comm.*, March 2018). Some fisheries have partial on-board observer coverage and, in these cases, catch is often associated with GPS coordinates. Fisheries with no at-sea observers do not have GPS coordinates attached to fishing locations; consequently, fishing effort in RCAs could not be assessed given the available data. Records of fisher-reported rockfish incidental catch were used for the salmon gillnet and seine net fishery from logbooks and phone-in reports in the Fishery Operations System (FOS) database to assess rockfish bycatch coast-wide from 2007 to 2017. Duplicates from logbooks and phone-in reports were removed.

C.9.2. Data Assessment

Between 2007 and 2017, the commercial salmon gillnet fishery reported 25 incidentally caught Black Rockfish and one China Rockfish. Incidental catch was spread across PFMAs 3, 4, 11, 12, 21, and 23.

There were no records of incidental rockfish catch in the salmon seine net fishery from 2007 to 2017.

C.9.3. Discussion

Based on fisher reported data, rockfish bycatch in the salmon seine and gillnet fishery appears to be low. Rockfish bycatch is low because fishers do not want to contact bottom habitats that may entangle their nets (G. Hornby, DFO, Fisheries and Oceans Field Office, Campbell River, *pers. comm.*, February 2018). However, more pelagic rockfishes (e.g. Black Rockfish and Yellowtail Rockfish) may be incidentally caught even when nets do not contact bottom habitats, or when accidental bottom contact does occur. Salmon seine and gillnetting activity in RCAs, particularly in Johnstone Strait, is considered to be infrequent based on a comparison of PFMA fishery openings and RCA locations (M. Mortimer, DFO, Fisheries and Oceans Field Office, Campbell River *pers. comm.*, March 2018).

Gillnet ghost fishing could be a concern for rockfish. The extent of lost fishing nets is unknown, but lost nets have been retrieved off rocky habitats in Area 24 with entangled rockfish as rockfish will enter the nets to feed on other entangled dead fish (M. Spence, DFO, Fisheries and Oceans Field Office, Port Alberni, *pers. comm*., February 2018). These nets will continue to ghost fish until they are removed or degrade, which may take years. Fishery notices encourage fishers to report lost fishing gear to area managers or charter patrol (G. Hornby, DFO, Fisheries and Oceans Field Office, Campbell River, *pers. comm.*, March 2018).

There are no reports of incidental rockfish catch in salmon seine net fishing. This could indicate that the technique adequately avoids rockfish habitat, or it may reflect under-reporting or difficulties finding rockfish buried among large quantities of salmon catch.

C.10. HAND-PICKING OF INVERTEBRATES

Commercial hand-picking of invertebrates while diving is permitted in RCAs. Commercial harvest data for Geoduck Clam (*Panopea generosa*), Horse Clam (*Tresus* sp.), Green Sea Urchin (*Strongylocentrotus droebachiensis*), Red Sea Urchin (*Mesocentrotus franciscanus*) and Sea Cucumber (*Parastichopus californicus*) by dive fisheries were assessed to determine the extent of fishing activities in RCAs.

C.10.1. Reporting Data

Geoducks and Horse Clams are harvested under the same commercial licence. Harvest logbook data from 2007 to 2017 were used to determine the amount of fishing in RCAs. Each harvest log includes a fishing location that represents one point per dive within a geoduck bed. All logs from 2007 to 2017 were extracted and points were mapped in ArcGIS. RCA boundaries were overlaid with fishing locations and all points overlapping RCAs were counted.

For Green Sea Urchin, Red Sea Urchin, and sea cucumber dive fisheries, commercial harvest logbook data from the last five years were used to assess fishing activity in RCAs (GeoduckLogs and HorseClamLogs). In addition to harvest records, spatial fishery footprints compiled by a third party service provider were available. Each spatial footprint of a fishing event (represented as linear or area-based features) corresponds to a harvest log. As each harvest log represents only one point per dive in a particular bed, the harvest log information was joined to the spatial fishery footprints for each of these fisheries to obtain better estimates of the extents of fishing grounds. The Green Sea Urchin, Red Sea Urchin, and Sea Cucumber fisheries data layers were then overlaid with RCA boundaries to determine overlap. The number of fishing events (harvest logs) was used as the measure of effort.

C.10.2. Data Assessment

The Geoduck and Horse Clam by dive fishery operates under a three-year area rotation period in the North Coast and most of the Inside waters area (some portions of Areas 16, 18 and 19 are fished annually). The West Coast Vancouver Island area is fished annually for all areas (DFO 2018A). From 2007 to 2017, 50 commercial vessels fishing for Geoduck reported 6,251 harvest logs in 34 RCAs (21%; Table 20).

Table 20: Number of Geoduck and Horse Clam Fishing Events in RCAs by Inside and Outside Waters. (Source: GeoduckLogs and HorseClamLogs, extracted November 2, 2018).

Geoduck				Horse Clam		
Year	**Inside**	**Outside**	**Inside/Outside**	**Inside**	**Outside**	**Inside/Outside**
2007	154	270	424	2	0	2
2008	73	383	456	4	0	4
2009	33	799	832	9	36	45
2010	226	251	477	5	3	8
2011	53	329	382	5	6	11
2012	40	934	974	0	68	68
2013	180	356	536	4	6	10
2014	119	292	411	3	3	6
2015	87	640	727	0	0	0
2016	131	421	552	0	1	1
2017	97	383	480	5	0	5
Total	1,193	5,058	6,251	37	123	160

Approximately 9% of the 66,269 logs that reported coast-wide fishing of Geoducks occurred in RCAs. The majority of fishing in RCAs occurred in Outside waters (5,058 reported harvest logs) compared to Inside waters (1,193 logs). Horse Clam harvesting in RCAs was minimal with 160 logs reported in 13 RCAs (8%) by 18 vessels during 2007-2017. Horse Clam harvesting in RCAs represented about 12% of fishing occurrences coast-wide (1,319 logs reported coast-wide).

The Green Sea Urchin by dive commercial fishery currently occurs in Inside waters only on the east coast of Vancouver Island (DFO 2018C). Based on commercial harvest logs, there were 778 fishing occurrences in 21 RCAs (13%) during the 2012/2013 to 2016/2017 seasons (Table 21).

Table 21: Number of Green Sea Urchin Fishing Events in RCAs from 2012-2017. (Source: GreenUrchinLogs, extracted November 3, 2018)

Season	Inside Waters	Total
2012-2013	70	70
2013-2014	138	138
2014-2015	145	145
2015-2016	188	188
2016-2017	237	237
Total	**778**	**778**

Approximately 40% of the coast-wide harvest (1,928 harvest logs) for Green Sea Urchins occurred in RCAs. In contrast, the Red Sea Urchin by dive fishery occurred coast-wide between the 2011/2012 to 2015/2016 seasons (16,044 harvest logs), with 2,060 harvest records (about 13% of coast-wide harvest logs) in 50 RCAs (30.5%; Table 22).

Table 22: Number of Red Sea Urchin Fishing Events in RCAs from 2011-2016. (Source: RedUrchinLogs, extracted November 6, 2018).

Season	Central Coast	Inside Waters	North Coast	Queen Charlotte	West Coast	Total
2011-2012	145	97	38	22	0	302
2012-2013	145	126	51	66	0	388
2013-2014	156	105	61	117	0	439
2014-2015	191	130	51	111	0	483
2015-2016	134	130	70	114	0	448
Total	**771**	**588**	**271**	**430**	**0**	**2,060**

Most fishing for Red Sea Urchins occurred in Outside waters (1,472 reported harvest logs [71%]) compared to Inside waters (588 logs [29%]). It appears that fishing for Red Sea Urchins in RCAs did not occur on the West Coast during this time period.

The Sea Cucumber dive fishery is managed through limited-entry licencing with 85 licence eligibilities distributed across four licence areas. This fishery has undergone significant changes, with fishers initially having access to approximately 25% of BC's coastline in 2008 to 48% in 2017 (DFO 2018G). From 2012 to 2017, 647 harvest logs (about 8% of coast-wide harvest logs) reported by 34 vessels occurred in 43 RCAs (26%), with 555 (86%) of the logs located in Inside waters (Table 23).

Table 23: Number of Sea Cucumber Fishing Events in RCAs from 2012-2017. (Source: SeaCucumberLogs, extracted November 3, 2018).

Year	Central Coast	Inside Waters	North Coast	Queen Charlotte	West Coast	Total
2012	8	152	4	0	0	164
2013	4	62	0	0	10	76
2014	0	174	27	0	4	205
2015	12	116	0	0	10	138
2016	7	46	0	0	6	59
2017	0	5	0	0	0	5
Total	**31**	**555**	**31**	**0**	**30**	**647**

In summary, when comparing the hand-picking dive fisheries, Red Sea Urchin harvesting occurs in the most RCAs (31%; Table 24).

Table 24: Summary of fishing effort in RCAs for those dive fisheries where the target species are captured by hand.

Fishery	# RCAs Where Fishing Occurs	% of RCAs Where Fishing Occurs	% of Coast-wide Fishing in RCAs	Years of Data
Geoduck	34	21	9	2007-17
Horse clam	13	8	12	2007-17
Green Sea Urchin	21	13	40	2012-17
Red Sea Urchin	50	31	13	2011-16
Sea cucumber	43	26	8	2012-17

RCAs are important to the Green Sea Urchin fishery as 40% of harvesting occurs inside these protected areas.

C.10.3. Discussion

Hand-picking of invertebrates in RCAs is considered to be a negligible risk to rockfish and their habitats due to the highly selective nature of these fisheries. However, there are potential limited effects to habitat due to diver bottom contact and siltation. The Geoduck fishery uses high pressure water jets to remove sediment; however, harvesting avoids rockfish habitat, including eelgrass beds (Liu et al. 2015) and siltation effects are likely to be minimal.

C.11. AQUACULTURE

BC's aquaculture industry is a significant component of the marine fisheries in BC, with 740 aquaculture operations. In 2010, DFO assumed responsibility for regulating, monitoring and licencing all marine finfish, shellfish, and freshwater (or land-based) aquaculture operations in BC. The Province of BC manages provincial Crown land, including the issuance of land tenures where operations take place in either the marine or freshwater environment. This includes tenures for aquaculture facilities. There is a federal-provincial harmonized process for reviewing applications to operate an aquaculture facility in BC. Aquaculture facilities must operate in compliance with key health and environmental legislation (e.g. *Species at Risk Act*). Licences are issued for the operation of a specific aquaculture site; issued mostly for multiple years; and must be renewed at the frequency specified in the licence conditions. We assessed aquaculture tenure and facility information to determine any potential impacts on the conservation effectiveness of RCAs.

C.11.1. Reporting Data

Aquaculture Tenure Overlap in RCAs (Shellfish and Finfish)

The latest aquaculture data provided by DFO Aquaculture Management Division (AMD) was analysed. The datasets included a tenures (polygon) layer and a spreadsheet of all aquaculture facilities in BC. The tenures dataset is a subset of the Tantalis Crown Tenures dataset published by the Province of British Columbia and publicly available through BC's Data Catalog. The tenures dataset was filtered to include only tenures for aquaculture purposes (with status as being disposition in good standing or application has been accepted) and includes tenures for finfish and shellfish. The aquaculture facilities spreadsheet was extracted by AMD from DFO's Aquaculture Integrated Information System (AQUIIS). This data includes currently valid licenced aquaculture facilities in BC.

The coordinates in the facilities spreadsheet were used to map the facility locations in GIS as point locations. Both the facilities and tenure layers were overlaid with the RCA boundaries in GIS to determine the number of RCAs that overlap with licenced and finfish aquaculture tenures. The total proportion and area of aquaculture tenure overlap (km^2 and percentage) in all affected RCAs was also analysed, and the number of licenced facilities for both shellfish and finfish.

Incidental Rockfish Catch in Finfish Aquaculture Nets

All finfish aquaculture facilities are required to record and report all species incidentally caught during aquaculture harvests and transfer events. Rockfish incidental catch can occur during finfish harvest when rockfish are removed from finfish pens by vacuums designed to remove farmed finfish species or when rockfish within pens become trapped in aquaculture nets as they are gathered together during harvest. Records are the responsibility of facility managers and are not monitored by third-party observers; however, DFO conducts occasional audits of harvests. Rockfish mortality within net pens during the grow out phase of finfish aquaculture is also reported to DFO if they are collected with farmed fish mortalities during routine removal. To assess the frequency and magnitude of incidental rockfish catch mortality during harvest in finfish aquaculture, data from 2011-2017 from the public access DFO aquaculture database was analysed. The number of finfish sites reporting incidental rockfish catch overlap with RCAs was also assessed.

C.11.2. Data Assessment

Aquaculture Tenure Overlap in RCAs (Shellfish and Finfish)

Coast-wide, 37 RCAs (22.5% of 164 RCAs) overlap with existing finfish and shellfish aquaculture tenures (Table 25; Figure 17; Figure 18). The aquaculture tenures cover 14.7 km^2 (2.6%) of the 37 overlapping RCAs (563.1 km^2 total area).

There are 87 shellfish aquaculture tenures (63 licenced sites) overlapping one or more of the 37 RCAs. The Read–Cortes Islands RCA has the greatest number of shellfish tenure overlaps coastwide with 14 licenced sites (0.2 km^2). There are 36 finfish aquaculture tenures (34 licenced sites) overlapping one or more of the 37 RCAs. Eight of the 34 licenced sites have rockfish habitat (rocky substrate) in their depositional zone, with the remaining 26 sites over soft sediment (muddy seabed).

Incidental Rockfish Catch in Finfish Aquaculture Nets

A total of 3,253 rockfish were reported to be incidentally caught during finfish aquaculture harvests between 2011-2017 at 22 different finfish aquaculture locations across BC. Of this total, 1,002 incidentally caught rockfish were Yellowtail Rockfish and 1,504 were inshore or unidentified rockfish. Most reports of incidental rockfish (3,150) catch were from seven different sites all owned by the same company, of which 3,085 rockfish were caught at three of these sites, all located in PFMA 27. Within RCAs, a total of 16 rockfish (14 of which were Inshore Rockfish) were reported to have been incidentally caught at five aquaculture sites between 2011-2017 (Table 25). RCAs with reported finfish aquaculture bycatch are marked with a * in Table 25.

*Table 25: Aquaculture tenure overlap in RCAs coastwide. * indicates RCAs with reported incidental rockfish catch at finfish sites between 2011-2017. Data sourced from DFO aquaculture online database.*

RCA Name	Total shellfish tenures	Total licenced shellfish tenures	Total finfish tenures	Total licenced finfish tenures	Total RCA area (km^2)	RCA area overlapping aquaculture tenure (km^2)	Percentage of RCA within aquaculture tenure (%)
Baynes Sound - Ship Point	1	0	0	0	2.5	0	0.1
*Bedwell Sound (area 24)	0	0	5	5	15.4	1.4	8.8
*Browning Island to Raynor Group	0	0	2	2	17.4	0.8	4.4
Burgoyne Bay	1	1	0	0	2.6	0	1.3
Chancellor Inlet West	0	0	2	2	13.9	1.1	7.8
Chrome Island	3	3	0	0	3.9	0.1	3.2
Coffin Point	2	2	0	0	4.3	0	0.7
Copeland Islands	1	1	0	0	15.3	0	0
De Courcy Island North	3	1	0	0	4	0.1	1.8

RCA Name	Total shellfish tenures	Total licenced shellfish tenures	Total finfish tenures	Total licenced finfish tenures	Total RCA area (km^2)	RCA area overlapping aquaculture tenure (km^2)	Percentage of RCA within aquaculture tenure (%)
Departure Bay	1	0	0	0	2.7	0	1.5
Desolation Sound	4	4	0	0	60	0.1	0.2
Eden-Bonwick-Midsummer-Swanson Islands	1	0	4	4	68.7	0.9	1.4
Forward Harbour	1	0	0	0	3.3	0.2	7.5
Gabriola Passage	5	1	0	0	2.7	0.2	6
Greenway Sound	0	0	2	2	17.9	1.4	8.1
Hardy Island	6	4	0	0	16	0.3	2.2
Hotham Sound	2	1	0	0	22.4	0.2	0.7
Kanish Bay	4	3	0	0	8	0.6	7.6
*Maud Island	0	0	1	1	3.1	0.1	3.6
Nelson Island	4	2	0	0	8.7	0.1	0.7
Octopus Islands to Hoskyn Channel	6	5	5	3	35.9	1	2.8
Port Elizabeth	0	0	1	1	6	0.2	4.1
Prevost Island North	1	0	0	0	9.1	0	0.3
Read-Cortes Islands	14	14	0	0	30.3	0.2	0.8
Sabine Channel-Jervis-Jedediah Islands	7	7	0	0	22.4	0.1	0.5
Salmon Inlet	0	0	1	1	17.5	0.2	0.9
Saltspring Island North	1	1	0	0	8.5	0.1	1.7
*Saranac Island (area 24)	1	1	2	2	10.9	0.3	3.2
Savoie Rocks - Maude Reef	2	2	0	0	1.7	0	1.9
Shelter Bay	0	0	2	2	15.5	1.1	7.2
Skookumchuck Narrows	1	0	2	2	13.2	0.3	2.1

RCA Name	Total shellfish tenures	Total licenced shellfish tenures	Total finfish tenures	Total licenced finfish tenures	Total RCA area (km^2)	RCA area overlapping aquaculture tenure (km^2)	Percentage of RCA within aquaculture tenure (%)
Teakerne Arm	3	2	0	0	8.4	0.1	1.4
Thetis-Kuper Islands	9	8	0	0	25.7	0.5	2.1
Thurston Bay	1	0	1	1	6.6	0.3	5
Viscount Island	0	0	3	3	21.9	1	4.6
Walken Island to Hemming Bay	2	0	1	1	13.6	0.3	1.9
Wellborne	0	0	2	2	23	1	4.4
37 RCAs TOTAL	**87**	**63**	**36**	**34**	**563.1**	**14.7**	**3% mean coverage**

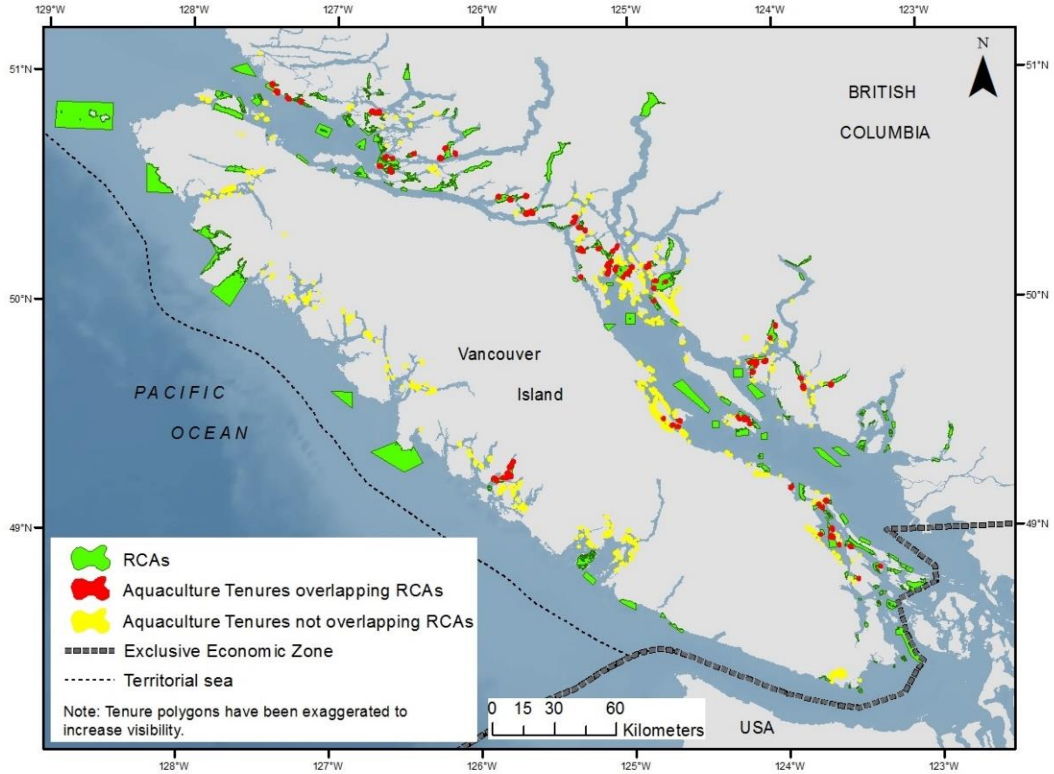

Figure 17: Spatial extent of aquaculture tenures overlapping with RCAs.

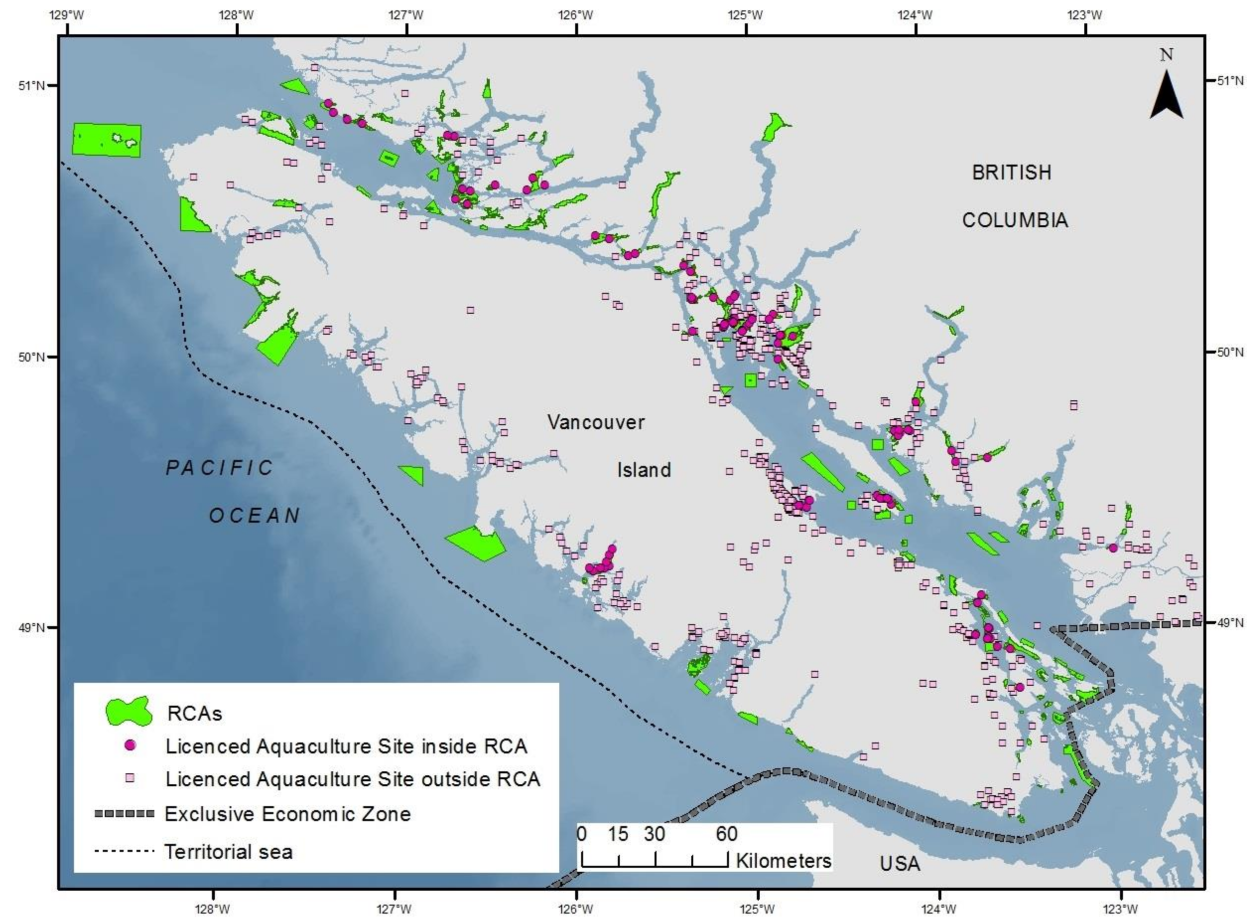

Figure 18: Spatial extent of licenced aquaculture facilities inside and outside of RCAs.

C.11.3. Discussion

All existing licenced finfish aquaculture sites within RCAs were in place before RCA implementation in 2007. No new finfish aquaculture sites have been created inside an RCA since their implementation. New applications for aquaculture site development within an RCA are permitted, but would be subject to review and assessment to ensure there are minimal effects to rockfish and their habitat (N. Blasco, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm*., March 2018).

Incidental rockfish catch during finfish aquaculture harvest is highly variable by year, species, and region. Feed pellets and harvest techniques are relatively consistent coastwide, so location specific differences in rockfish abundance and movement patterns is the most likely cause of incidental catch variations (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm*., March 2018). DFO's Aquaculture Office conducts occasional harvest audits at some sites to ensure proper harvesting and recording techniques are followed (approximately four audits per year, 2011-2016) (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm*., February 2018).

As the data above indicates, incidental rockfish catch and mortality is low at some licenced finfish aquaculture farms that overlap with RCA boundaries. DFO Groundfish Management currently considers all incidentally caught rockfish to have 100% mortality even if released due to severe barotrauma effects. However, more information is needed to assess rockfish survival rates after catch and release during harvest in aquaculture pens. Some state fishery agencies in the United States suggest that mortality risk from barotrauma and the inability of rockfish to submerge once released is higher when they are brought up from deeper depths (below 18 m). The maximum depth of aquaculture pens is 30 m.

New finfish aquaculture sites are unlikely to directly affect juvenile rockfish habitat in eelgrass beds in RCAs, as all companies are required to have an environmental survey with baseline video before opening a new facility. Video of the seafloor in the area of the farm is collected and a company must report on all habitat types and fish species usage. Sites cannot be placed over eelgrass beds and must be in waters deeper than 30 m to avoid shading the seabed and to minimize any organic enrichment to the seabed in the photic zone.

Typically, sites are located at depths of 80-120 m. The effects of aquaculture on adult rockfish habitat, which often overlap with the 80-120 m depth range, are monitored by the aquaculture industry and DFO. Finfish sites can be located on any kind of substrate (excluding sensitive and critical habitats such as eelgrass, glass sponge reefs, kelp beds, shellfish beds, spawning areas, etc.), including rocky cliff faces often favoured by Inshore Rockfish species such as Quillback Rockfish and Yelloweye Rockfish (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm*., February 2018).

Research in the Broughton Archipelago, BC, found that finfish aquaculture sites can act as fish aggregating devices through the introduction of infrastructure and the addition of food pellets to the surrounding environment. Yellowtail, Quillback, and Copper Rockfish populations were significantly higher around finfish aquaculture sites compared to reference sites (Stabel 2005). In BC, harmful effects from organic enrichment are typically localized to 30 m or less from pens and measurable effects are usually found within 125 m. The aquaculture management framework attempts to constrain impacts within those boundaries (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm*., March 2018). Some older studies have found trace effects at distances of 900 m (Kutti et al. 2007), but such results may not reflect current practices or may be atypical.

The aggregating effects of finfish aquaculture sites could be beneficial to RCAs, as finfish sites located entirely within the boundary of an RCA could help draw rockfish into the protected area. Conversely, sites that only partially overlap RCAs could draw rockfish out of RCAs and into unprotected waters. However, it is unlikely fishing would occur close enough to aquaculture infrastructure to affect aggregated rockfish outside RCAs (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm*., March 2018).

The concentration of rockfish species aggregating around net pens could place predatory pressures on lower trophic levels within RCAs, especially when finfish sites enter a fallow period after finishing their grow out phases (periods vary depending on the site). Without the constant input of additional food subsidies from the finfish sites, the increased numbers of rockfish around a finfish site could cause trophic cascades within the ecosystem (Stabel 2005).

Shellfish aquaculture sites can also act as fish aggregating devices with potentially mixed effects on rockfish. However, most shellfish facilities add only minimal amounts of additional nutrients to the surrounding area since most shellfish filter-feed from the natural environment. The aggregating effects of shellfish aquaculture should be smaller than finfish aquaculture sites.

Contaminants associated with finfish aquaculture which could potentially harm the marine environment include hydrocarbons and lubricants, disinfectants, formic acid, metals (antifoulants and feed), and drugs/medications.

Hydrocarbons and lubricants are used in equipment, generators, boats, and support industry (barges, divers, installation and decommissioning of sites, etc.). These contaminants can reach the water by accidental discharge, but incidents are rare. A recent example is the 2017 spill in Burdwood farm in the Broughton Archipelago (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019).

Disinfectants are used in footbaths and on gear for biosecurity purposes. These can be discharged into the marine environment frequently; however, the products (bleach or virkon) break down in UV light and dissipate quickly. It is not expected that discharge of disinfectants in the water column would occur in volumes large enough to cause harm to the marine environment (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019).

Formic acid is used at some sites to start to compost dead fish in situ (with the resulting ensilage being sold) (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019).

Metals: copper can be released from antifoulant net treatments, zinc from feed, and other trace metals from infrastructure. Effects on marine biota is documented from metals in localized environments (Haggarty 2003). Both zinc and copper are measureable near farms, and can be shown to originate from farms (Canadian Council of Ministers of the Environment 1999A, 1999B). Monitoring of metals is no longer required by industry, however, has been measured in the past (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019). While there are currently no restrictions on what antifouling agents can be used at aquaculture facilities, copper is being phased out by all companies and most sites no longer use it on their nets. (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* February 2018).

Another potential contaminant from finfish aquaculture is drugs, which includes in-feed use of antibiotics to treat diseases (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019). Pest control products used to manage sea lice at finfish aquaculture sites includes SLICE (emmamectin benzoate EB) and hydrogen peroxide (Paramove50). The residuals of SLICE and antibiotics found mirror the deposition of biochemical oxygen demanding (BOD) matter (DFO 2012B). It is understood that antibiotics can kill bacteria in sediments, and there are also concerns that it can contribute to resistant bacteria. In aquaculture, antibiotics are not used prophylactically, but only in the case of clinical disease and prescribed by a veterinarian. This reduces usage, so less antibiotics are used in fish farming than in any land based protein farming. Companies may only use therapeutants if they are allowed by the Food and Drugs Act, and in that case, the Canadian Food Inspection Agency is the group responsible to ensure that the therapeutant is not unduly toxic to other non-target animals. They must follow proper usage of the product, which includes where and in what quantity it may be used. The use of all therapeutants must be reported to DFO (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, pers. comm., January 2019). The persistence of hydrogen peproxide (Paramove 50) when used in finfish aquaculture is on the scale of metres and minutes (Page and Burridge 2014) and once introduced to the marine environment, hydrogen peroxide is expected to remain in the water column and disperse with the prevailing ocean currents (Health Canada Pest Management Regulatory Agency 2014).

Biological material includes biochemical oxygen demanding (BOD) matter: fecal material coming from fish, dead fish, and blood generated from harvest. BOD is monitored every production cycle (for the past 15 years; K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019). The majority of measureable effects are contained to within 125 from the cage edge, although sometimes traces of impacts can be found up to 250 m away if sites have very high bottom currents or other unique conditions (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019).

Monitoring is targeted to the area from the cage edge to 160 m away from the farms (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019). In addition to this routine monitoring, a program run by NHQ called the Aquaculture Monitoring Program started 2 years ago to look beyond routine benthic monitoring. Therefore, they are covering the area from near the farm out to 1.5 km away. While the program above is looking for feed/fecal impacts from BOD matter, this program also intentionally samples metals, antibiotics and a suite of therapeutants, including SLICE (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019).

An assessment of the effects of aquaculture on sponge reef habitat (known to be prime rockfish habitat) determined that aquaculture posed a low risk to sponge reefs due to smothering, direct sponge mortality (crushing), and water quality changes due to minimised exposure (Hemmera 2010). Video baseline studies of proposed sites are used to avoid the placement of facilities on existing sponge gardens and reefs (Hemmera 2010). Smothering of rocky rockfish habitat through sedimentation, and water quality changes from increased nutrient input are a concern in the development of aquaculture sites. Keeley et al. (2014) and DFO staff have found conditions beneath finfish cages can become entirely anoxic and azoic. However, the aquaculture management framework assesses all proposed sites with video ground-truthing to avoid habitats important to rockfish species (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm*., March 2018).

Contaminants used in marine shellfish aquaculture include hydrocarbons and lubricants, wood treatment products, plastics, Styrofoam, and general chemicals used where humans live and work. Hydrocarbons and lubricants are used in equipment, generators, boats, and support industry (barges, divers, installation and decommissioning of sites, etc.) (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019). Discharge of these chemicals into the environment is accidental. The quantities and potential exposure is considered to be smaller than that of finfish aquaculture (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019). However, machinery may operate on the beach or intertidal areas in shellfish aquaculture, so small spills could end up in a more sensitive area than for finfish (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019).

Wood treatment products are used at shellfish aquaculture sites, as wood is used in the infrastructure (as rafts etc.). Additionally, plastics (e.g. can buoys, infrastructure floatation, etc.) and Styrofoam are used at these sites, although Styrofoam will be phased out in the future (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm.,* January 2019).

C.12. RECREATIONAL FISHING

The recreational tidal waters fishery in BC includes all non-commercial and non-First Nation fishing for sport or food purposes. There is a wide range of experience and fishing intensity within this group of fishers which includes BC residents as well as out-of-province and out-of-country fishers. All tidal water fishers must purchase an annual recreational fishing licence (free for children under 16). From 2006 to 2017, the annual number of tidal water recreational licences purchased in BC ranged between 234,138 to 293,389 for resident licences and between 41,716 to 73,834 for non-resident licences (Table 26). A total of 3,468,146 licences were issued in BC and included all licence types and duration (Table 26). Recreational fishers often fish from shore, from their own boats, or hire professional guides. Recreational individual catch quotas are regulated by DFO.

Table 26: Total number of Tidal Water Recreational Licences Issued from 2006-2017 (Source: Pacific Region Statistics from Tidal Waters Sportfishing Database and National Recreational Licensing System).

Licence Type	Total	Minimum	Maximum	Mean
Resident	2,891,159	234,138	293,389	262,833
Non-Resident	576,987	41,716	73,834	52,453
Total	**3,468,146**	-	-	-

There is currently no requirement for all fishers to report detailed catches, fishing locations, or incidental catch. Here incidental catch is defined as any species unintentionally caught while targeting a different species (e.g. catching a rockfish when targeting Pacific Halibut). Although some incidentally caught species may be retained, for the purposes of this paper and to assess the effects of gear on rockfish, we refer to these catches as incidental. Certain catch records (i.e. Chinook, Lingcod, and Halibut) must be recorded in case of inspection by Fishery Officers, which occurs coast-wide on a random basis; however, such inspections are not designed to be a comprehensive monitoring program like the commercial groundfish monitoring program. Recreational catch records are not required to be submitted to DFO.

Monthly Internet Recreational Effort and Catch (iREC) surveys are sent to a cross-section of the recreational fishing population. Participation in online iREC surveys has been mandatory since 2012 when holding a BC tidal waters sport fishing licence (Fisheries and Oceans 2018E). A portion of licence holders are randomly sampled each month with approximately 6,000 participants requested in off-peak months and up to 18,000 participants requested in peak months (July and August; R. Houtman, DFO, Pacific Biological Station, Nanaimo*, pers. comm.*, Jan 2018). Although participation is mandatory, the survey response rate is approximately 32%. Complete monthly survey responses are provided by about 20% of the licence population annually, with monthly sample rates varying between 0.75 and 5%. Only adult and senior licence holders are asked to complete surveys. Adult licence holders who fish with juvenile licence holders are also requested to complete information about juvenile fishing activity. Catch data are specific to month, year, and PFMA, and do not define precise fishing locations. Shellfish catches are self-reported by recreational fishers and are not verified. Recreational fishers are not asked questions about fishing locations beyond PFMA and incidental trap catches. There is currently no way to enforce survey completion or ensure responses perfectly reflect actual fishing activity. The survey design protects against certain biases (e.g. fishing effort variation by PFMA), but response data and the resulting estimates are still subject to a variety of biases (A. Rahme, DFO, Pacific Biological Station, Nanaimo, *pers. comm.* Nov 2017). However, the iREC survey does cover a wide sample of the fishing population each year and currently provides the best available data on recreational crab and prawn/shrimp trapping effort.

Most recreational fishing is restricted in RCAs. Permitted activities include crab and prawn/shrimp trapping, smelt by gillnet, and handpicking invertebrates.

C.12.1. Reporting Data

iRec survey information was used to determine crab and prawn/shrimp trapping effort (in fisher days) coast-wide and by PFMA from 2012 to 2017. Crab and prawn/shrimp effort are combined in iRec surveys. Data selected were expanded to the total licence population, and the expansion was stratified by licence type (R. Houtman, DFO, Pacific Biological Station, Nanaimo, *pers. comm.*, Mar 2018).

Creel survey and fishing lodge logbooks also collect data for certain recreational fishing activities (primarily salmon fishing) in particular areas. However, unfortunately information is only specific to PFMAs, so shellfish trapping effort in RCAs could not be determined.

C.12.2. Data Assessment

Recreational fishers spent 1,405,026 fisher days (mean days per year = 234,171) crab and prawn/shrimp trapping coast-wide from 2012-2017 (Table 27).

Table 27: iRec coast-wide recreational shellfish trapping days (from boat, shore, and docks). Data from 2012 were only collected July onwards.

Year	**Fisher Days (adult and juvenile)**
2012	194,006
2013	300,192
2014	293,710
2015	233,225
2016	192,266
2017	191,626
Total	**1,405,026**

Seventy-one percent of recreational fishing activity occurred in southern BC, in particular in the Strait of Georgia, Juan de Fuca Strait, and Johnstone Strait (Figure 19) where 97 RCAs (59%) are located.

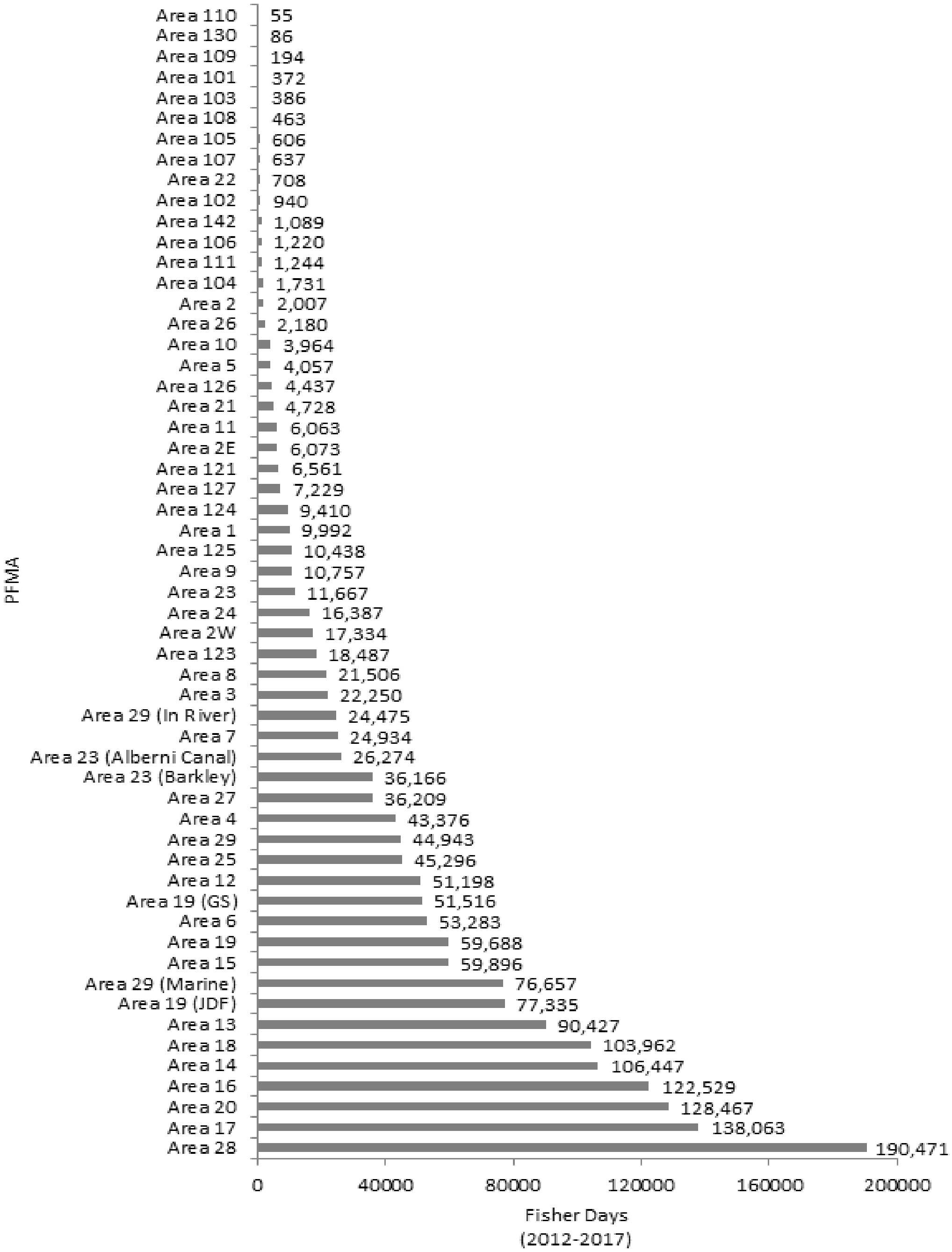

Figure 19: iREC crab and prawn/shrimp trap recreational fisher days (2012-2017) by PFMA.

C.12.3. Discussion

According to iREC data from 2012-2017 invertebrate trapping from boats and shore by both adult and juvenile recreational licence holders make up 19.5% of recreational fishing activity. Similar to commercial prawn and crab trap fisheries, these recreational activities may affect rockfish recovery in RCAs by direct rockfish incidental catch (primarily a concern for prawn traps), prey species removals (particularly Coonstripe Shrimp), bottom habitat impacts (e.g.

sponge reefs), and ghost-fishing by derelict gear. Recreational prawn trap rockfish encounter rates may be similar to those found in the commercial fishery. However, it is believed loss rates of prawn traps in the recreational sector are much higher than in the commercial sector due to single trap deployment versus anchored ground lines. In Puget Sound, 2.33% of prawn traps were lost in the recreational fishery in 2012-13, an average of 793 traps lost per year (Antonelis et al. 2018). High recreational prawn and crab trapping effort in southern RCAs may be of concern. Effort is heaviest near densely populated areas around Victoria, Vancouver, and the Gulf Islands where nearly two thirds of all RCAs in BC are located.

Smelt by gillnet is permitted in RCAs, but does not make up a large portion of recreational fishing activity (B. Spence, *pers. comm.*, Feb 2018). This fishery occurs in shallow, cobble, and gravel habitats near shore. It is unlikely that smelt fishing with gillnets encounters large numbers of adult rockfish; however, juvenile rockfish in eelgrass beds may be vulnerable to this fishery (C. Wells, *pers. comm*., Feb 2018).

Handpicking of invertebrates is permitted in RCAs. However, the effects are presumed to be low due to the highly selective nature of handpicking invertebrates and the limited number of fishers who participate in this activity (e.g. primarily limited to scuba divers/free divers). There may be minimal effects on the seafloor from diving activities and potential low levels of prey species reductions.

Recreational fisher knowledge of, and compliance to, RCA regulations has been highlighted as a concern in several studies (Haggarty et al. 2016, Lancaster et al. 2017). This issue is discussed in more detail in the compliance and enforcement (Section 3).

C.13. FOOD, SOCIAL, AND CEREMONIAL FISHING

First Nations are permitted to fish within RCAs in accordance with regulations outlined on their Food, Social, and Ceremonial (FSC) licences. FSC licences are issued by the National Special Licence Issue System (NSLIS). FSC licences require periodic catch reporting to DFO. Reporting requirements vary depending on the conditions of individual FSC licences but they do not require precise records of FSC fishing locations or effort within RCAs.

Dual fishing occurs when commercial and FSC harvesting occurs during the same fishing trip. It is permitted in commercial groundfish and other fisheries. To authorize a vessel and vessel master, an aboriginal organization provides a dual fishing designation certificate to catch and retain groundfish for FSC purposes on their behalf. The FSC portion of dual fishing trips is permitted to occur in RCAs. However, an aboriginal organization may choose to prohibit fishing in RCAs by including a provision in their dual fishing designation certificate.

Our assessment of FSC fishing activities within RCAs is limited to groundfish dual fishing, as it is the most robust data on FSC fishing in RCAs that is collected by DFO. It is acknowledged that other FSC fishing activities take place within RCAs, which require further study. However, at the time of writing insufficient data were available with DFO databases to provide an accurate assessment. DFO receives reports on FSC catch for some of the fisheries, but often the information has been aggregated to the larger management areas, often larger than individual PFMAs. FSC fishing can use a wide variety of gear types (e.g. traps, nets, hook and line). Hook and line gear in particular can pose a direct threat of rockfish removals in addition to other indirect threats.

All groundfish FSC dual fishing on commercial groundfish vessels is subject to DFO groundfish electronic monitoring standards (e.g. on-board monitoring for groundfish bottom trawl and electronic monitoring for groundfish hook and line) (Commercial Groundfish Conditions of Licence, Section 10: Electronic Monitoring (EM)). All groundfish dual fishing activity must be recorded and sent to DFO for storage in the Fishery Operations System (FOS) database. Adherence to these regulations is discussed in the FSC compliance section. As per groundfish conditions of licence, FSC offloads may occur in a First Nation's traditional territory before commercial catch is offloaded at designated commercial docks (called split offloading).

C.13.1. Reporting Data

FSC dual fishing data provided by DFO's Groundfish Data Unit was analyzed to estimate the amount of groundfish dual fishing activity within RCAs. Data from 2007-2017 was extracted from FOS and included all reported fishing sets (any groundfish sector) with non-null latitude and longitude from trips which had offloads categorized as FSC non-quota or from trips which had any type of Aboriginal communal commercial licence (licences prefixed with an "F"). The latitude and longitude of each fishing set record represents the start position of the vessel or the end position if no start position was available. Each fishing set record for all reported dual fishing trips from 2007-2017 included one of the following categories:

- Trip has both FSC non-quota offloads and other offloads
- Trip has only FSC non-quota offloads
- Trip has Aboriginal licence only and no FSC offloads
- Trip has both aboriginal and non-aboriginal licences and no FSC offloads

Dual fishing offloads from commercial vessels are not consistently recorded so these trips do not represent a comprehensive record of all FSC dual fishing activity within RCAs. Furthermore, we do not know the full extent of the fishing ground as each fishing set is represented by only a single data point (start or end position of a vessel). Although both start and end positions for many (not all) fishing sets are available, it is still unknown where vessels traverse between the start and end positions. The coordinates for each fishing set were mapped in ArcGIS as point locations. Any points located outside of BC waters or located on land were discarded. The point locations were then overlaid with the RCAs to determine how many points intersected with the RCAs. A count of the number of fishing sets coast-wide and for all RCAs per year was determined.

C.13.2. Data Assessment

Coast-wide, recorded dual fishing trips represent an estimated 9% of groundfish fishing trips within the FOS from 2007-2017. Most recorded dual fishing trips did not occur within RCAs, with only about 4.4% of coast-wide dual fishing trips occurring within RCAs (Table 29). From 2007-2017, 215 fishing sets were recorded within 32 RCAs. All of these trips used commercial hook and line or longline gear and halibut was the most targeted species in RCAs and coast-wide, with 80% and 42.6% of trips respectively (Table 28). There were no recorded groundfish bottom trawl dual fishing trips between 2007-2017.

Table 28: Proportion of FSC Dual Fishing from 2007-2017 by Fishery Sector. (Source: Compiled from data provided by the Groundfish Data Unit, September 2017).

Fishery Sector	RCAs[1]	Coast-wide[2]
Halibut	80.0%	42.6%
Halibut/Sablefish Combo Trips	0.0%	14.4%
Lingcod	0.5%	2.5%

Fishery Sector	**RCAs[1]**	**Coast-wide[2]**
Rockfish Inside	0.5%	3.6%
Rockfish Outside	7.9%	17.3%
Sablefish	1.4%	7.3%
Spiny dogfish	9.8%	12.4%

[1] Proportion (%) of total FSC dual fishing sets in RCAs

[2] Proportion (%) of total FSC dual fishing sets coast-wide

According to the 2007-2017 data, the majority (30,022 sets or 97%) of FSC dual fishing coast-wide occurred in the Outside Waters, while dual fishing in RCAs represented an estimated 0.7% of the coast-wide total (Table 30). The data shows a general downward trend in the amount of recorded FSC dual fishing activity in RCAs over the last few years (Table 30). However, this may be due to a lack of reporting as there is currently no requirement for FSC catches to be landed and recorded, so FSC catches can be offloaded unmonitored prior to dockside monitoring and hence, the data are almost certainly incomplete.

Table 29: Number of FSC Dual Fishing Trips within RCAs and Coast-wide. (Source: Compiled from data provided by the Groundfish Data Unit, September 2017).

Year	**In RCAs**	**Coast-wide**	**% of Coast-wide Trips in RCAs**
2007	13	196	6.6%
2008	13	193	6.7%
2009	17	183	9.3%
2010	6	181	3.3%
2011	11	173	6.4%
2012	7	202	3.5%
2013	10	229	4.4%
2014	7	191	3.7%
2015	8	238	3.4%
2016	3	267	1.1%
2017	3	187	1.6%
Total	**98**	**2,240**	**4.4%**

C.13.3. Discussion

There is fishing data on groundfish dual fishing within RCAs from Electronic Monitoring. Dual fishing hook and line trips are subject to audits to verify logbook accuracy via video analysis and dockside monitoring programs are in place. However, dual fishing offloads from commercial vessels are not consistently recorded, as there is currently no requirement for FSC portion of catches to be landed and recorded at designated commercial docks. Further, DFO's capacity to conduct thorough assessments of all dual fishing trips is limited. The use of commercial scale groundfish gear in RCAs could affect the ability of rockfish populations to rebuild within RCAs. The original intent for allowing FSC to be permitted within the RCAs was based on the anecdotal information suggesting that a few small scale vessels may be fishing in RCAs that would be a low risk the rockfish mortality. DFO has no RCA specific information on FSC fishing rates or gear types from non-commercial vessels. Some First Nation groups request that their members avoid fishing in RCAs.

Table 30: Estimated number of FSC Dual Fishing Sets within RCAs, Inside/Outside Waters and Coast-wide (2007-2017). All sets represent longline or hook and line fishing. (Source: Compiled from data provided by the Groundfish Data Unit, September 2017).

Year	RCAs	Inside Waters	Outside Waters	Coast-wide	% of Coast-wide Fishing in RCAs
2007	27	84	2,878	2,962	0.9%
2008	26	93	2,918	3,011	0.9%
2009	54	77	2,730	2,807	1.9%
2010	16	145	2,623	2,768	0.6%
2011	22	52	2,577	2,629	0.8%
2012	29	162	2,757	2,919	1.0%
2013	13	128	3,259	3,387	0.4%
2014	10	22	2,511	2,533	0.4%
2015	8	12	2,953	2,965	0.3%
2016	4	122	2,774	2,896	0.1%
2017	6	101	2,042	2,143	0.3%
Total	**215**	**998**	**30,022**	**31,020**	**0.7%**

C.14. COASTAL INFRASTRUCTURE (DOCKS AND MARINAS)

C.14.1. Reporting Data

Data on existing floating docks, floating marina-sized areas, and float homes were used to determine how much floating coastal infrastructure exists in RCAs coast-wide. These data were collected by DFO by scanning shorelines in Google Earth (J. Iacarella, DFO, Institute of Ocean Science, Sidney, *pers. comm*., March 2018; contact Anya Dunham (Marine Spatial Ecology, DFO) for data access). Data are separated into small docks (67 m^2), medium docks (430 m^2), and marina-sized areas (2,756 m^2). Float homes are recorded as point data with no size information. Coordinates of floating infrastructures were mapped in ArcGIS as point locations, and overlaid with RCA boundaries to determine the number of floating infrastructures in RCAs.

C.14.2. Data Assessment

Seventy-three RCAs contain one or more floating dock, floating marina-sized area, or float home within their boundaries (Table 31; Figure 20). There are 703 floating structures in RCAs. The majority of structures are small docks; however, there are five floating marina-sized areas in four RCAs. Nelson Island RCA has the greatest number of floating structures (78), and Maple Bay RCA (3.25 km^2) has the greatest structure coverage with 0.0098 km^2 (including two marinas).

Table 31: Floating infrastructure inside RCAs.

RCA NAME	RCA Area (km^2)	Total dock/ marina area in RCA (km^2)	Total docks/ marina/ float homes in RCA	Total small docks in RCA	Total medium docks in RCA	Total marina areas in RCA	Total float homes in RCA
Bate - Shadwell Passage	17.77	0.0001	1	1	0	0	0
Bedwell Harbour	2.5	0.0031	6	5	0	1	0
Belleisle Sound	5.13	0.0001	1	1	0	0	0
Bentinck Island	0.55	0.0001	1	1	0	0	0
Bowyer Island	3.15	0.0011	17	17	0	0	0
Brentwood Bay	3.4	0.0003	5	5	0	0	0
Brethour Domville Forrest Gooch Islands	18.8	0.0017	9	6	3	0	0
Browning Island to Raynor Group	17.43	0	1	0	0	0	1
Browning Passage - Hunt Rock	9.99	0	1	0	0	0	1
Burgoyne Bay	2.57	0.0006	11	9	0	0	2
Bute Inlet North	46.24	0.0001	1	1	0	0	0
Coal Island	3.14	0.0053	18	13	4	1	0
Coffin Point	4.32	0.0001	1	1	0	0	0
De Courcy Island North	4.02	0.0008	6	5	1	0	0
Departure Bay	2.7	0.0001	1	1	0	0	0
Desolation Sound	60.03	0.0004	1	0	1	0	0

RCA NAME	RCA Area (km^2)	Total dock/ marina area in RCA (km^2)	Total docks/ marina/ float homes in RCA	Total small docks in RCA	Total medium docks in RCA	Total marina areas in RCA	Total float homes in RCA
Discovery - Chatham Islands	3.76	0.0001	1	1	0	0	0
Drury Inlet - Muirhead Islands	11.66	0.0001	1	1	0	0	0
Eastern Burrard Inlet	2.75	0.0003	5	5	0	0	0
Eden-Bonwick-Midsummer-Swanson Islands	68.69	0.0001	2	1	0	0	1
Fish Egg Inlet	28.23	0	1	0	0	0	1
Gabriola Passage	2.68	0.0034	23	18	5	0	0
Greenway Sound	17.89	0.0004	2	0	1	0	1
Hardy Island	15.97	0.0025	26	24	2	0	0
Havannah Channel	32.1	0.0004	6	6	0	0	0
Holberg Inlet	22.49	0.0001	2	2	0	0	0
Hotham Sound	22.4	0.0001	2	2	0	0	0
Indian Arm - Crocker Island	8.96	0.0049	73	73	0	0	0
Indian Arm - Twin Islands	2.86	0.0045	62	61	1	0	0
Kanish Bay	8.3	0.0006	5	2	1	0	2
Lions Bay	4.84	0.0004	1	0	1	0	0
Loughborough Inlet	37.14	0.0001	2	2	0	0	0
Lower Clio Channel	13.93	0.0006	10	2	1	0	7
Lyell Island	331.84	0	1	0	0	0	1
Mackenzie - Nimmo	3.97	0.0001	2	2	0	0	0

RCA NAME	RCA Area (km^2)	Total dock/ marina area in RCA (km^2)	Total docks/ marina/ float homes in RCA	Total small docks in RCA	Total medium docks in RCA	Total marina areas in RCA	Total float homes in RCA
Maple Bay	3.25	0.0098	44	38	4	2	0
Mariners Rest	1.86	0.0001	2	2	0	0	0
Maud Island	3.09	0.0001	2	2	0	0	0
Mayne Island North	7.06	0.0003	5	5	0	0	0
McNaughton Point	2.2	0.0005	8	8	0	0	0
Menzies Bay	3.91	0.0004	1	0	1	0	0
Nanoose - Schooner Cove	12.01	0.0028	1	0	0	1	0
Navy Channel	8.29	0.0006	9	9	0	0	0
Nelson Island	8.88	0.0077	78	70	7	0	1
Northumberland Channel	14.82	0.0006	9	9	0	0	0
Octopus Islands to Hoskyn Channel	35.85	0.0019	31	29	0	0	2
Pam Rock	5.65	0.0003	4	4	0	0	0
Pasley Island	12.04	0.001	9	8	1	0	0
Portland Island	3.04	0.0003	5	5	0	0	0
Prevost Island North	9.13	0.0026	28	26	2	0	0
Princess Louisa Inlet	6.25	0.0009	3	1	2	0	0
Queen's Reach East	4.52	0.0002	3	3	0	0	0
Read - Cortes Islands	30.32	0.001	15	15	0	0	0
Russell Island	2.43	0.0003	4	4	0	0	0
Ruxton - Pylades Island	6.81	0.0006	9	9	0	0	0
Saltspring Island North	8.49	0.0012	12	11	1	0	0

RCA NAME	RCA Area (km^2)	Total dock/ marina area in RCA (km^2)	Total docks/ marina/ float homes in RCA	Total small docks in RCA	Total medium docks in RCA	Total marina areas in RCA	Total float homes in RCA
Saranac Island	10.92	0	1	0	0	0	1
Savoie Rocks - Maude Reef	1.74	0.0006	3	2	1	0	0
Shelter Bay	15.55	0.0001	1	1	0	0	0
Skookumchuck Narrows	13.22	0.0004	6	6	0	0	0
Sooke Bay	3.39	0.0006	3	2	1	0	0
South Saturna	30.92	0.0001	2	2	0	0	0
Teakerne Arm	8.41	0	1	0	0	0	1
Thetis-Kuper Islands	25.69	0.0017	14	12	2	0	0
Thompson Sound	13.95	0.0001	2	2	0	0	0
Thormanby Island	3.25	0.001	15	15	0	0	0
Trincomali Channel	21.73	0.0003	4	4	0	0	0
Upper Centre Bay	1.13	0.0018	11	8	3	0	0
Wakeman Sound	12.47	0.0001	1	1	0	0	0
Walken Island to Hemming Bay	13.59	0.0004	6	6	0	0	0
West Bay	1.06	0.0028	37	36	1	0	0
West Vancouver	2.82	0.0003	5	5	0	0	0
Woolridge Island	3.79	0.0001	1	1	0	0	0
73 RCAs Total	**1215.7**	**0.0762**	**703**	**629**	**47**	**5**	**22**

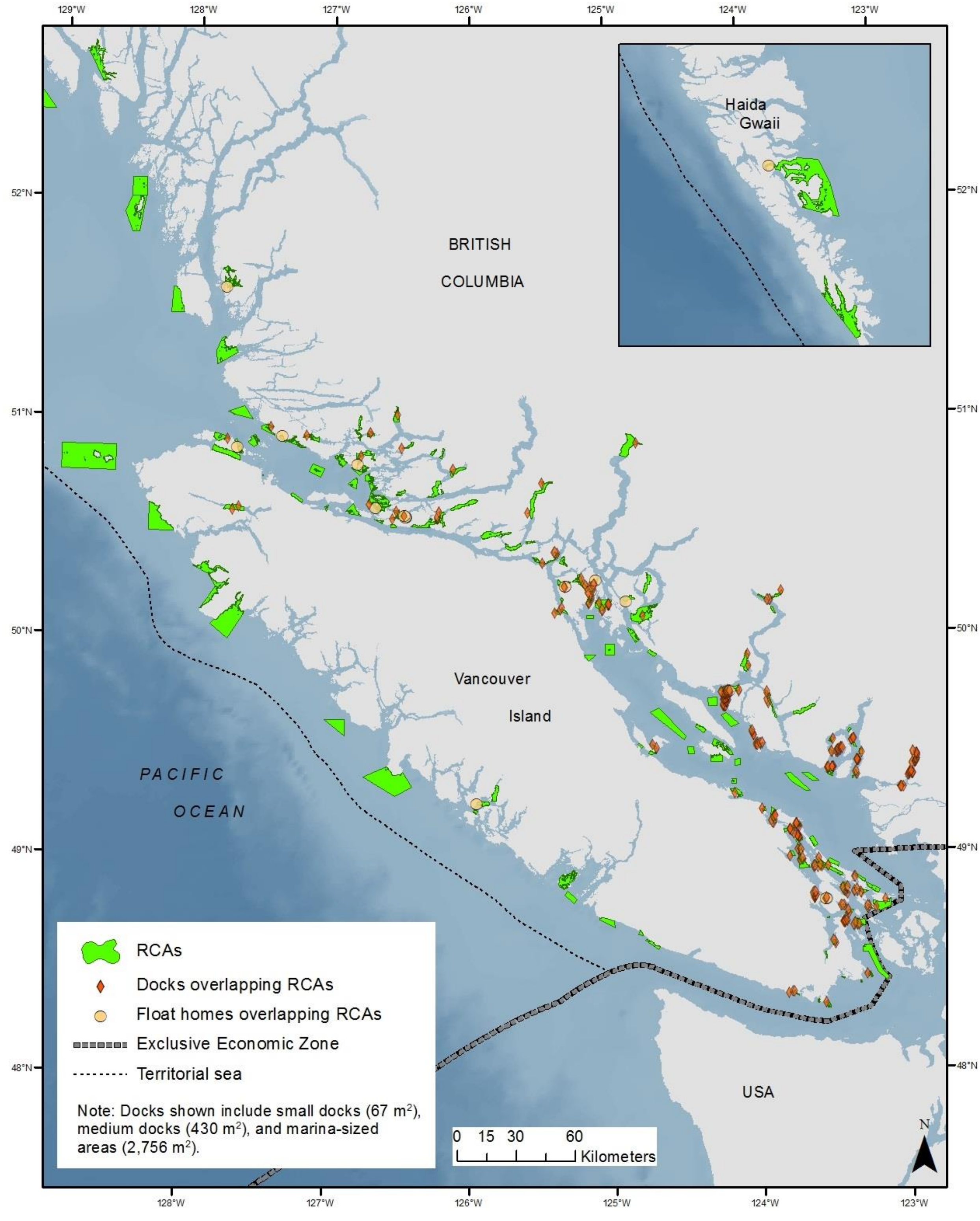

Figure 20: Location of coastal infrastructure (docks and float homes) overlapping RCAs.

C.14.3. Discussion

Effects of floating structures in RCAs will be highly dependent upon the size, location, and popularity of these areas. A full assessment of the potential effects to RCAs from coastal infrastructure was not possible with available data.

Some fixed coastal structures can create artificial reefs that may encourage rockfish assemblages in RCAs. However, certain construction materials do not support artificial reefs, and artificial structures can create unnatural habitats that are not always well suited to local species. For example, steep dock pilings or concrete walls can provide habitat for species like barnacles, tube worms, and anemones, but may lack crevices that provide habitat for rockfish species (Bulleri et al. 2010).

Fixed coastal infrastructure can also have negative consequences on biogenic habitat areas like eelgrass beds because hard structures can crush these habitats or alter water flow which can wash away substrate. Floating and fixed structures can also shade eelgrass beds (Bulleri et al. 2010). Anthropogenic disturbance, including effects from coastal infrastructure, has also been shown to homogenize fish assemblages in seagrass beds. Juvenile rockfish were also found in greater numbers at low anthropogenic impact seagrass sites compared to medium and high impact sites (Iacarella et al. 2018).

Fixed and floating docks and marinas typically attract higher boat traffic than undeveloped areas, which can cause increased impacts from noise, propeller wash, pollution, and exotic or invasive species imports (Iacarella et al. 2018, Bulleri et al. 2010).

C.15. EXTRACTIVE RESEARCH SURVEYS

Scientific research occurs in RCAs. Sometimes it may have nothing to do with the particular RCA, other times the RCA is integral to the research such as monitoring and evaluating the RCA’s effectiveness at protecting rockfish. Extractive sampling can injure and kill rockfish (e.g. long line fishing gear) or damages habitat (e.g. trawl gear). Limited extractive scientific sampling is currently permitted in RCAs (e.g. no trawl surveys, Outside Hard Bottom Longline (PHMC) surveys, Inside Hard Bottom Longline surveys; D. Haggarty, DFO, Pacific Biological Station, Nanaimo, *pers. comm*., Feb 2018). In contrast, non-extractive sampling does not harm rockfish or their habitat, and includes visual survey methods such as Remotely Operated Vehicles, towed cameras, and observations made while SCUBA diving.

C.15.1. Reporting Data

The International Pacific Halibut Commission (IPHC) Longline Survey has numerous permanent survey stations sampled each year across the Pacific coast. The BC portion of this survey has been conducted annually in various configurations since 1963. Since 2003, a third observer has been deployed to collect hook-by-hook data required for rockfish stock assessment as well as rockfish biological sampling (Flemming et al. 2011). The IPHC Longline Survey has one permanent survey station inside Estevan Point RCA on the WCVI, and one permanent station on the boundary of North Danger Rocks RCA on the North Coast. Data were obtained from the DFO database GFBio to assess how many rockfish have been removed from IPHC sample stations inside RCAs.

C.15.2. Data Assessment

Between 2003 and 2017, there were 493 Inshore Rockfish removed from the Estevan Point RCA IPHC longline sampling station and 123 Inshore Rockfish removed from the North Danger

Rocks RCA station (Table 32). Most Inshore Rockfish extracted from the RCAs were Yelloweye Rockfish.

Table 32: Rockfish catches (2003-2017) at International Pacific Halibut Commission Longline Survey sampling stations inside two RCAs, Estevan Point and North Danger Rocks. Inshore Rockfish species are bolded.

2024-Estevan point RCA (~55 m)

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2014	2015	2016	2017	Total
Canary Rockfish	3	-	1	5	2	3	-	1	3	2	3	-	2	2	**27**
China Rockfish	-	2	-	-	1	-	-	-	1	-	-	1	1	-	**6**
Quillback Rockfish		4	5	8	3	3	5	12	5	6	13	1	5	-	**70**
Rosethorn Rockfish	-	-	-	-	-	1	-	-	-	-	-	-	-	-	**1**
Silvergray Rockfish	-	-	-	1	-	1		1	-	1	-	-	-	-	**4**
Tiger Rockfish	-	-	-	-	-	-	-	-	-	-	-	-	1	-	**1**
Vermilion Rockfish	-	-	-	-	-		1	-	-	-	1	1	-	-	**3**
Yelloweye Rockfish	14	32	16	36	30	34	32	38	43	38	25	55	23	-	**416**
Yellowtail Rockfish	-	-	-	-	-	-	-	-	1	-	-	-	-	-	**1**
Total	**17**	**38**	**22**	**50**	**36**	**42**	**38**	**52**	**53**	**47**	**42**	**58**	**32**	**2**	**529**

2137-North Danger Rocks RCA (~156 m)

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2014	2015	2016	2017	Total
Quillback Rockfish	-	-	-	1	-	-	-	-	-	-	-	-	1	-	**2**
Redbanded Rockfish	16	10	23	24	21	36	7	26	11	3	21	4	-	34	**236**
Shortspine Thornyhead	-	-	2	-	-	-	-	1	-	-	-	-	-	-	**3**
Silvergray Rockfish	-	-	-	-	-	-	-	-	1	-	-	-	-	-	**1**
Thornyhead	-	-	-	-		-	-	-	-	-	1	-	-	-	**1**

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2014	2015	2016	2017	Total
Yelloweye Rockfish	6	25	16	5	7	3	26	4	14	2	7	4	1	1	**121**
Total	**22**	**35**	**41**	**30**	**28**	**39**	**33**	**31**	**26**	**5**	**29**	**8**	**2**	**35**	**364**

C.15.3. Discussion

Limited extractive scientific sampling occurs in RCAs. As mentioned the IPHC Longline Survey has two survey stations RCAs. Hook and line (jig) surveys were conducted in several newly established RCAs in 2004 and 2005 (Haggarty and King 2005, 2006), at sites sampled in the 1980's and 1990's (Richards and Cass 1987; Yamanaka and Murie 1995). Catches were low and hook and line surveys have not been repeated since (D. Haggarty, DFO, Pacific Biological Station, Nanaimo, *pers. comm*., Feb 2018). Some academics, First Nations groups, and other researchers have also conducted extractive scientific sampling in RCAs in recent years, including with hook and line and beach seine gear. The frequency of occurrence of academic and First Nations research in RCAs was not assessed in this study.

C.16. OUTFALLS

Effluent in this assessment includes sewage and waste from industry (e.g. oil processing, sawmills, etc.). Outfalls are discharge points of drains or sewers into a body of water.

C.16.1. Reporting Data

Active effluent outfalls located either inside RCAs and in close proximity to RCA boundaries were assessed using data from the Government of BC Waste Discharge Authorizations. Data were available in Excel format with coordinate information for each outfall facility, and these were mapped in ArcGIS as points. Only outfalls categorized as effluent and active were extracted and overlaid with RCA boundaries.

Effluent dilution rates and plume areas are highly variable based on outfall design and local environmental conditions. However, due to the mobile nature of effluent, assessing only outfalls inside RCAs might underestimate potential effects of effluent outfalls in very close proximity to RCAs. A study of wastewater outfalls in southern California found that outfall plumes covered approximately16 km^2 (DiGiacomo et al. 2004). For this reason we applied a 1.284 km buffer distance (resulting in a 4 km^2 circular buffer area) to all active effluent outfalls, the assumption being effluent concentrations would be higher at one-quarter (or 4 km^2) the plume area found by DiGiacomo et al. (2004) and, therefore, more likely to affect RCAs at that distance. RCAs overlapping with the 4 km^2 buffer areas were also included in the assessment.

C.16.2. Data Assessment

Coast-wide there are 10 active effluent outfalls located in nine RCAs (5.5%; Table 33; Figure 21).

Table 33: Active outfalls inside RCAs and within 4 km^2 of RCA boundaries.

RCA	Outflows in RCAs	Outflows Within 4 km^2 Buffer Area	Total Outfall
Bedwell Harbour	1	0	1
Browning Passage - Hunt Rock	0	1	1
Chrome Island	0	1	1
Departure Bay	0	1	1
Eastern Burrard Inlet	0	4	4
Haddington Passage	0	1	1
Hardy Bay - Five Fathom Rock	0	1	1
Holberg Inlet	0	1	1
Hotham Sound	0	1	1
Lions Bay	1	1	2
Mackenzie - Nimmo	1	0	1
Maple Bay	1	0	1
Maud Island	0	1	1
Mayne Island North	0	2	2
McNaughton Point	0	2	2
Nanoose - Schooner Cove	1	0	1
Northumberland Channel	2	3	5
Octopus Islands to Hoskyn Channel	1	1	2
Pam Rock	0	1	1
Princess Louisa Inlet	0	2	2
Queen's Reach East	0	2	2
Skookumchuck Narrows	0	1	1
Sooke Bay	0	1	1
South Saturna	0	1	1
Thetis-Kuper Islands	0	2	2
Thormanby Island	1	2	3
Vargas Island to Dunlap Island	1	0	1
Total	**10**	**33**	**43**

There are 33 active outfalls within 4 km^2 of 22 RCAs. In total, 43 outfalls are located in or near 27 RCAs. Northumberland Channel RCA has the maximum number of outfalls (5) within 4 km^2 of its boundary.

C.16.3. Discussion

Sixteen point five percent of RCAs are within 4 km^2 of an active effluent outfall. We were unable to make a detailed assessment of the possible effects of these effluent outfalls on RCA habitats and rockfish populations given the available data. The effects of effluent on marine habitats are highly variable depending upon the type of effluent (e.g. sewage, pulp mill, oil processing), the amount of effluent being discharged, and the environment around the outfall. Municipal sewage effluent can cause eutrophication and changes to community assemblages in marine environments (Costanzo et al. 2001; Hindell et al. 2000). While nutrient input from sewage outfalls can increase food availability, which might benefit rockfish populations directly and indirectly, they can also create anoxic zones (Hindell et al. 2000). Sewage effluent can introduce pollutants into marine systems with a variety of potential effects. Pulp mill and oil processing effluent can also affect marine environments through the introduction of toxic chemicals (Yanko et al. 1999).

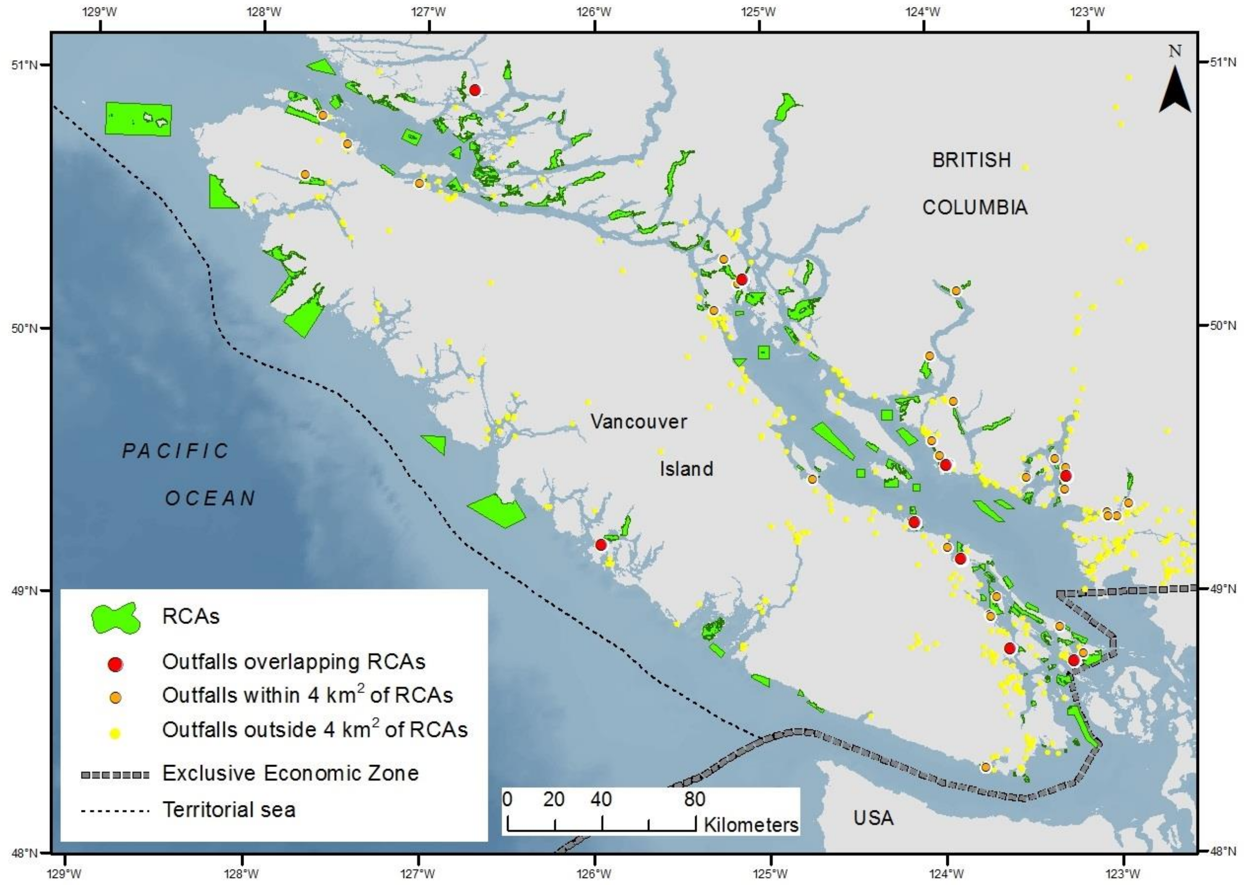

Figure 21: Location of outfalls overlapping with RCAs (red), within 4 km^2 of RCAs (orange), outside 4 km^2 of RCAs, and RCA distribution (green).

C.17. LOG STORAGE

Water-based log handling is an important component of coastal BC logging operations. Often the remote location of the timber and the mountainous terrain characteristic of the region prohibit cost effective land based transportation of logs from harvest sites to sorting and processing centers. Water-based log handling frequently occurs in marine waters and includes the following activities: log dumping, log booming, log transportation, log storage, and log sorting. Log dumps are typically located in marine waters close to the river mouth in which a given licencee is logging. Harvested timber is transported by truck to the log dump where log bundles or individual logs are then dumped into the water. These logs are then organized into log booms and transported to offsite sort yards and mills by tug and/or barge (Triton).

C.17.1. Reporting Data

Data on log dump sites for forestry companies from the BC government data catalogue TANTALIS crown tenures was used for analysis. BC current land act tenures are “issued for specific purposes and periods of time under an agreement between an individual or company and the provincial government for an interest in crown land”. Conveyances of ownership are not included (TANTALIS crown tenures). Log dump sites were intersected with RCA boundaries in ArcGIS to determine the total overlap of tenures in RCAs.

C.17.2. Data Assessment

Thirty-one RCAs, and on average 3% of these RCAs, overlap with log dump sites (Table 34; Figure 22). Menzie's Bay RCA has the greatest overlap with 1.15 km^2 (29%) of its 3.91 km^2 total area inside a log dump tenure. Woolridge Island, Queen's Reach West, and Mariners Rest RCAs have 9-11% of their areas within log dump tenures. The remaining 27 RCAs have less than 3.4% of their areas in tenures.

C.17.3. Discussion

Log dumps can cause serious bottom impacts and alter water quality in surrounding areas. Bark and sawdust can accumulate under log dumps (up to 60 cm) and smother important juvenile and adult rockfish habitat like kelp beds and eelgrass (Van der Slagt et al. 2003). Logs can shade bottom habitats, and woody debris can create anaerobic conditions below and adjacent to log dump sites and alter ecosystem dynamics (Barker 1974). Logs can also cause bottom damage when they are dragged across the seafloor and rest on exposed intertidal flats during low tides, or when helicopters drop logs from great heights into storage areas (Levings and Northcote 2004). Logs stored in salt water can also leach toxic acidic resin that can contaminate the water column and substrate (Van der Slagt et al. 2003). Hemlock resin killed 50% of Pink Salmon test fish at 100–120 mg L^{-1} and Sitka Spruce was lethal at even lower levels (Buchanan et al. 1976). Key rockfish prey species like crabs and shrimp have also been shown to avoid habitats disturbed by woody debris. It takes several years for marine habitats to recover from log dump impacts, and some areas never regain their original functionality (Levings and Northcote 2004).

There are no formal regulations in place to prevent shading and smothering of sensitive rockfish habitats. Fisheries Protection Policies suggest avoiding adverse impacts to fish habitat, or unavoidable impacts must be mitigated in other locations. All activities that can affect fish habitat are subject to the FPP project review process (B. Naito, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm*., Mar 2018).

Table 34: Log dump tenures that overlap in RCAs.

RCA	RCA Area (km^2)	Total RCA area overlapping log dump tenure (km^2)	Percentage of RCA within log dump tenure (%)
Belleisle Sound	5.13	0.17	3.33
Brooks Bay	72.27	0.07	0.1
Browning Passage - Hunt Rock	9.99	0.06	0.61
Burley Bay - Nepah Lagoon	10.74	0.07	0.62
Bute Inlet North	46.24	0.23	0.5
Chancellor Inlet West	13.87	0.02	0.17
Davie Bay	10.22	0.02	0.2
Desolation Sound	60.03	0.35	0.58

RCA	RCA Area (km^2)	Total RCA area overlapping log dump tenure (km^2)	Percentage of RCA within log dump tenure (%)
Drury Inlet - Muirhead Islands	11.66	0.3	2.58
Greenway Sound	17.89	0.15	0.84
Havannah Channel	32.1	0.1	0.31
Hotham Sound	22.4	0.02	0.07
Loughborough Inlet	37.14	0.67	1.82
Lower Clio Channel	13.93	0.12	0.83
Mackenzie - Nimmo	3.97	0.09	2.22
Mariners Rest	1.86	0.17	9.13
Menzies Bay	3.91	1.15	29.46
Nelson Island	8.74	0.24	2.79
Northumberland Channel	14.82	0.21	1.41
Octopus Islands to Hoskyn Channel	35.85	0.05	0.14
Queen's Reach West	3.49	0.34	9.82
Salmon Inlet	17.54	0.02	0.14
Saranac Island	10.92	0.13	1.17
Skookumchuck Narrows	13.22	0.01	0.11
Teakerne Arm	8.41	0.02	0.29
Thompson Sound	13.95	0.06	0.46
Upper Call Inlet	21.05	0.27	1.28
Viscount Island	21.86	0.1	0.47
Wakeman Sound	12.47	0.25	2.01
Walken Island to Hemming Bay	13.59	0.2	1.46
Woolridge Island	3.79	0.42	11.2
31 RCAs total	**573.04**	**6.11**	**3% mean overlap**

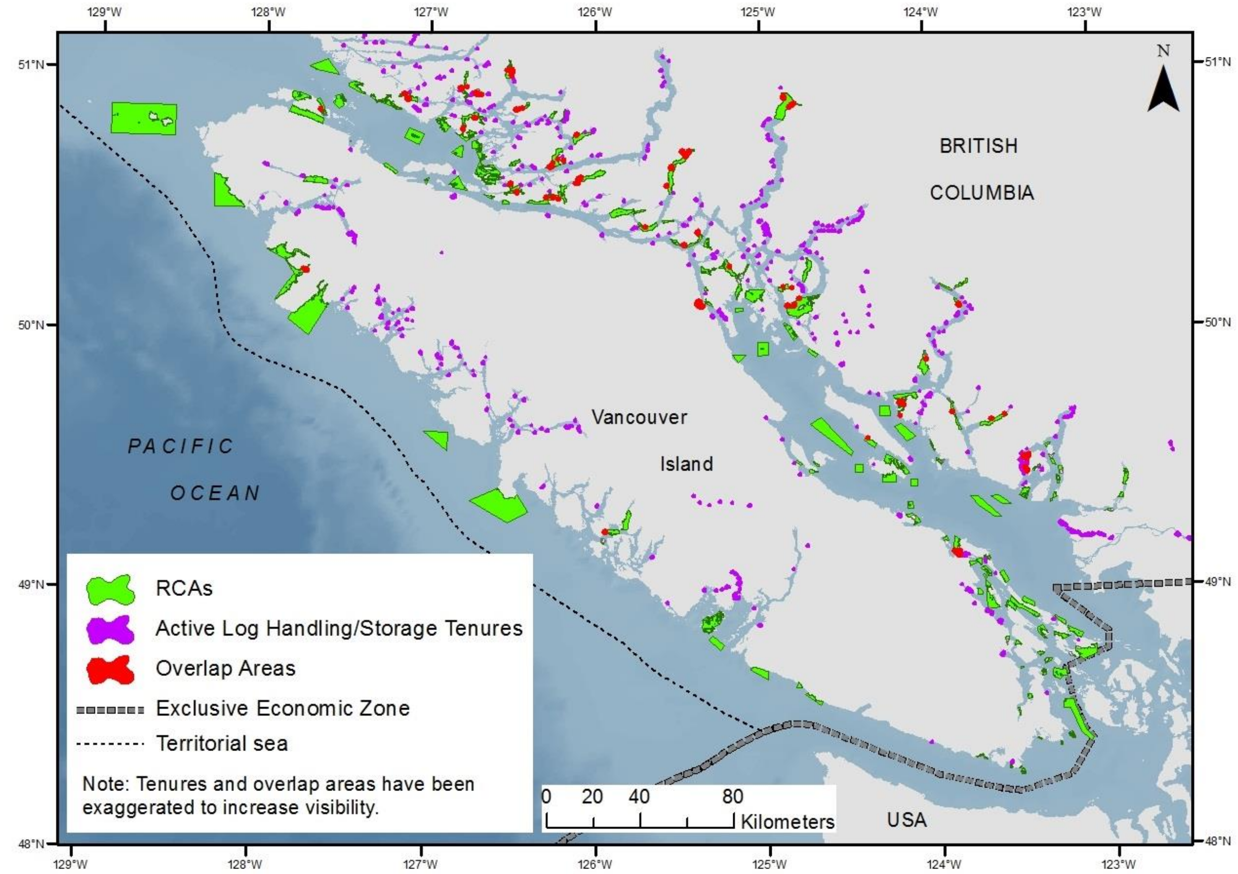

Figure 22: Location of active log handling/storage tenures and overlap with RCAs.

C.18. PETROLEUM TENURES (OIL AND GAS EXPLORATION)

Moratoria on offshore oil and gas exploration in BC were established by the federal government in 1972 and the provincial government in 1989. To date, there has been no decision whether the moratoria should be lifted. While offshore activity could generate major benefits to the Canadian economy, they may pose environmental risks that could adversely affect marine life and ecosystems, and rockfish and their habitat in RCAs.

C.18.1. Reporting Data

Oil and gas tenures data were mapped to estimate their extent inside RCAs. Data were sourced from existing provincial and federal petroleum tenures from the Ministry of Energy, Mines and Petroleum Resources. Petroleum tenure polygons were overlaid with RCA boundaries in ArcGIS. The number of RCAs that partially or fully overlap with existing petroleum tenures, and the total tenure overlap in each RCA, were calculated.

C.18.2. Data Assessment

Eighteen RCAs (11%) partially or completely overlap with existing petroleum tenures (mean overlap is 77%; Table 35; Figure 23). Coast-wide, 1,855 km^2 of area protected in RCAs overlaps with existing petroleum tenures. Seven RCAs (4.3%) fully overlap with petroleum tenures, and 14 RCAs (8.5%) have more than 50% overlap.

Table 35: RCAs with overlapping petroleum tenures.

RCA	**RCA Area (km^2)**	**Total RCA Area Overlapping Petroleum Tenure (km^2)**	**Percentage of RCA Within Petroleum Tenure (%)**
Baynes Sound - Ship Point	2.53	2.53	100
Brooks Bay	72.27	66.66	92.23
Checleset Bay	149.35	87.19	58.38
Estevan Point	186.27	186.27	100
Folger Passage	16.99	14.71	86.6
Frederick Island	113.88	30.43	26.72
Goose Island	105.47	105.47	100
McMullin Group	68.75	68.75	100
North Danger Rocks	128.82	128.82	100
Otter Passage	162.48	41.35	25.45
Porcher Peninsula	50.08	24.09	48.1
Scott Islands	339.17	338.85	99.91
Stephens Island	111.98	0.03	0.03
Topknot	96.1	64.85	67.48
West Aristazabal Island	493.06	446.2	90.5
West Banks Island	154.5	154.5	100
West Calvert	57.13	52.05	91.11
West of Bajo Reef	41.79	41.79	100
18 RCAs total	**2350.62**	**1854.55**	**77% mean overlap**

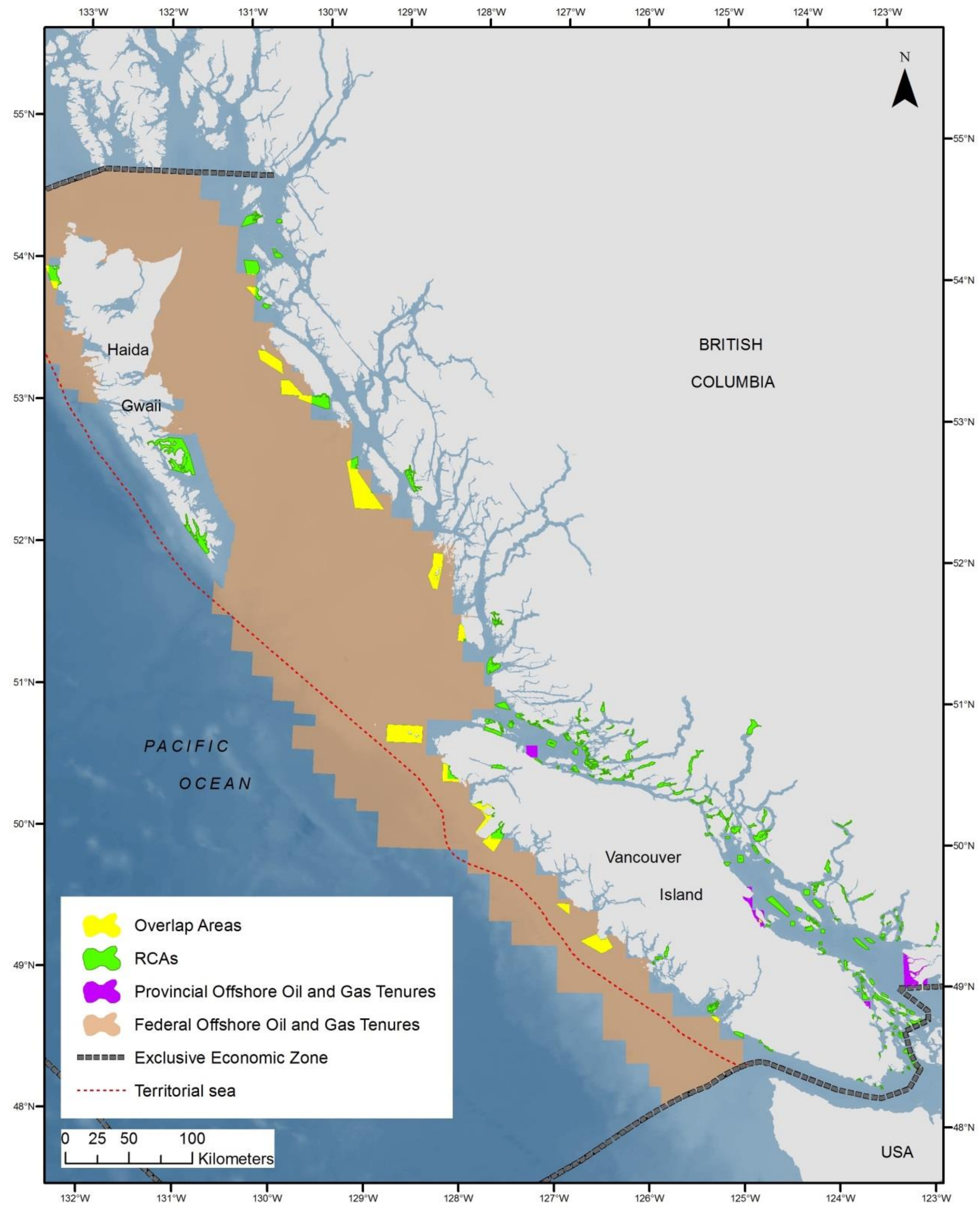

Figure 23: Locations of RCAs in relation to Petroleum Tenures in BC.

C.18.3. Discussion

There are currently moratoria on offshore oil and gas exploration on BC’s coast. However, they could be lifted in the future and those 18 RCAs with overlapping existing tenures would be vulnerable to a variety of stressors that could affect recovery of Inshore Rockfish populations. An assessment of potential oil and gas exploration concerns was conducted in 2003 for various biota including groundfish. Effects are largely unknown, but are expected to be primarily negative. Seismic exploration was expected to have unknown, but likely negative effects on juvenile and adult groundfish, as well as the groundfish fishery (Haggarty et al. 2003). Seismic air guns can cause long-term damage to fish ears up to 500 m from the source (McCauley et al. 2003). Catch rates of rockfish species can decrease by up to 80% near seismic activities (Skalski et al. 1992). The use of seismic air guns in RCAs could force rockfish avoiding noise to move outside RCA boundaries. Noise pollution was expected to have unknown negative effects on groundfish eggs and larvae, and the installation of a pipeline was anticipated to have unknown negative effects on adult groundfish (Haggarty et al. 2003). There were also anticipated negative effects on invertebrate species (major rockfish prey) from noise and oil spills, and expected negative effects on herring (major rockfish prey) from oil spills (Haggarty et al. 2003). In contrast, construction of oil platforms may have a positive effect. Built structures can function as corridors or stepping stones connecting otherwise separated populations. Oil and gas platforms enhanced the dispersal of coral populations in the Gulf of Mexico, including dispersal into areas where they were previously absent (Bulleri et al. 2010). Nevertheless, it is generally believed oil and gas exploration would pose numerous problems for ecosystems surrounding oil activities (Weilgart 2013; Haggarty et al. 2003) and likely would make effective rockfish recovery in RCAs more challenging.

APPENDIX D: ACTIVITIES AND ASSOCIATED STRESSORS AND INTERACTION MATRIX

*Table D: Activities and associated stressors included in the risk assessment and interaction matrix, used to filter out stressors that do not impact or overlap with SECs. SEC-stressor interactions with the potential to result in a negative are indicated by a "1". Non-negative or non-existent interactions are indicated by a "0". (*Stressors that were filtered out at this stage in the assessment and not included in the detailed scoring phase). While the names of stressors are repetitive, each stressor is specific to the activity producing it. For example, substrate disturbance (sediment resuspension) [prawn and shrimp by trap] will have a different load from substrate disturbance (sediment resuspension) [log handling and storage].*

Activity Category	Activity	Stressor	Rockfish	Rocky reef	Prey species (various)
Commercial fishing	Prawn and shrimp by trap	Removal of biological material	1	0	1
		Entrapment/entanglement	1	0	1
		Substrate disturbance (crushing)	0	1	0
		Substrate disturbance (sediment resuspension)	1	1	1
		Introduction of aquatic invasive species	0	1	1
	Crab by trap	Removal of biological material	1	0	1
		Entrapment/entanglement	1	0	1
		Substrate disturbance (crushing)	0	1	0
		Substrate disturbance (sediment resuspension)	1	1	1

Activity Category	Activity	Stressor	Rockfish	Rocky reef	Prey species (various)
		Introduction of aquatic invasive species	0	1	1
	Groundfish by mid-water trawl	Substrate disturbance (sediment resuspension)	1	1	1
		Substrate disturbance (crushing)	0	1	0
		Removal of biological material	1	0	1
		Entrapment/entanglement	1	0	1
		Introduction of aquatic invasive species	0	1	1
	Scallop by trawl	Removal of biological material	0	0	1
		Entrapment/entanglement	1	0	1
		Substrate disturbance (sediment resuspension)	1	0	1
		Introduction of aquatic invasive species	0	0	1
	Salmon by seine	Removal of biological material	1	0	1
		Entrapment/entanglement	1	0	1
	Salmon by gillnet	Removal of biological material	1	0	1
		Entrapment/entanglement	1	0	1
	Herring seine net	Removal of biological material	1	0	1

Activity Category	Activity	Stressor	Rockfish	Rocky reef	Prey species (various)
		Entrapment/entanglement	0	0	1
	Herring gillnet	Removal of biological material	1	0	1
		Entrapment/entanglement	1	0	1
	Herring spawn-on-kelp	Removal of biological material	0	0	1
		Substrate disturbance (sediment resuspension)*	0	0	0
	Euphausiid (krill) by mid-water trawl	Removal of biological material	1	0	1
		Entrapment/entanglement*	0	0	0
		Substrate disturbance (crushing) *	0	0	0
		Substrate disturbance (sediment resuspension) *	0	0	0
		Introduction of aquatic invasive species	0	0	1
	Handpicking of invertebrates	Removal of biological material*	0	0	0
		Substrate disturbance (crushing) *	0	0	0
		Substrate disturbance (sediment resuspension) *	0	0	0
Dual-FSC commercial fishing	Dual-FSC groundfish (hook and line)	Entrapment/entanglement	1	0	1

Activity Category	Activity	Stressor	Rockfish	Rocky reef	Prey species (various)
		Substrate disturbance (crushing) *	0	0	0
		Substrate disturbance (sediment resuspension)	1	1	1
		Introduction of aquatic invasive species*	0	0	0
		Removal of biological material	1	0	1
Recreational fishing	Smelt by gillnet	Entrapment/entanglement	1	0	1
		Substrate disturbance (crushing)*	0	0	0
		Substrate disturbance (sediment resuspension)	1	1	1
		Introduction of aquatic invasive species*	0	0	0
		Removal of biological material	1	0	1
Aquaculture	Finfish aquaculture	Introduction of biological material/nutrients	1	1	1
		Shading*	0	0	0
		Introductions of aquatic invasive species	0	1	0
		Contaminants	1	1	1
		Removal of biological material	1	0	1

Activity Category	Activity	Stressor	Rockfish	Rocky reef	Prey species (various)
	Shellfish aquaculture	Introduction of biological material/nutrients	1	1	1
		Shading*	0	0	0
		Introduction of aquatic invasive species	0	1	0
		Contaminants	1	1	1
		Substrate disturbance (sediment resuspension)	1	1	1
		Removal of biological material*	0	0	0
Scientific Research	Invasive (bottom long-line) fishery surveys	Substrate disturbance (crushing)	0	1	0
		Substrate disturbance (sediment resuspension)	0	1	1
		Removal of biological material	1	0	1
Vessel use	Discharge	Introductions of aquatic invasive species	0	1	1
		Substrate disturbance (crushing)	0	1	0
		Substrate disturbance (sediment resuspension)	1	1	1
		Contaminants	1	1	1

Activity Category	Activity	Stressor	Rockfish	Rocky reef	Prey species (various)
		Introduction of biological material/nutrients	0	1	0
	Movement underway	Substrate disturbance (sediment resuspension)	0	1	1
		Noise disturbance	1	0	1
	Oil spill	Oil	1	1	1
Log storage	Movement and storage of logs	Substrate disturbance (crushing) *	0	0	0
		Substrate disturbance (sediment resuspension)	1	0	1
		Introduction of foreign material*	0	0	0
		Contaminants	1	0	1
		Shading*	0	0	0
Land use	Outfalls	Introduction of biological material/nutrients	1	1	1
		Contaminants	1	1	1
Infrastructure	Existing coastal infrastructure	Contaminants	1	1	1
		Introduction of foreign material	1	0	1
		Introduction of aquatic invasive species	0	1	1

APPENDIX E: EXPOSURE SCORING

E.1. OVERVIEW OF EXPOSURE SCORES

Table E.1: Overview of Exposure Scores. Exposure scoring was informed by the information presented in Appendix B and C. Spatial scale scoring relates to the spatial overlap between the stressor and RCAs (in this case, number of RCAs it occurs in), temporal scale scoring relates to the proportion of the year the stressor occurs (the incidence of a single stressor event), and load considers the stressor effort or load relative to other activities and stressors assessed in this risk assessment. Uncertainty scores are associated with each term of Exposure. Exposure scoring is not specific to an individual SEC, but is applied across all RCAs, collectively. Scoring of fishery activities is specific to commercial fisheries (excluding recreational and FSC fisheries) except for the recreational Smelt by Gillnet fishery.

Activity	Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty
Coastal_infrastructure	Contaminants	1	2	4	1	2	2
Coastal_infrastructure	Introductions_AIS	2	2	3	3	2	2
Coastal_infrastructure	Introductions_foreign_material	2	2	4	1	2	2
Crab_by_trap	Entrapment_entanglement	1	4	4	1	3	1
Crab_by_trap	Introductions_AIS	1	4	1	3	1	4
Crab_by_trap	Removal_of_biological_material	2	3	4	1	3	1
Crab_by_trap	Substrate_disturbance_crushing	1	3	4	1	2	3
Crab_by_trap	Substrate_disturbance_sediment_resuspension	1	3	4	1	3	1
Dual_FSC_groundfish_hook_and_line	Entrapment_entanglement	1	4	3	3	2	2
Dual_FSC_groundfish_hook_and_line	Removal_of_biological_material	2	4	4	3	2	2
Dual_FSC_groundfish_hook_and_line	Substrate_disturbance_sediment_resuspension	1	3	4	3	2	2

Activity	Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty
Euphausiid_by_midwater_trawl	Introductions_AIS	1	4	1	3	1	2
Euphausiid_by_midwater_trawl	Removal_of_biological_material	1	4	4	1	1	2
Finfish_aquaculture	Contaminants	2	1	4	1	1	1
Finfish_aquaculture	Introductions_AIS	1	2	3	1	1	1
Finfish_aquaculture	Introductions_nutrients_biological_material	2	1	4	1	1	1
Finfish_aquaculture	Removal_of_biological_material	1	1	3	1	1	1
Groundfish_by_midwater_trawl	Entrapment_entanglement	1	2	1	3	1	1
Groundfish_by_midwater_trawl	Introductions_AIS	1	4	1	3	1	1
Groundfish_by_midwater_trawl	Removal_of_biological_material	1	1	2	3	1	1
Groundfish_by_midwater_trawl	Substrate_disturbance_crushing	1	2	2	3	1	1
Groundfish_by_midwater_trawl	Substrate_disturbance_sediment_resuspension	1	2	2	3	1	1
Herring_by_gillnet	Entrapment_entanglement	1	4	2	1	1	4
Herring_by_gillnet	Removal_of_biological_material	1	4	2	1	1	4
Herring_seine_net	Entrapment_entanglement	1	4	2	4	2	4
Herring_seine_net	Removal_of_biological_material	1	4	3	2	3	4
Herring_spawn_on_kelp	Removal_of_biological_material	1	3	2	1	1	3

Activity	Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty
Herring_spawn_on_kelp	Substrate_disturbance_sediment_resuspension	1	4	2	1	1	3
Invasive_bottom_long_line_fishery_survey	Removal_of_biological_material	1	1	1	1	1	1
Invasive_bottom_long_line_fishery_survey	Substrate_disturbance_crushing	1	2	1	1	1	1
Invasive_bottom_long_line_fishery_survey	Substrate_disturbance_sediment_resuspension	1	2	1	1	1	1
Movement_and_storage_of_logs	Contaminants	2	3	4	1	2	2
Movement_and_storage_of_logs	Substrate_disturbance_sediment_resuspension	2	3	4	1	2	2
Outfalls	Contaminants	2	3	4	1	2	2
Outfalls	Introductions_nutrients_biological_material	2	3	4	1	2	2
Prawn_and_shrimp_by_trap	Entrapment_entanglement	1	3	2	1	3	1
Prawn_and_shrimp_by_trap	Introductions_AIS	1	4	1	3	1	4
Prawn_and_shrimp_by_trap	Removal_of_biological_material	2	2	2	1	3	1
Prawn_and_shrimp_by_trap	Substrate_disturbance_crushing	1	3	2	1	3	1
Prawn_and_shrimp_by_trap	Substrate_disturbance_sediment_resuspension	1	3	2	1	3	1
Salmon_by_gillnet	Entrapment_entanglement	1	3	1	4	2	4
Salmon_by_gillnet	Removal_of_biological_material	1	3	3	1	3	4
Salmon_by_seine_net	Entrapment_entanglement	1	3	1	4	1	4

Activity	Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty
Salmon_by_seine_net	Removal_of_biological_material	1	3	3	2	3	4
Scallop_by_trawl	Entrapment_entanglement	1	3	2	1	1	2
Scallop_by_trawl	Introductions_AIS	1	4	1	3	1	2
Scallop_by_trawl	Removal_of_biological_material	1	1	2	1	1	2
Scallop_by_trawl	Substrate_disturbance_crushing	1	2	2	1	1	2
Scallop_by_trawl	Substrate_disturbance_sediment_resuspension	1	2	2	1	1	2
Shellfish_aquaculture	Contaminants	1	2	4	1	1	1
Shellfish_aquaculture	Introductions_AIS	1	3	4	1	1	1
Shellfish_aquaculture	Introductions_nutrients_biological_material	1	2	4	1	1	1
Shellfish_aquaculture	Removal_of_biological_material	1	1	4	1	1	1
Shellfish_aquaculture	Substrate_disturbance_sediment_resuspension	1	2	4	1	1	1
Smelt_by_gillnet_recreational	Entrapment_entanglement	1	3	3	3	1	2
Smelt_by_gillnet_recreational	Removal_of_biological_material	1	3	4	1	1	2
Smelt_by_gillnet_recreational	Substrate_disturbance_sediment_resuspension	1	3	4	1	1	2
Vessels_discharge	Contaminants	2	3	2	3	1	4
Vessels_discharge	Introductions_AIS	2	4	1	3	1	4

Activity	Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty
Vessels_discharge	Introductions_nutrients_biological_material	1	4	2	3	1	4
Vessels_discharge	Substrate_disturbance_crushing	1	4	1	3	1	2
Vessels_discharge	Substrate_disturbance_sediment_resuspension	1	4	1	4	1	2
Vessels_movement_underway	Noise_disturbance	2	1	4	1	4	1
Vessels_movement_underway	Substrate_disturbance_sediment_resuspension	1	4	3	3	3	3
Vessels_oil_spill	Oil	3	4	1	2	2	5

E.2. EXPOSURE SCORES AND JUSTIFICATIONS BY ACTIVITY

Table E.2.1: Exposure scores and justifications: Crab by Trap

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	2	3	4	1	3	1	**Temporal**: 4 (scoring bin = >6 months), uncertainty = low • Information available • Scoring based on the maximum potential exposure (i.e. open all year) • Commercial: 3 areas open all year (commercial crab areas G, E, and H); 4 areas have seasonal commercial softshell closures (3-6 months). All Crab Management Areas have sub-area commercial closures for various reasons (e.g. FSC access).
							Spatial: 3 (scoring bin = >50 RCS), uncertainty = low • Occurs in 106 RCAs (65%)
							Load: 2 (moderate), uncertainty = moderate • ~4% of crab trap effort occurs in RCAs annually (~2,388 traps per year) • There were 5,576,796 commercial trap days within 102 RCAs coastwide between 2007-2015. Crab EM data, which provides more accurate location information, showed effort in 106 RCAs between 2010 and 2016. A total of 967,178 traps were deployed within RCA boundaries and they soaked for 3,031,358 hours (126,307 days) • Load low relative to total crab fishery, but effort high in RCAs compared with other activities

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Entrapment/ entanglement	1	4	4	1	3	1	• Trap losses are relatively consistent each year (mean = 2,388, SE = 78.5). • Coastwide, 35,857 commercial crab traps were recorded lost in commercial logbooks between 2000-2014 (L. Barton, pers. comm., Feb 2018). A 1987 report found 11% of crab traps from the Dungeness Crab fishery were lost each year in the Fraser River Estuary with the ability to ghost fish ~7% of annual commercial hauls (Breen 1987). • The commercial fishery is now required to use rot cord to facilitate escapements in the case of lost traps (although scoring based on incidents of lost traps) **Temporal**: 4 (scoring bin=>6 months), uncertainty = low • No way to predict when gear loss will occur, but an average loss of 2,388 traps per annum could indicate loss >6 months of the year • Fishery occurs all year in some RCAs **Spatial**: 3 (scoring bin = >50 RCAs), uncertainty low • Limited information available and stressor is unpredictable. However, spatial extent would not exceed that of the activity. • Could occur in any of the RCAs where fishing occurs • Limited information available and stressor is unpredictable. **Load**: 1 (low), uncertainty = moderate/high • Presumed low load of lost traps in RCAs relative to traps set, but very limited information available.
Substrate disturbance	1	3	4	1	3	1	Crab traps are a bottom contact fishing method that can resuspend sediments

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
(sediment resuspension)							**Temporal**: 4 (scoring bin=>6 months), Uncertainty = low • Specific data related to sediment resuspension from crab traps in RCAs limited **Spatial**: 3 (bin=occurs in >50 RCAs (>30%)), uncertainty = low • Spatial scale presumed to be limited to each RCA where the activity occurs. Conservative estimate as load and distribution unknown. • Spatial footprint of resuspended sediments in RCAs is unknown, but won't exceed footprint of the activity. **Load**: 1 (low), uncertainty = moderate • Load of resuspended sediments presumed low, but very limited information available.
Substrate disturbance (crushing)	1	3	4	1	2	3	Crab traps are a bottom contact fishing method that can result in crushing **Temporal**: 4 (scoring bin=>6 months), Uncertainty =low • Specific data related to sediment resuspension from crab traps in RCAs limited **Spatial**: 3 (bin=occurs in >50 RCAs (>30%)), uncertainty = moderate/high • Spatial scale presumed to be limited to each RCA where the activity occurs. Main target (Dungeness) prefer soft sediments and rocky areas are generally avoided. Conservative estimate as load and distribution unknown. • Spatial footprint of crushing in RCAs is unknown **Load**: 1(low), uncertainty = moderate • Load of crushed substrate presumed low, but very limited information available

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Introductions (AIS)	1	4	1	3	1	4	• Scored based on the establishment of AIS, rather than exposure to a propagule, etc. • High uncertainty associated with each risk variable due to a lack of information on the presence of AIS on trap gear in the area and in general for BC. No documented cases of AIS becoming established as the result of crab traps. **Temporal**: 1 (scoring bin=<3.5 days), uncertainty = mod • The maximum (precautionary) frequency of potential exposure of AIS during trap fishing is every time a trap is dropped (i.e. high temporal overlap). However, it is unlikely that AIS would be transported and establish a population very frequently. No documented cases. **Spatial**: 1 (scoring bin=occurs in 0-25 RCAs (0-15%)), uncertainty = mod/high • Spatial overlap expected to be low, due to the distribution and number of RCAs • No documented cases **Load**: 1 (low), uncertainty = mod/high • The amount of AIS present on traps (which will have had to been fishing in an area containing AIS previously) operating in the area would be expected to be low • No documented cases in BC resulting from crab trap

Table E.2.2: Exposure scores and justifications: Groundfish by mid-water trawl

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	1	1	2	3	1	1	**Temporal** scale: 2 (scoring bin: 3.5 days to 2.5 months), uncertainty = moderate • Commercial season: Open all year and coastwide under Option A licences only. However, with the exception of a few RCAs, mid-water trawling has generally been an infrequent activity in RCAs. • Trawl activity was highest in 2017 in RCAs when 78 fishing events were recorded. Mid-water trawling was concentrated in the Goletas Channel RCA where approximately 83% of all trawl activity occurred (269 fishing events). The Goose Island RCA received approximately 5% (17 events) while Ajax/Achilles Bank received approximately 4% (13 events) of the fishing effort. The remaining 12 RCAs received six or fewer events.
							Spatial scale: 1 (scoring bin = 0-25 RCAs), uncertainty low • Occurs coastwide. However, data available on fishing events within RCAs • Four RCAs experienced 12 or more mid-water trawl fishing events between 2007-2017, and the remaining 11 RCAs received six or fewer events. • There were 387 mid-water trawl data points recorded in 9% (15) of RCAs between 2007-2017.
							Load: 1 (low), uncertainty = low • There were 387 mid-water trawl data points recorded in 15 RCAs (9%) between 2007 and 2017. • Approximately one percent of the reported 35,108 (8,057 trips) mid-water trawl fishing events that occurred coast-wide from 2007 to 2017 were in RCAs. Trawl activity was highest in 2017 in RCAs when 78 fishing events were recorded. Mid-water trawling was concentrated in the Goletas Channel RCA where approximately 83% of all trawl activity occurred (269 fishing events). The Goose Island RCA received approximately 5% (17 events) while Ajax/Achilles Bank received approximately 4% (13 events) of the fishing effort. The remaining 12 RCAs received six or fewer events. • Relatively low load compared with other activities in RCAs.

Entrapment/ entanglement	1	2	1	3	1	1	No information included in this assessment on incidents of gear loss for mid-water trawl. Lost mid-water trawl gear can cause seafloor damage if it sinks as a result of encrusting organisms and dying animals (Morgan and Chuenpagdee 2003).
							Temporal: 1 (scoring bin: <3.5 days), uncertainty = mod • It is not known what the incidence of lost gear is but would be expected to be low and lost gear is likely to be speedily recovered as it is expensive (*pers. obs.* L. Yamanaka, DFO). No way to predict when gear loss will occur.
							Spatial: 1 (scoring bin = 0-25 RCAs), uncertainty = low • Limited information available and stressor is unpredictable • Could occur in any RCA where fishing occurs
							Load: 1 (low), uncertainty = low/moderate • Presumed low load of lost trawl gear in RCAs relative to number of trawls
Substrate disturbance (sediment resuspension)	1	2	2	3	1	1	Mid-water trawls can touch bottom (Donaldson 2010; Chuenpagdee et al. 2003) where they can temporarily resuspend bottom sediment as in a bottom trawl (Leys 2013).
							Temporal: 2 (scoring bin=3.5 days 2.5 months), Uncertainty mod (limited information) • Specific data related to sediment resuspension from bottom contact by mid-water trawl gear in RCAs limited • Temporal scale lower than total activity because bottom contact is accidental.
							Spatial: 1 (scoring bin = 0-25 RCAs), uncertainty = low • Spatial scale presumed to be limited to each RCA where the activity occurs. Conservative estimate as load and distribution unknown. • Spatial footprint of resuspended sediments in RCAs is unknown
							Load: 1(low), uncertainty = low/mod • Load of suspended sediment presumed low. Scoring supported by HS/QCS MPA Level 2 ERAF scoring.

Substrate disturbance (crushing)	1	2	2	3	1	1	Mid-water trawls can have significant active effects on benthic habitats as they, or parts of the gear, contacts the bottom. These effects are localized and less than that caused by active bottom gear, but could be significant if applied to patchy or sensitive habitats (Donaldson et al. 2010). Occasional contact with the seafloor can damage fragile ecosystems such as those containing corals and sponges. However, the problem has been little studied (Morgan and Chuenpagdee 2003; Zbicz and Short 2007). A level 2 risk assessment conducted at Hecate Strait MPA summarised: "A study on the US West coast mid-water hake fishery used the presence of benthic organisms in the catch/net was used as a proxy for bottom contact and found values for bottom contact for this fishery ranging from 13% for the offshore fishery to 70% for the shore side fishery (pers. comm. W. Wakefield, NOAA). For the US West Coast mid-water pollock fishery the incidence is estimated at 44% or higher (C. Rooper, NOAA) (Hannah et al. 2019). Considered a benthic impact fishery in HS/QCS MPA Level 2 ERAF.
							Temporal: 2 (scoring bin=3.5 days to 2.5 months), Uncertainty =moderate (limited information) • Specific data related to crushing from bottom contact by mid-water trawl gear in RCAs limited • Temporal scale lower than total activity because bottom contact is accidental.
							Spatial: 1 (scoring bin = 0-25 RCAs), uncertainty = low • Spatial scale presumed to be limited to each RCA where the activity occurs. Conservative estimate as load and distribution unknown.
							Load: 1(low), uncertainty = low/mod • Load of crushed substrate presumed low. Scoring supported by HS/QCS MPA Level 2 ERAF scoring.
Introductions (AIS)	1	4	1	3	1	1	Scored based on the establishment of AIS, rather than exposure to a propagule, etc.

							Temporal: 1 (scoring bin=<3.5 days), uncertainty = mod • The maximum (precautionary) frequency of potential exposure of AIS during trawl fishing is every time the gear is dropped. However, it is unlikely that AIS would be transported and establish a population very frequently. No documented cases in BC.
							Spatial: 1 (scoring bin=occurs in 0-25 RCAs (0-15%)), uncertainty = low • Spatial overlap expected to be low, due to the distribution and number of RCAs • The spatial distribution of AIS introductions cannot exceed that of the activity. Low uncertainty.
							Load: 1 (low), uncertainty = mod/high • The amount of AIS present on mid-water trawl gear (which will have had to been fishing in an area containing AIS previously) operating in the area would be expected to be low • High uncertainty associated with load risk variable due to a lack of information on the presence of AIS on trawl gear in the area and in general for BC. No documented cases of AIS becoming established as the result of mid-water trawls.

Table E.2.3: Exposure scores and justifications: Prawn and shrimp by trap

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	2	2	2	1	3	1	**Temporal:** 2 (scoring bin = 3.5 days - 2.5 months), Uncertainty = low • Commercial fishery: open coastwide starting in May for about 40 days (6 weeks) depending on in-season sampling. May be open up to 60 days; however, many areas don't see a 30-40 day season, and some close within a week or two. • Fall Humpback shrimp by trap fishery in Prince Rupert Harbour PFMA 4-10 and 4-11; potential for Nov/Dec Coonstripe shrimp trap fishery in Sooke PFMA 20-6 and 20-7. However, there are no RCAs located in these areas. • Fished annually • Precautionary scoring **Spatial:** 3 (scoring bin = occurs in >50 RCAs (>30%)), uncertainty = low • On average, 103 RCAs (63%) have been fished annually since RCA implementation (The Humpback Shrimp commercial fishery is a small directed trap fishery that occurs in Prince Rupert Harbour and rarely in Masset Inlet (DFO 2018D). According to 2007-2017 logbook data, Humpback Shrimp were caught coast-wide with an annual average of 1% of the coast-wide catch landed in RCAs. The Coonstripe Shrimp commercial fishery is a small directed trap fishery and may occur in the Sooke Harbour and Basin (DFO 2018D). Based on 2007-2017 logbook data, retention of Coonstripe Shrimp occurred coast-wide with a yearly average of 21% of the catch reported in a small number of RCAs.) **Load:** 2 (moderate), uncertainty = low/moderate • From 2007 to 2017, on average about 17% of commercial prawn trap fishing representing 8,675 strings (9,940 days) occurred in RCAs annually. Effort has not varied before and after RCA implementation. Load moderate

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							relative to other activities that include removal of biological material included in this risk assessment.
Entrapment/ entanglement	1	3	2	1	3	1	There is no information available on annual commercial prawn trap losses in BC. By comparison, commercial trap losses are common in the Dungeness Crab trap fishery and lost prawn traps have been located with submersibles in BC (Breen 1989). In Puget Sound, prawn trap loss from commercial sectors is believed to be very low (<0.1% of traps fished). The overall estimated density of derelict prawn traps was 14 traps per square kilometer in an average depth of 59 m (Antonelis et al. 2018). The majority of traps used in the prawn and shrimp trap fishery are mesh traps (minimum mesh size) with tunnels (DFO 2018D). The requirement for a biodegradable escape panel in prawn and shrimp traps is 30 cm in length #30 untreated cotton twine in the side wall (DFO 2018D), such that on deterioration or parting produces an unrestricted opening. Deterioration of the twine allows the mesh to gape and fall (horizontal opening) open, i.e. immediately. Bycatch, small enough to have entered the trap through the tunnel and not yet found the way back out through the mesh or the tunnel; will be small enough to escape through the gape in the mesh (L. Convey, DFO, pers. comm., Jan 2019). Prawns leave traps as the bait is used up (Jaimeson and Bourne 1986; Boutillier 1988).
							Temporal: 2 (scoring bin= 3.5 days - 2.5 months), Uncertainty = low • Limited information available and therefore cannot accurately predict how frequently gear loss occurs but the commercial fishery is open up to 60 days only; many areas don't see a 30-40 day season, and some close within a week or two. • Scored based on incidents of trap loss (not duration of ghost fishing potential – persistence is captured in a level 2 ERAF instead) • Precautionary scoring, uncertainty low (no way of predicting when gear loss will occur within the season).

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							Spatial: 3 (bin=occurs in >50 RCAs (>30%)), uncertainty = low • Limited information available and stressor is unpredictable. • Could occur in any of the RCAs where fishing occurs (occurs in 103 RCAs on average). **Load**: 1 (low), uncertainty = moderate • Presumed low load of lost traps in RCAs relative to traps set. • The number of replacement tags issued for lost traps are <1% of the annual trap hauls. • Load of lost gear difficult to predict, uncertainty moderate.
Substrate disturbance (sediment resuspension)	1	3	2	1	3	1	Prawn traps are a bottom contact fishing method that can resuspend sediments **Temporal:** 2 (scoring bin= 3.5 days - 2.5 months), Uncertainty = low • Specific data related to sediment resuspension from prawn traps in RCAs limited but commercial fishery is open up to 60 days only; many areas don't see a 30-40 day season, and some close within a week or two. **Spatial:** 3 (scoring bin = occurs in >50 RCAs (>30%)), uncertainty = low • Spatial scale presumed to be limited to each RCA where the activity occurs. The scoring bin is at the highest spatial scale (>50 RCAs). • Spatial footprint of resuspended sediments in RCAs is unknown, but presumed small (due to small size of trap). **Load**: 1 (low), uncertainty = moderate • Load of resuspended sediments presumed low, but very limited information available. Due to small trap size, load expected to be low compared with other activities. Uncertainty moderate - unknown how number of strings correlates with sediment resuspension.

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Substrate disturbance (crushing)	1	3	2	1	3	1	Prawn traps are a bottom contact fishing method that can result in crushing **Temporal:** 2 (scoring bin= 3.5 days - 2.5 months), Uncertainty =low • Specific data related to sediment resuspension from prawn traps in RCAs limited but commercial fishery is open up to 60 days only; many areas don't see a 30-40 day season, and some close within a week or two. • Precautionary scoring **Spatial:** 3 (scoring bin = occurs in >50 RCAs (>30%)), uncertainty = low • Spatial scale presumed to be limited to each RCA where the activity occurs; scoring is at the highest spatial scale (>50 RCAs). • Spatial footprint of resuspended sediments in RCAs is unknown; scoring bin is at the highest spatial scale (>50 RCAs). **Load:** 1 (low), uncertainty = moderate • Load of substrate disturbance (crushing) presumed low, but limited information available. Small footprint and weight of traps likely means low load compared with other activities
Introductions (AIS)	1	4	1	3	1	4	• Scored based on the establishment of AIS, rather than exposure to a propagule, etc. • High uncertainty associated with each risk variable due to a lack of information on the presence of AIS on trap gear in the area and in general for BC. No documented cases of AIS becoming established as the result of prawn traps and occurrence cannot be known for this stressor. **Temporal:** 1 (scoring bin=<3.5 days), uncertainty = moderate • The maximum (precautionary) frequency of potential exposure of AIS during trap fishing is every time a trap is dropped (i.e. high temporal overlap). However, it is unlikely that AIS would be transported and establish a population very frequently. No documented cases. Uncertainty moderate

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							based on lack of data showing connection between an AIS outbreak and prawn/shrimp by trap in RCAs.
							Spatial: 1 (scoring bin=occurs in 0-25 RCAs (0-15%)), uncertainty = high • Spatial overlap expected to be low, due to the distribution and number of RCAs • No documented cases linked to prawn and shrimp traps in RCAs. Uncertainty mod/high, as AIS outbreak could occur in any RCA.
							Load: 1 (low), uncertainty = moderate/high • The amount of AIS present on traps (which will have had to been fishing in an area containing AIS previously) operating in the area would be expected to be low • No documented cases

Table E.2.4: Exposure scores and justifications: Scallop by trawl

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	1	1	2	1	1	2	**Temporal**: 2 (scoring bin= 3.5 days to 2 months), uncertainty = low • Commercial: Open May-April annually. Seven participants have been eligible and less than five have been active in recent years. Occurs in southern BC (PFMAs 13 and 14) subject to biotoxin and sewage contamination closures. • Effort in all but two years since 2007 **Spatial**: 1 (scoring bin=0-25 RCAs), uncertainty low/mod • The commercial scallop fishery is small scale (five vessels between 2007-2017) and highly localized to the Campbell River/Quadra Island Area. **Load**: 1 (low) uncertainty = low • Between 10 and 121 tows per year RCAs. • Between 2007-2017 there were 3,012 tows and 125.17 fishing days (hours fished/24) (open year round, but actual fishing days less) • Two RCAs were fished in 2008 and 2009 respectively for a total of 63 tows and 2.04 fishing days.
Entrapment/ entanglement	1	3	2	1	1	2	No data on lost gear, but assumed low. Precautionary scoring with high uncertainty **Temporal** scale: 2 (scoring bin= 3.5 days to 2 months), uncertainty = low • No way to predict when gear loss will occur. Could occur for >3.5 days **Spatial**: 1 (scoring bin=0-25 RCAs), uncertainty low/mod • Limited information available and stressor is unpredictable • Could occur in any RCA where fishing occurs

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							Load: 1 (low) uncertainty mod • Presumed low load of lost gear in RCAs relative to total effort.
Substrate disturbance (crushing)	1	2	2	1	1	2	• This net is designed to remain ~20 cm off the bottom to catch swimming Scallops, although occasional bottom contact can occur. Likely to occur, but exact incidents unknown. • This fishery is considered a bottom contact fishery as the net sits on several steel runners that roll across the bottom during tows. **Temporal**: 2 (scoring bin=3.5 days to 2.5 months), uncertainty = low • Likely to occur when the activity occurs • Data specific to crushing limited **Spatial**: 1 (scoring bin= 0-25 RCAs), uncertainty = low/moderate • Likely to occur where the activity occurs • Data specific to crushing limited **Load**: 1 (low), uncertainty low • Load of crushed substrate presumed low.
Substrate disturbance (sediment resuspension)	1	2	2	1	1	2	• This net is designed to remain ~20 cm off the bottom to catch swimming Scallops, although occasional bottom contact can occur. Likely to occur, but exact incidents unknown. • This fishery is considered a bottom contact fishery as the net sits on several steel runners that roll across the bottom during tows. **Temporal**: 2 (scoring bin=3.5 days to 2.5 months), uncertainty = low • Likely to occur when the activity occurs • Data specific to sediment resuspension limited

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							Spatial: 1 (scoring bin= 0-25 RCAs), uncertainty = low/moderate • Likely to occur where the activity occurs • Data specific to sediment resuspension limited **Load**: 1 (low), uncertainty low/mod • Load of resuspended sediments presumed low.
Introductions (AIS)	1	4	1	3	1	2	• Scored based on the establishment of AIS, rather than exposure to a propagule, etc. • High uncertainty associated with each risk variable due to a lack of information on the presence of AIS on trawl gear in the area and in general for BC. No documented cases of AIS becoming established as the result of water trawls. **Temporal**: 1 (scoring bin=<3.5 days), uncertainty = moderate • The maximum (precautionary) frequency of potential exposure of AIS during trawl fishing is every time the gar is dropped (i.e. high temporal overlap). However, it is unlikely that AIS would be transported and establish a population very frequently. No documented cases. **Spatial**: 1 (scoring bin=occurs in 0-25 RCAs (0-15%)), uncertainty = low/mod • Spatial overlap expected to be low, due to the distribution and number of RCAs • No documented cases **Load**: 1 (low), uncertainty = mod/high • The amount of AIS present on water trawl gear (which will have had to been fishing in an area containing AIS previously) operating in the area would be expected to be low • No documented cases in BC from this activity

Table E.2.5: Exposure scores and justifications: Euphausiid (krill) by mid-water trawl

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	1	4	4	1	1	2	This fishery has limited entry licensing, periodic openings, conservative harvest quotas, and a dockside monitoring program (Donaldson et al. 2010). The annual total allowable harvest is 500 tonnes (DFO 2018l). However, there is minimal information on the krill fisheries, nor is there much information available on bycatch. The DFO 2018-2022 Euphausiid Integrated Fisheries Management Plan (IFMP) states that vessels in Canada “are requested to cease trawling in any location if the catch of larval or juvenile fish exceeds 10 per litre drained catch”. Information about the location, date and level of catch is to be reported to DFO so that “appropriate action can be taken to prevent any fishing of larval or juvenile fish” (DFO 2018l). **Temporal**: 4 (scoring bin=>6 months), uncertainty = low • Commercial: fishery open November to March; Inlets with quota remaining may re-open in August until October. (i.e. could be open for at least 6 months) Small limited entry fishery with seasonal and area closures. **Spatial**: 1 (scoring bin=0-25 RCAs), uncertainty = low/mod • The fishery occurs only in the Strait of Georgia and mainland inlets. Small limited entry fishery with seasonal and area closures. Occurs in upper Strait of Georgia and a few mainland inlets in the south coast of BC. **Load**: 1 (low), uncertainty = moderate/high • Most of catch comes from Jervis Inlet and Strait of Georgia. TAC is 500 tonnes. • This fishery has no logbook data for bycatch or GPS coordinates for fishing locations so effort within RCAs and rockfish bycatch could not be assessed

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Introductions (AIS)	1	4	1	3	1	2	• Scored based on the establishment of AIS, rather than exposure to a propagule, etc. • Uncertainty associated with each risk variable due to a lack of information on the presence of AIS on trawl gear in the area and in general for BC. No documented cases of AIS becoming established as the result of water trawls. **Temporal**: 1 (scoring bin=<3.5 days), uncertainty = moderate • The maximum (precautionary) frequency of potential exposure of AIS during trawl fishing is every time the gar is dropped (i.e. temporal overlap). However, it is unlikely that AIS would be transported and establish a population very frequently. No documented cases. **Spatial**: 1 (scoring bin=occurs in 0-25 RCAs (0-15%)), uncertainty = low/mod • Spatial overlap expected to be low, due to the distribution and number of RCA. **Load**: 1 (low), uncertainty = low/mod • The amount of AIS present on water trawl gear (which will have had to been fishing in an area containing AIS previously) operating in the area would be expected to be low • No documented cases in BC resulting from this fishery.

Table E.2.6: Exposure scores and justifications: Herring by gillnet

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	1	4	2	1	1	4	**Temporal**: 2 (scoring bin=3.5 days -2.5 months), uncertainty = low • Commercial: Roe gillnet: late February-early April **Spatial**: 1 (scoring 0-25 RCAs), uncertainty = mod/high • Full extent unknown (known to overlap RCAs in Area 17 and Area 14); occurs in unknown # RCAs **Load**: 1 (low), uncertainty = mod/high • The commercial roe Herring gillnet fishery has 100% dockside validation but it is difficult to see bycatch in large offloads of Herring (B. Spence, pers. comm., Feb 2018). Anchors and nets may contact bottom in some areas. • There is no location specific logbook information for this fishery to assess fishing effort inside RCAs. • Load presumed low relative to other activities in this assessment, but high uncertainty scoring reflects lack of information.
Entrapment/ entanglement	1	4	2	1	1	4	**Temporal**: 2 (scoring bin = 3.5 days to 3.5 months), uncertainty = low • Frequency is unknown but does occur • Would not exceed extent of activity, but would likely not occur during every fishing occurrence **Spatial**: 1 (scoring bin=0-25 RCAs), uncertainty = moderate/high • Presumed low, moderate/high uncertainty due to limited information • Spatial extent unknown • Would not exceed extent of activity, but would likely not occur during every fishing occurrence **Load**: 1 (low), uncertainty moderate/high • Presumed low load of lost gear in RCAs relative to total effort, but unknown and unpredictable stressor

Table E.2.7: Exposure scores and justifications: Herring spawn-on-kelp

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	1	3	2	1	1	3	The herring spawn-on-kelp fishery is permitted in RCAs. There is bottom contact from net anchors and pond enclosures at times. However, this fishery is highly selective and is harvested from the surface by hand with a knife (S. Groves, DFO, Fisheries and Oceans Field Office, Prince Rupert, pers. comm., September 2017).
							Temporal: 2 (scoring bin=3.5 days to 2.5 months), uncertainty low • Commercial fishery open between early March – late April.
							Spatial: 1 (scoring bin=0-25 RCAs), uncertainty = moderate • Presumed low, moderate uncertainty due to limited information
							Load: 1 (low), uncertainty = mod/high • Load in RCAs presumed low (particularly relative to other activities), but mod/high uncertainty reflects lack of information
Substrate disturbance (sediment resuspension)	1	4	2	1	1	3	**Temporal:** 2 (scoring bin=3.5 days to 2.5 months), uncertainty low • Commercial fishery open between early March – late April.
							Spatial: 1 (scoring bin=0-25 RCAs), uncertainty = moderate • Presumed low, moderate uncertainty due to limited information
							Load: • Benthic contact does occur that could result in sediment resuspension. Load assumed low, but moderate/high uncertainty due to lack of information.

Table E.2.8: Exposure scores and justifications: Herring seine net

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	1	4	3	2	3	4	The commercial Herring seine net fishery has 100% dockside validation **Temporal**: 3 (scoring bin=2.5-6 months), uncertainty = low/mod • Commercial: Food & Bait and Special Use (by seine): Nov 7-Feb 12; Roe seine and gillnet: late February-early April **Spatial**: 3 (scoring bin=>50 RCAs), uncertainty mod/high • There is no location specific logbook information for this fishery to assess fishing effort inside RCAs. Vessels fish in deep water only and avoid bottom contact to prevent gear entanglement (B. Spence, pers. comm., Feb 2018). • Precautionary scoring **Load**: • Fishing effort within RCAs could not be assessed given the available data. • Load presumed low (compared with other activities that include removal of biological material), but mod/high uncertainty scoring reflects lack of information.
Entrapment/ entanglement	1	4	2	4	2	4	**Temporal**: 2 (scoring bin = 3.5 days to 3.5 months), uncertainty = mod/high • Frequency is unknown but does occur • Would not exceed extent of activity, but would likely not occur during every fishing occurrence **Spatial**: 2 (scoring bin=25-49 RCAs), uncertainty = high • Spatial extent unknown • Would not exceed extent of activity, but would likely not occur during every fishing occurrence **Load**: 1 (low), uncertainty mod/high • Presumed low load of lost gear in RCAs relative to total effort, but stressor unpredictable and limited information available.

Table E.2.9: Exposure scores and justifications: Salmon by gillnet

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	1	3	3	1	3	4	**Temporal**: 3 (scoring bin=2.5 – 6 months), uncertainty = low • Commercial: June to end of October
							Spatial: 3 (scoring bin=>50 RCAs), uncertainty mod/high • Precautionary scoring, as fishery is not spatially restricted
							Load: 1 (low), uncertainty = moderate • Salmon gillnetting activity in RCAs, particularly in Johnstone Strait, is considered low based on a comparison of PFMA fishery openings and RCA locations (M. Mortimer, *pers. comm*., March 2018).
Entrapment/ entanglement	1	3	1	4	2	4	**Temporal**: 1 (scoring bin=<3.5 days), uncertainty =mod/high • Gear loss presumed low, but does occur • Limited data available in this report.
							Spatial: 2 (scoring bin=25-49 RCAs), uncertainty mod/high • Precautionary scoring, as fishery is not spatially restricted • Presumed to occur in not every area fished (unlikely to occur in >49 RCAs, but data unavailable)
							Load: 1 (low), uncertainty = mod • Fishing effort within RCAs could not be assessed given the available data. • Load presumed low, but high uncertainty scoring reflects lack of information • The extent of lost fishing nets is unknown but lost nets have been retrieved off rocky habitats in Area 24 (M. Spence, *pers. comm*., Feb 2018). Fishery notices advise fishers to report lost fishing gear to area managers or charter patrol (G. Hornby, *pers. comm*., Mar 2018).

Table E.2.10: Exposure scores and justifications: Salmon by seine net

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	1	3	3	2	3	4	**Temporal**: 2 (scoring bin=3.5 days to 2.5 months), uncertainty = low/mod • Commercial: June to end of October. Salmon seine netting in RCAs, particularly in Johnstone Strait, is considered to be infrequent based on a comparison of PFMA fishery openings and RCA locations (M. Mortimer, DFO, Fisheries and Oceans Field Office, Campbell River pers. comm., March 2018). **Spatial**: 3 (scoring bin=>50 RCAs), uncertainty mod/high • Precautionary scoring, as fishery is not spatially restricted **Load**: 1 (low), uncertainty = moderate • Fishing effort within RCAs could not be assessed given the available data. • Load presumed low, but moderate uncertainty scoring reflects lack of information
Entrapment/ entanglement	1	3	1	4	1	4	**Temporal**: 1 (scoring bin=<3.5 days), uncertainty = high • Gear loss presumed low due to nature of the fishery. • No data available in this report. **Spatial**: 1 (scoring bin=0-25 RCAs), uncertainty mod/high • Precautionary scoring, as fishery is not spatially restricted • Presumed to occur in not every area fished (unlikely to occur in >49 RCAs, but data unavailable)

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							Load: 1 (low), uncertainty = moderate • Salmon by seine activity in RCAs, particularly in Johnstone Strait, is considered low based on a comparison of PFMA fishery openings and RCA locations (M. Mortimer, pers. comm., March 2018). • Fishing effort within RCAs could not be assessed given the available data. • Load presumed low, but moderate uncertainty scoring reflects lack of information.

Table E.2.11: Exposure scores and justifications: Smelt by gillnet (recreational). NB: This scoring is specific to recreational smelt by gillnet only (i.e. excluding commercial and FSC fisheries).

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	1	3	4	1	1	2	• This fishery occurs in shallow near shore and intertidal areas, sandy, and gravel habitats near shore where smelt return to spawn. • Scored based on recreational fishery (largely beach based, and generally not near RCAs). **Temporal**: 4 (scoring bin=>6 months), uncertainty = low **Spatial**: 1 (scoring bin=0-25 RCAs), uncertainty = low/mod • Occurs in an unknown number of RCAs, however, expected to occur in only very limited areas (likely only one or two RCAs) **Load**: 1 (low), uncertainty = moderate • Presumed very low load across all RCAs relative to other activities in this assessment
Entrapment/ entanglement	1	3	3	3	1	2	• Scored based on recreational fishery **Temporal**: 3 (scoring bin=2.5-6 months), uncertainty = moderate • Stressor unpredictable and presumed to be rare, but precautionary scoring used due to lack of information **Spatial**: 2 (scoring bin=25-49 RCAs), uncertainty = high • Occurs in an unknown number of RCAs, but would not exceed extent of the activity **Load**: 1 (low), uncertainty = moderate • Presumed low load in RCAs relative to total effort
							• Scored based on recreational fishery

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Substrate disturbance (sediment resuspension)	1	3	4	1	1	2	**Temporal**: 2 (scoring bins=3.5 days to 2.5 months), uncertainty low • Presumed not to occur during every incidence of fishing **Spatial**: 2 (scoring bin=25-49 RCAs), uncertainty = low/mod • Occurs in an unknown number of RCAs • Precautionary scoring **Load**: 1 (low), uncertainty = moderate • Presumed low load in RCAs relative to other activities in this assessment

Table E.2.12: Exposure scores and justifications: FSC dual fishing groundfish (hook and line). Scoring focuses on FSC dual fishing for groundfish and includes long line (commercial size long line gear and FSC communal long line with max 50 hooks) and single hook line (rod or hand line).

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	2	4	4	3	2	2	Dual fishing occurs when commercial and FSC harvesting occur during the same fishing trip. It is permitted in commercial groundfish and other fisheries. The FSC portion of dual fishing trips is permitted to occur in RCAs. However, an aboriginal organization may choose to prohibit fishing in RCAs by including a provision in their dual fishing designation certificate.
							Temporal: 4 (scoring bin=>6 months), uncertainty = low • Dual-fishing trips have associated hail out and landing dates available in FOS; each type of dual-fishing trip is limited to the commercial period associated with that licence (e.g. Halibut 2019 = March 15 – Nov 14). •
							Spatial: 2 (scoring bin=25-49 RCAs), uncertainty = low/mod • Dual fishing documented in 32 RCAs (20%). • Due to the limited number of dual-FSC licences, the spatial distribution of this activity it is unlikely to overlap with >50 RCAs. • Fishing event data captures single position and uncertainty around spatial extent low/moderate.
							Load: 2 (moderate), uncertainty = mod/high • Load expected to be moderate in RCAs (catch unknown; some vessels told to avoid RCA areas, but this is difficult to quantify), but high uncertainty reflects unknown load
Entrapment/ entanglement	1	4	3	3	2	2	NB: This includes lost gear from commercial dual-FSC groundfish hook and line.

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							Temporal: 3 (scoring bin=2.5-6 months), uncertainty = moderate • Unlikely gear loss would occur during all incidents of activity • No reporting and limited information reflected in uncertainty score
							Spatial: 2 (scoring bin=25-49 RCAs), uncertainty = low/moderate • Dual fishing documented in 32 RCAs (20%) • Reporting not mandatory • Gear loss could occur in all RCAs where activity occurs
							Load: 1 (low), uncertainty = mod/high • No data available on load (assumed low) • Load of lost gear expected to be low in RCAs, but high uncertainty reflects unknown load
Substrate disturbance (sediment resuspension)	1	3	4	3	2	2	NB: This includes FSC hook and line.
							Temporal: 3 (scoring bin=2.5-6 months), uncertainty = moderate • Sediment resuspension would likely occur during most incidents of hook and line fishing
							Spatial: 2 (scoring bin=25-49 RCAs), uncertainty = low/moderate • Dual fishing documented in 32 RCAs (20%) • Stressor would occur where activity occurs
							Load: 1 (low), uncertainty = mod • No data available on load • Load expected to be low in RCAs, but moderate uncertainty reflects unknown load

Table E.2.13: Exposure scores and justifications: Finfish aquaculture

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	1	1	3	1	1	1	**Temporal:** 3 (scoring bin=2.5-6 months), uncertainty low • Nature of the fishery means year-round exposure to the activity. However, the stressor only occurs during harvest and transfer events. • Transfer events may occur once during a production cycle at sea (approximately every 2 years), and harvest at the end. Harvest can take many weeks – a few months. **Spatial:** 1 (scoring bin=0-25 RCAs), uncertainty low • There are 34 licenced finfish aquaculture sites overlapping one or more of the 37 RCAs. Eight of the licenced sites have rockfish habitat (rocky substrate) in their depositional zone, with the remaining 26 sites over soft sediment (muddy seabed). **Load:** 1 (low), uncertainty = low • Load in some RCAs (e.g. Bedwell Sound RCA) is high. Load across total RCAs is low. Scored moderate to capture variable load between RCAs where this activity occurs
Introductions (nutrients/biological material)	2	1	4	1	1	1	**Temporal:** 4 (scoring bin=>6 months), uncertainty low • Nature of the fishery means year-round exposure for farms that are operating. At any given time, about 60% of licenced farms are operating. However, this results in some sites within RCAs having year round exposure. **Spatial:** 1 (scoring bin=0-25 RCAs), uncertainty low • There are 34 licenced finfish aquaculture sites overlapping one or more of 37 RCAs. Eight of the 34 licenced sites have rockfish habitat

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							(rocky substrate) in their depositional zone, with the remaining 26 sites over soft sediment (muddy seabed). **Load:** 2 (moderate), uncertainty = low • Load of nutrients/biological material moderate relative to other stressors in RCAs. • However, management measures (including the Aquaculture Activities Regulations) are in place to reduce the overall exposure of RCAs to contaminants. Uncertainty low as stressor is monitored extensively.
Introductions (AIS)	1	2	3	1	1	1	**Temporal:** 3 (scoring bin=2.5-6 months), uncertainty low • Nature of the fishery means year-round exposure to the activity. However, the stressor only occurs during harvest and transfer events. • Transfer events may occur once during a production cycle at sea (approximately every 2 years), and harvest at the end. Harvest can take many weeks – a few months (pers. comm. K. Shaw, DFO, February 2019). • The nature of aquaculture and the conditions it creates in the surrounding waters could result in a higher chance of an aquatic invasive species becoming established. However, this stressor is scored on potential introduction during finfish transfer events. **Spatial:** 1 (scoring bin=0-25 RCAs), uncertainty low • Presumed not to occur at all aquaculture sites within RCAs. • Benthic monitoring of the seabed every production cycle has not identified any AIS (pers. comm. K. Shaw, DFO, February 2019). **Load:** 1 (low), uncertainty = low/moderate • Load of invasive species low due to preventative management measures and lack of historical establishment of AIS. Uncertainty

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							moderate as occurrence cannot be known (type of AIS, etc.), reflecting the unpredictable nature of this stressor.
Contaminants	2	1	4	1	1	1	**Temporal:** 4 (scoring bin=>6 months), uncertainty low • Nature of the fishery means year-round exposure **Spatial:** 1 (scoring bin=0-25 RCAs), uncertainty = low • Likely occurs at all RCAs where active licenses are operating • There are 34 licenced finfish aquaculture sites overlapping one or more of the 37 RCAs. Eight of the 34 licenced sites have rockfish habitat (rocky substrate) in their depositional zone, with the remaining 26 sites over soft sediment (muddy seabed). **Load:** 2 (moderate), uncertainty = low • Contaminants associated with finfish aquaculture which could potentially harm the marine environment include hydrocarbons and lubricants, disinfectants, formic acid, metals (antifoulants and feed), and drugs/medications. • Load of contaminants moderate relative to other stressors in RCAs. However, management measures (including the Aquaculture Activities Regulations) are in place to reduce the overall exposure of RCAs to contaminants. Uncertainty low as stressor is monitored extensively.

Table E.2.14: Exposure scores and justifications: Shellfish aquaculture

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Removal of biological material	1	1	4	1	1	1	**Spatial:** 1 (scoring bin=0-25 RCAs), uncertainty low • There are 63 licenced shellfish aquaculture sites inside RCAs. 16 RCAs have spatial overlap with shellfish tenures. • The Read–Cortes Islands RCA has the greatest number of shellfish tenure overlaps coastwide with 14 licenced sites (0.2 km^2). **Temporal:** 4 (scoring bin=>6 months), uncertainty low • Nature of the fishery means year-round exposure **Load:** 1 (low), uncertainty = low • Load in some RCAs (e.g. Read-Cortes Islands RCA) is high. However, load across total RCAs is low. Scored moderate to capture variable load between RCAs where this activity occurs
Introductions (nutrients/biological material)	1	2	4	1	1	1	**Temporal:** 4 (scoring bin=>6 months), uncertainty low • Nature of the fishery means year-round exposure **Spatial:** 1 (scoring bin=0-25 RCAs), uncertainty low • There are 63 licenced shellfish aquaculture sites. 16 RCAs have spatial overlap with shellfish tenures. • The Read–Cortes Islands RCA has the greatest number of shellfish tenure overlaps coastwide with 14 licenced sites (0.2 km^2). **Load**: 1 (low), uncertainty = low • Load low relative to other activities. Uncertainty low/moderate.
Introductions (AIS)	1	3	4	1	1	1	**Spatial:** 1 (scoring bin=0-25 RCAs), uncertainty low • Presumed not to occur at all aquaculture sites within RCAs, but incidents cannot be known

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							Temporal: 4 (scoring bin=>6 months), uncertainty low • Nature of the fishery means year-round exposure • The nature of aquaculture and the conditions it creates in the surrounding waters results in a potential constant exposure to aquatic invasive species becoming established **Load:** 1 (low), uncertainty = moderate • Load of invasive species low due to preventative management measures and lack of historical establishment of AIS. Uncertainty moderate as occurrence cannot be known (type of AIS, etc.)
Contaminants	1	2	4	1	1	1	**Temporal:** 4 (scoring bin=>6 months), uncertainty = low • The nature of aquaculture results in a potential constant exposure **Spatial:** 1 (scoring bin=0-25 RCAs), uncertainty = low • Conservative scoring **Load:** 1 (low), uncertainty = low • Load presumed to be low
Substrate disturbance (sediment resuspension)	1	2	4	1	1	1	**Temporal:** 4 (scoring bin=>6 months), uncertainty = low • The nature of aquaculture results in a potential constant exposure **Spatial:** 1 (scoring bin=0-25 RCAs), uncertainty low • There are 87 shellfish aquaculture tenures (63 licenced sites) 16 RCAs have spatial overlap with shellfish tenures. • The Read–Cortes Islands RCA has the greatest number of shellfish tenure overlaps coastwide with 14 licenced sites (0.2 km^2). **Load:** 1 (low), uncertainty = low/moderate

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							- Sediment resuspension specific to clams (i.e. not all shellfish aquaculture types). Load low relative to other activities. Uncertainty associated with lack of data on how many shellfish aquaculture sites have benthic contact within RCA.

Table E.2.15: Exposure scores and justifications: Coastal infrastructure

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Contaminants	1	2	4	1	2	2	Scored based on the presence of existing infrastructure, not the construction of new infrastructure. Stressors related to use of infrastructure by vessels captured under discharge, movement underway, and oil spill.
							Temporal: 4 (scoring bin=>6 months), uncertainty = low • Fixed locations of infrastructure results in continual exposure from this stressor
							Spatial: 2 (scoring bin=25-49 RCAs), uncertainty = low • 73 RCAs (44.5 %) contain one or more floating dock, floating marina sized areas, or float home • Total of 703 floating structures within RCAs • The majority of structures are small docks • 5 x floating marina sized areas in 4 RCAs • Nelson Island RCA has the greatest number of floating structures (78) • Maple Bay RCA (3.25 km^2) has the greatest structure coverage with 0.0098 km^2 (including two marinas)
							Load: 1 (low), uncertainty = low • Low presumed load of contaminants from infrastructure across all RCAs (although infrastructure is concentrated in some RCAs, e.g. Maple Bay RCA).

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Introduction of foreign material	2	2	4	1	2	2	Scored based on the presence of existing infrastructure, not the construction of new infrastructure. Stressors related to use of infrastructure by vessels captured under discharge, movement underway, and oil spill. **Temporal**: 4 (scoring bin=>6 months), uncertainty = low • Fixed locations of infrastructure results in continual exposure from this stressor **Spatial**: 2 (scoring bin=25-49 RCAs), uncertainty = low • 3 RCAs (44.5%) contain one or more floating dock, floating marina sized areas, or float home **Load**: 2 (moderate) uncertainty = low • Low presumed load of introduced foreign material from infrastructure across all RCAs (although infrastructure is concentrated in some RCAs, e.g. Maple Bay RCA).

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Introductions (aquatic invasive species)	2	2	3	3	2	2	**Temporal**: 3, mod uncertainty • Documented cases of aquatic invasive species (AIS) associated with coastal infrastructure in BC (Iacella et al. 2018). • Temporal scale is representative of the season in which AIS fouling organisms are growing and reproducing during warmer months (Iacella et al. 2018). **Spatial**: 2 (bin=25-49 RCAs), uncertainty = low/mod • Could occur in any of the RCAs infrastructure is. **Load**: 2, low/mod uncertainty. • Load moderate compared with other activities

Table E.2.16: Exposure scores and justifications: Invasive (bottom long-line) fishery survey

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Substrate disturbance (crushing)	1	2	1	1	1	1	**Temporal**: 1 (scoring bin=<3.5 days), uncertainty = low • Two sampling periods per annum (each site is only fishes once per annum). Each period between 5 hours and a maximum of 24 hours (therefore the two sets from the two RCAs would be 10-48 hours/year). **Spatial**: 1 (scoring bin=0-25 RCAs), uncertainty = low • Occurs in 2 RCAs (1%) • The IPHC Longline Survey has one permanent survey station inside the Estevan Point RCA on the WCVI, and one permanent station on the edge of the North Danger Rocks RCA on the North Coast. **Load**: 1 (low), uncertainty = low/mod
Substrate disturbance (sediment resuspension)	1	2	1	1	1	1	**Temporal**: 1 (scoring bin=<3.5 days), uncertainty = low • Two sampling periods per annum (each site is only fishes once per annum). Each period between 5 hours and a maximum of 24 hours (therefore the two sets from the two RCAs would be 10-48 hours/year). **Spatial**: 1 (scoring bin=0-25 RCAs), uncertainty = low • Occurs in 2 RCAs (1%) • The IPHC Longline Survey has one permanent survey station inside the Estevan Point RCA on the WCVI, and one permanent station on the edge of the North Danger Rocks RCA on the North Coast. **Load**: 1 (low), uncertainty = low/mod
Removal of biological material	1	1	1	1	1	1	**Temporal**: 1 (scoring bin=<3.5 days), uncertainty = low • Two sampling periods per annum (each site is only fishes once per annum). Each period between 5 hours and a maximum of 24 hours (therefore the two sets from the two RCAs would be 10-48 hours/year)

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							Spatial: 1 (scoring bin=0-25 RCAs), uncertainty = low • Occurs in 2 RCAs (1%) • The IPHC Longline Survey has one permanent survey station inside the Estevan Point RCA on the WCVI, and one permanent station on the edge of the North Danger Rocks RCA on the North Coast.
							Load: 1 (low), uncertainty = low • Load is low; From 2003-2017 there were 493 Inshore Rockfish removed from the Estevan Point RCA IPHC longline sampling station and 123 Inshore Rockfish removed from the North Danger Rocks RCA IPHC sampling station. Load on an individual RCA level may be high, but across all RCAs load is low.

Table E.2.17: Exposure scores and justifications: Outfalls

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Introductions (nutrients/biological material)	2	3	4	1	2	2	**Temporal**: 4 (scoring bin=>6 months), uncertainty = low • Fixed locations of outfalls results in continual exposure from this stressor **Spatial**: 2 (scoring bin=25-49 RCAs), uncertainty = low • 71 RCAs (43%) within 4 km of an outfall • There are ten active effluent outfalls located within nine RCAs coast-wide, and an additional 33 active outfalls within 4 km^2 of an RCA boundary. Total of 43 outfalls are located within an RCA or within 4 km^2 of an RCA boundary. **Load**: 2 (moderate), uncertainty = moderate • Load from outfalls expected to be moderate, moderate associated uncertainty
Contaminants	2	3	4	1	2	2	**Temporal**: 4 (scoring bin=>6 months), uncertainty = low • Fixed locations of outfalls results in continual exposure from this stressor **Spatial**: 2 (scoring bin=25-49 RCAs), uncertainty = low • 71 RCAs (43%) within 4 km • There are ten active effluent outfalls located within nine RCAs coast-wide, and an additional 33 active outfalls within 4 km2 of an RCA boundary. Total of 43 outfalls are located within an RCA or within 4 km^2 of an RCA boundary. **Load**: 2 (moderate), uncertainty = moderate • Load from outfalls expected to be moderate, moderate associated uncertainty

Table E.2.18: Exposure scores and justifications: Movement and storage of logs

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Substrate disturbance (sediment resuspension)	2	3	4	1	2	2	**Temporal**: 4 (scoring bin=>6 months), uncertainty = low • Constant stressor/continual instances of sediment resuspension **Spatial**: 2 (scoring bin=25-49 RCAs), uncertainty = low/moderate • Log dumps occur in 31 RCAs (19% of RCAs) and a mean 3% spatial overlap • Presumed sediment resuspension occurs in all log dump areas **Load**: 2 (moderate), uncertainty = moderate • Load of resuspended sediments moderate/high compared with resuspension from other activities in RCAs. • No information available on load of resuspended sediment from log dumps in RCAs.
Contaminants	2	3	4	1	2	2	**Temporal**: 4 (scoring bin=>6 months), uncertainty = low • Constant stressor/continual instances of contaminants **Spatial**: 2 (scoring bin=25-49 RCAs), uncertainty = moderate/low • Log dumps occur in 31 RCAs (19% of RCAs) and a mean 3% spatial overlap • Presumed contaminants occurs in all log dump areas **Load**: 2 (moderate), uncertainty = moderate • Load of contaminants moderate/high compared with contaminants from other activities in RCAs. • No information available on load of contaminants from log dumps in RCAs.

Table E.2.19: Exposure scores and justifications: Vessels - movement underway

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Substrate disturbance (sediment resuspension)	1	4	3	3	3	3	**Temporal**: 3, uncertainty = moderate • Year-round stressor **Spatial**: 3, uncertainty = mod • Unlikely to occur in all RCAs **Load**: 1 (low), uncertainty = mod/high • Vessel generally needs to come in either direct contact, or close proximity to the benthic substrate (including creating turbulence, waves, etc.) • Sediment resuspension from vessels is a low intensity stressor. Kept in assessment for precautionary approach. • Currently no data on sediment resuspension from moving vessels in RCAs • Unpredictable occurrence
Noise disturbance	2	1	4	1	4	1	Justifications adapted from HS/QCS MPA Level 2 ERAF (reviewed and in press) scoring: **Temporal**: 4 (scoring bin=>6 months), uncertainty low • Year-round stressor **Spatial**: 4 (scoring bin=>50 RCAs), uncertainty = low/moderate • Long-range stressor that impacts all RCAs **Load**: 2 (moderate), uncertainty = low • Sound propagation from vessels is a low/moderate intensity chronic stressor. • Scored using precautionary scoring • Currently no quantification of vessel noise specific to RCAs

Table E.2.20: Exposure scores and justifications: Vessels – oil spill

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Oil	3	4	1	2	2	5	Justifications adapted from HS/QCS MPA Level 2 ERAF (reviewed and in press) scoring: **Temporal**: 1 (scoring bin= <3.5 days), uncertainty = low/mod • Spills unpredictable. However, based on historical incidents of spills, temporal scale expected to be low. • NB: This stressor was scored based on the incidence of a spill, not the persistence of oil in RCAs **Spatial**: 2 (scoring bin=25-49 RCAs), uncertainty high • There is regular vessel traffic in the area and a large oil spill from a vessel transiting the area could potentially have a moderate overlap RCAs (depending on spill location) • It is not expected that a single spill would impact all RCAs. However, depending on the location of the spill, up to 30% of RCAs could have spatial overlap • Spatial overlap unpredictable but even small amounts of oil can cover large areas. • Precautionary scoring **Load**: 3 (high), uncertainty = mod/high • The load of oils and contaminants from an oil spill is high relative to other activities in RCAs (expected to result in higher amounts of oil in a spill than chronic discharges over a year) • Uncertainty as there is no data available on large oil spills from this area and a spill event is unpredictable

Table E.2.21: Exposure scores and justifications: Vessels – discharge

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
Introductions (AIS)	2	4	1	3	1	4	Justifications adapted from HS/QCS MPA Level 2 ERAF (reviewed and in press) scoring: • The primary determinant of invasion success is propagule pressure - a measure of the number of viable AIS individuals, genotypes and taxa, the number of discrete introduction events and their frequency and duration. • Two types of vessel discharge could act as vectors here: loss of fouling organisms and ballast water exchange. Canadian guidelines for ballast exchange locations for transoceanic voyages: >200 miles offshore in water > 2,000 m deep, or at the very least, > 50 miles offshore in water > 500 m deep. For coastal voyages: >50 miles offshore in water >500 m deep (Anderson, 2007) and sensitive aquatic areas avoided when possible (IMO resolution MEPC.151(55)). • This is much deeper than the water depth where the RCAs are located
							Temporal: 1 (scoring bin=<3.5 days), uncertainty moderate • Incidence of AIS establishment as the result of discharge is expected to be very low
							Spatial: 1 (scoring bin=0-25 RCAs), uncertainty = mod/high • It is expected that there would be only low levels of discharges of small patches of fouling organisms, so potential area overlap of an established AIS population is scored low. • Uncertainty reflects lack of knowledge as to what extent fouling debris is discharged in the area resulting in unknown and unpredictable spatial overlap.

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							Load: 2 (moderate), uncertainty = mod/high • A proportion of fouling AIS dislodged from vessel fouling will remain close to the surface and those that do reach the seabed may be shallow water / intertidal species not be suited for all RCA areas. • The amount of dislodged fouling material that would reach RCAs and be viable would be low. • Uncertainty due to the lack of knowledge on the degree and nature of fouling material discharged in the area.
Substrate disturbance (crushing)	1	4	1	3	1	2	Justifications adapted from HS/QCS MPA Level 2 ERAF (reviewed and in press) scoring:
							Temporal: 1 (scoring bin=<3.5 days), uncertainty = moderate • Incidents of debris from discharge impacting the seafloor and crushing estimated to be low • High uncertainty due to unknown type and frequency of debris discharged that may result in crushing
							Spatial: 1 (scoring bin=0-25 RCAs), uncertainty low/mod • Unpredictable stressor • Incidents of debris that can result in crushing expected to be low and would likely not occur in most RCAs
							Load: 1 (low), uncertainty = mod/high • Relative to other bottom contact activities (e.g. traps) the amount of crushing by debris is expected to be low • Uncertainty due to the lack of information on types and extent of solid debris reaching the benthos and amount of crushing
Substrate disturbance	1	4	1	4	1	2	Justifications adapted from HS/QCS MPA Level 2 ERAF (reviewed and in press) scoring:

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
(sediment resuspension)							**Temporal**: 1 (scoring bin=<3.5 days), uncertainty mod/high • Incidents of debris from discharge impacting the seafloor and resuspending sediment estimated to be low • High uncertainty due to unknown type and frequency of debris discharged that may result in sediment resuspension
							Spatial: 1 (scoring bin=0-25 RCAs), uncertainty low/mod • Unpredictable stressor • Incidents of debris that can result in sediment resuspension expected to be low and would likely not occur in most RCAs
							Load: 1 (low), uncertainty = mod/high • Relative to other bottom contact activities (e.g. traps) the amount of sediment re-suspended by debris is expected to be low • Sediment would be expected only be re-suspended upon the initial settlement of solid debris, with some movement via currents into other areas. • Uncertainty due to the lack of information on types and extent of solid debris reaching the benthos and amount of sediment re-suspended.
Contaminants	2	3	2	3	1	4	Justifications adapted from HS/QCS MPA Level 2 ERAF (reviewed and in press) scoring: • Vessels discharge oily wastewater ('operational discharges') such as bilge water. Bilge water contains solids, contaminants and oil, and represents ~20% of oily wastewater discharges, and can be released in high volumes depending on vessel size (0.5-50m3 a day /150-65,000 gal/day, e.g. ~25,000 gal/week for Alaskan cruise ships) (Edmiston 2014). • Discharged bilge is estimated to have a residual oil content of <15 ppm (International Maritime Organisation).

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							Temporal: 2 (scoring bin=3.5 days to 3.5 months), uncertainty = moderate. • Incidents of discharge estimated to be low in RCAs • High uncertainty due to unknown type and frequency of discharge **Spatial**: 1 (scoring bin=0-25 RCAs), uncertainty moderate/high • Unpredictable stressor • Incidents of discharge containing contaminants expected to be low and would likely not occur in most RCAs • Operational discharges are generally concentrated close to shore and only low levels of oily discharges have been observed in aerial surveys of the more offshore areas **Load**: 2 (moderate), uncertainty = moderate • The amount of oil/contaminants from chronic level vessel discharges in RCAs is estimated to be moderate relative to the worst-case scenario of a large oil spill where oil content may be high. • Uncertainty as no specific data quantifying amounts of chronic discharges in the specific area of interest.
Introductions (nutrients/biological material)	1	4	2	3	1	4	Justifications adapted from HS/QCS MPA Level 2 ERAF (reviewed and in press) scoring: **Temporal**: 2 (scoring bin=3.5 days to 2.5 months), uncertainty = moderate • Incidents of discharge estimated to be low in RCAs • Moderate uncertainty due to unknown type and frequency of discharge

Stressor	Load	Load uncertainty	Temporal	Temporal uncertainty	Spatial	Spatial uncertainty	Justifications
							Spatial: 1 (scoring bin=0-25 RCAs), uncertainty = mod/high • Unpredictable stressor • Incidents of discharge containing biological material/nutrients expected to be low and would likely not occur in most RCAs
							Load: 1 (low), uncertainty = mod/high • The amount of material (black water) introduced from shipping (fishing processing and general discharges combined) is to be expected to be low relative to other areas where vessels are not just transiting the area.

APPENDIX F: CONSEQUENCE SCORING

F.1. ROCKFISH

Table F.1.1: Rockfish score overview Consequence scoring is based on the negative interaction between a stressor and a SEC. The impact on the SEC is based on impacts to population size and condition for Inshore Rockfish and Prey SECs, and spatial extent and condition of Rocky Reefs SEC. Scoring is informed by the information provided in Appendix C, and the justifications associated with these scores are largely sourced from this material.

Activity	Stressor	Consequence	Uncertainty
Coastal_infrastructure	Contaminants	1	3
Coastal_infrastructure	Introductions_foreign_material	1	2
Crab_by_trap	Entrapment_entanglement	2	3
Crab_by_trap	Removal_of_biological_material	2	2
Crab_by_trap	Substrate_disturbance_sediment_resuspension	1	2
Dual_FSC_groundfish_hook_and_line	Entrapment_entanglement	2	4
Dual_FSC_groundfish_hook_and_line	Removal_of_biological_material	3	3
Dual_FSC_groundfish_hook_and_line	Substrate_disturbance_sediment_resuspension	1	3
Euphausiid_by_midwater_trawl	Removal_of_biological_material	1	2
Finfish_aquaculture	Contaminants	2	2
Finfish_aquaculture	Introductions (nutrients/biological material)	1	1
Finfish_aquaculture	Removal_of_biological_material	1	2
Groundfish_by_midwater_trawl	Entrapment_entanglement	1	3
Groundfish_by_midwater_trawl	Removal_of_biological_material	1	2

Activity	Stressor	Consequence	Uncertainty
Groundfish_by_midwater_trawl	Substrate_disturbance_sediment_resuspension	1	3
Herring_by_gillnet	Entrapment_entanglement	1	4
Herring_by_gillnet	Removal_of_biological_material	1	3
Herring_seine_net	Removal_of_biological_material	1	2
Invasive_bottom_long_line_fishery_survey	Removal_of_biological_material	1	2
Movement_and_storage_of_logs	Contaminants	2	3
Movement_and_storage_of_logs	Substrate_disturbance_sediment_resuspension	1	2
Outfalls	Contaminants	2	4
Outfalls	Introductions (nutrients/ biological material)	1	3
Prawn_and_shrimp_by_trap	Entrapment_entanglement	2	2
Prawn_and_shrimp_by_trap	Removal_of_biological_material	2	2
Prawn_and_shrimp_by_trap	Substrate_disturbance_sediment_resuspension	1	2
Salmon_by_gillnet	Entrapment_entanglement	1	3
Salmon_by_gillnet	Removal_of_biological_material	1	2
Salmon_by_seine_net	Entrapment_entanglement	1	3
Salmon_by_seine_net	Removal_of_biological_material	1	3
Scallop_by_trawl	Entrapment_entanglement	1	3
Scallop_by_trawl	Substrate_disturbance_sediment_resuspension	1	3

Activity	Stressor	Consequence	Uncertainty
Shellfish_aquaculture	Contaminants	2	2
Shellfish_aquaculture	Introductions (nutrients/biological material)	1	2
Shellfish_aquaculture	Substrate_disturbance_sediment_resuspension	1	2
Smelt_by_gillnet_recreational	Entrapment_entanglement	1	4
Smelt_by_gillnet_recreational	Removal_of_biological_material	1	4
Smelt_by_gillnet_recreational	Substrate_disturbance_sediment_resuspension	1	3
Vessels_discharge	Contaminants	2	4
Vessels_discharge	Substrate_disturbance_sediment_resuspension	1	2
Vessels_movement_underway	Noise_disturbance	1	2
Vessels_oil_spill	Oil	4	3

Table F.1.2: Consequence scores and justifications for inshore rockfish SEC by activity.

Stressor	Consequence	Uncertainty	Justification
Prawn and shrimp trapping			
Removal of biological material	2	2	The direct removal of juvenile rockfish in traps as bycatch is a documented occurrence. The encounter rate of Inshore Rockfish species (bolded) in RCAs (2007-2015) in the commercial prawn fishery is 0.32 (SE 0.02) fish per string. Rockfish caught in prawn traps are mostly juveniles (typically year three or four) (Rutherford et al. 2010). In Howe Sound, from 1999 to 2008, the overall rockfish catch rate in research traps (similar to commercial traps, but the mesh size is smaller) was 0.015 rockfish per trap (Favaro et al. 2010). In Puget Sound, from 2004-2013, the overall rockfish catch rate (mostly Copper and Quillback) in prawn traps was 0.023 rockfish per trap drop. Rockfish bycatch was higher in the fall compared to the spring (when the fishery in BC occurs). The number of rockfish estimated to be caught in prawn traps by all fishing sectors in Puget Sound is approximately 2,600 fish each year (Antonelis et al. 2018). The mean estimated rockfish bycatch (all species) coastwide from 2007 to 2016 (ten years) is 226,565 with an upper 95% confidence interval of 266,990 (K. Fong, DFO, unpublished data). Overall, Inshore Rockfish species comprised 87.9% of incidentally caught rockfish within RCAs from 2007-2015. Although rockfish encounters in traps do not occur on all strings, the magnitude of commercial fishing that occurs within RCAs may impact rockfish recovery. Quillback is the most common rockfish species caught (Rutherford et al. 2010). Most incidentally caught rockfish (typically year three or four) are not sexually mature and, thus, will not recruit to the fishery for another 6 to 10 years (Yamanaka et al. 2012). Natural mortality of juvenile Quillback Rockfish is high (Yamanaka et al. 2012). Consequence: the removal of a juveniles could result in minor impacts to the rockfish population (scored to take into consideration the potential lower impact of removing juvenile rockfish compared with removing adult rockfish). Uncertainty = low/mod.
Entrapment/ entanglement	2	2	Lost trap gear can continue to catch and kill marine species until they become disabled by disintegration of escape (rot) cord, or lose their structural integrity (NRC 2008). There is no information available on annual commercial prawn trap losses in BC. However, lost prawn traps have been located with submersibles (Breen 1989). In Puget Sound, prawn trap loss from commercial sectors is believed to be very low (<0.1% of traps fished). The overall estimated density of derelict prawn traps was 14 traps per square kilometer in an average depth of 59 m (Antonelis et al. 2018). The commercial fishery is required to use rot cord to facilitate escapements in the case of ghost fishing. Rot cord is designed to take 90-130

Stressor	Consequence	Uncertainty	Justification
			days to disintegrate, but research has shown it can take much longer for cords to break and marine growth and rust can prevent some cages from opening for years (Arthur et al. 2014). Bycatch, small enough to have entered the trap through the tunnel and not yet found the way back out through the mesh or the tunnel; will be small enough to escape through the gape in the mesh (L. Convey, DFO, *pers. comm*., Jan 2019). Because of the unknown amount of rockfish impacted by ghost fishing (despite mitigation measures such as escape tunnels and rot cord), precautionary scoring of minor impact on the overall population of rockfish across RCAs.
Substrate disturbance (sediment resuspension)	1	2	From 2007 to 2017, on average about 17% of commercial prawn trap fishing representing 8,675 strings (9,940 days) occurred in RCAs annually. Trap fishing causes temporary resuspension of bottom sediment. It is expected that sediment re-suspension in RCAs would not be sufficient to result in mortality in the rockfish prey population, which are mobile species and able to move away from this stressor. This stressor is considered short term. There are no documented cases of acute impacts to rockfish from sediment re-suspension from traps.
Crab by trap			
Removal of biological material	2	2	Coast-wide, there were three rockfish recorded during 2,756 fishing events from 2007-2017. These rockfish were caught outside RCAs - one China Rockfish was caught in 2008 in Hecate Strait and two Copper Rockfish were caught in 2017 in the Strait of Georgia. Approximately 15% of sampling of commercial gear occurred in RCAs. Direct mortality of rockfish as bycatch in crab traps appears low based on scientific sampling data. Target crab size is generally too large to be prey for rockfish, but trap bait or other bycatch may attract rockfish to traps.

Stressor	Consequence	Uncertainty	Justification
Entrapment/ entanglement	2	3	Coastwide, 35,857 commercial crab traps were recorded lost in commercial logbooks between 2000-2014 (L. Barton, pers. comm., Feb 2018). A 1987 report found 11% of crab traps from the Dungeness Crab fishery were lost each year in the Fraser River Estuary with the ability to ghost fish ~7% of annual commercial hauls (Breen 1987). Target crab size is generally too large to be prey for rockfish, but trap bait or other bycatch may attract rockfish to traps. The commercial fishery is now required to use rot cord to facilitate escapements in the case of lost traps. A study of the Dungeness Crab fishery in the USA found that rot cord is expected to take 90-130 days to disintegrate but often takes much longer (up to 2.5 years in Washington and over 6 years in Alaskan fisheries) (Arthur et al. 2014). Marine growth and metal fatigue often inhibit escape panels from opening (Arthur et al. 2014). Minor impact on rockfish population anticipated.
Substrate disturbance (sediment resuspension)	1	2	Trap fishing causes temporary resuspension of bottom sediment. It is expected that sediment re-suspension in RCAs would not be sufficient to result in mortality in the rockfish population, which is a mobile species able to move away from this stressor. This stressor is a short-term stressor. There are no documented cases of acute impacts to rockfish from sediment re-suspension from traps. Negligible impacts on RCA rockfish populations. Uncertainty moderate due to lack of information specific to the fishery and rockfish.
Groundfish by mid-water trawl			
Substrate disturbance (sediment resuspension)	1	3	Mid-water trawls can touch bottom (Donaldson 2010; Chuenpagdee et al. 2003) where they can temporarily resuspend bottom sediment as in a bottom trawl (Leys 2013). However, it is not expected that there will be sufficient sediment suspended to cause a change in population size of mobile rockfish. Scored low with uncertainty due to lack of knowledge on the degree of bottom interaction of this fishery in this area and amounts of sediment suspended.

Stressor	Consequence	Uncertainty	Justification
Removal of biological material	1	2	Rockfish are one of the target species of this fishery. Catches of Inshore Rockfish species in trawl gear are very rare. Coast-wide, 17 species of rockfish were caught in mid-water trawl gear between 2007 and 2017. None of the rockfish species listed in mid-water trawl records were Inshore Rockfish species protected by RCA regulations. It is possible that Inshore Rockfish may have been captured by mid-water trawl gear and recorded as “rockfish complexes” or “unknown fish” in species catch records. However, it is unlikely that Fishery Observers would be unable to correctly identify Inshore Rockfish species as they are trained to recognize common rockfish species, which include all inshore species (Rob Tadey, DFO, Regional Head Quarters, Vancouver, *pers. comm*., December 2018). Approximately one percent of the reported 35,108 (8,057 trips) mid-water trawl fishing events that occurred coast-wide from 2007 to 2017 were in RCAs. Trawl activity was highest in 2017 in RCAs when 78 fishing events were recorded. Mid-water trawling was concentrated in the Goletas Channel RCA where approximately 83% of all trawl activity occurred (269 fishing events). The Goose Island RCA received approximately 5% (17 events) while Ajax/Achilles Bank received approximately 4% (13 events) of the fishing effort. The remaining 12 RCAs received six or fewer events. With the exception of a few RCAs, mid-water trawling has generally been an infrequent activity in RCAs. Many other species of finfish, including rockfish species like Canary Rockfish and Yellowtail Rockfish, which RCAs were not designed to protect, are regularly removed by mid-water trawls. Negligible impacts scored with low/mod uncertainty (due to lack of information).
Entrapment/ entanglement	1	3	No information included in this assessment on incidents of gear loss for mid-water trawl. Lost mid-water trawl gear can cause seafloor damage if it sinks as a result of encrusting organisms and dying animals (Morgan and Chuenpagdee 2003). Justifications adapted from HS-QCS MPA Level 2 ERAF: Death of trapped organisms from entanglement in derelict mid-water trawl gear could occur quickly from injury or predation and entangled fish may die from predation, starvation, and suffocation (Laist 1997). It is not known what the incidence of lost gear is but would be expected to be low and lost gear is likely to be speedily recovered as it is expensive (*pers. comm.* L. Yamanaka, DFO). Unlikely that enough gear would be lost to have a population scale impact. Moderate uncertainty related to availability of information.

Stressor	Consequence	Uncertainty	Justification
Scallops by trawl			
Entrapment/ entanglement	1	3	Death of trapped organisms from entanglement in derelict trawl gear could occur quickly from injury or predation and entangled fish may die from predation, starvation, and suffocation (Laist 1997). Between 10 and 121 tows per year RCAs. Effort in all but two years since 2007; occurs in 2 RCAs (1%). This stressor likely has a negligible impact on the RCA rockfish population. Uncertainty due to lack of information on gear loss and impacts on the RCA rockfish population.
Substrate disturbance (sediment resuspension)	1	3	This net is designed to remain ~20 cm off the bottom to catch swimming scallops, although occasional net contact can occur. This fishery is considered a bottom contact fishery as the net sits on several steel runners that roll across the bottom during tows. Bottom contact can temporarily resuspend bottom sediment. Elevated levels of sediment (over background levels) may harm fish through sublethal effects, compromising well being and survival (Birtwell 1999). However, it is not expected that there will be sufficient sediment suspended to cause a change in population size of mobile rockfish. Scored low with uncertainty due to lack of knowledge on the degree of bottom interaction of this fishery in this area and amounts of sediment suspended.
Salmon by seine			
Removal of biological material	1	3	There are no reports of incidental rockfish catch in salmon seine net fishing from 2007 to 2017. This could indicate that the technique adequately avoids rockfish habitat, or it may reflect under-reporting or difficulties finding rockfish buried among large quantities of salmon catch. Rockfish bycatch is presumed low as fishers do not want to contact bottom habitats that may entangle their nets (G. Hornby, *pers. comm*., Feb 2018). However, more pelagic rockfishes (e.g. Black Rockfish and Yellowtail Rockfish) may be incidentally caught even when nets do not contact bottom habitats and accidental bottom contact does occur. Negligible impact expected on RCA rockfish population. Uncertainty moderate
Entrapment/ entanglement	1	3	It is expected that ghost fishing would have a negligible impact on the RCA rockfish population, but uncertainty reflects lack of information about lost seine nets.

Stressor	Consequence	Uncertainty	Justification
Salmon by gillnet			
Removal of biological material	1	2	Between 2007-2017 the commercial salmon gillnet fishery reported 25 incidentally caught Black Rockfish and one China Rockfish. Incidental catch was spread across PFMAs 3, 4, 11, 12, 21, and 23. It is expected that this fishery has a negligible impact on the RCA rockfish population. Specific reporting data on this fishery reduces the uncertainty.
Entrapment/ entanglement	1	3	The extent of lost fishing nets is unknown, but lost nets have been retrieved off rocky habitats in Area 24 with entangled rockfish as rockfish will enter the nets to feed on other entangled dead fish (M. Spence, DFO, Fisheries and Oceans Field Office, Port Alberni, *pers. comm*., February 2018). These nets will continue to ghost fish until they are removed or degrade, which may take years. Fishery notices encourage fishers to report lost fishing gear to area managers or charter patrol (G. Hornby, DFO, Fisheries and Oceans Field Office, Campbell River, *pers. comm.*, March 2018) – but is not mandatory. This stressor is expected to have a negligible impact on the RCA rockfish community.
Herring seine net			
Removal of biological material	1	2	Minimal concerns for herring seine netting; The commercial herring seine net fishery has 100% dockside validation. However, it is difficult to see rockfish bycatch in large quantities of Herring (V. Postlethwaite, pers. comm., Feb 2018). Comprehensive assessments of rockfish bycatch in seine nets are not available. There is no location specific logbook information for this fishery to assess fishing effort inside RCAs. Vessels fish in deep water only and avoid bottom contact to prevent gear entanglement (B. Spence, pers. comm., Feb 2018). Negligible impact on RCA rockfish population.
Herring by gillnet			
Removal of biological material	1	3	Full extent unknown (known to overlap RCAs in Area 17 and Area 14); occurs in unknown number of RCAs; rockfish removals (unknown impacts from rockfish caught in gillnets in some RCAs); The commercial Herring gillnet fishery also has 100% dockside validation but it is difficult to see bycatch in large offloads of Herring (B. Spence, *pers. comm*., Feb 2018). There is no location specific logbook information for this fishery to assess fishing effort inside RCAs. There is a concern about rockfish bycatch

Stressor	Consequence	Uncertainty	Justification
			in certain RCAs that overlap with herring spawning and gillnet fishing locations. Specifically gillnet fishing in Area 17 RCAs and Area 14 Savoie Rocks - Maude Reef and Chrome Island, DeCoursey Group RCAs). Moderate uncertainty.
Entrapment/ entanglement	1	4	Ghost fishing from lost nets is a concern in any RCA that overlaps with gillnet fishing locations. Area 17 and 14 are significant gillnet fishing locations and consultation on any proposed changes would be required (B. Spence, pers. comm., Feb 2018). Mod/high uncertainty reflects lack of information.
Euphausiid (krill) by mid-water trawl			
Removal of biological material	1	2	Rockfish bycatch is presumed to be low in the krill trawl fishery due to typical fishing depths and slow tow speeds. This fishery has 100% dockside validation but it is unlikely that small quantities of rockfish would be seen in large amounts of krill. Occurs in unknown # RCAs; This fishery has no logbook data for bycatch or GPS coordinates for fishing locations so effort within RCAs and rockfish bycatch could not be assessed. Juvenile Rockfish are occasionally encountered in the krill trawl fishery. The commercial krill fishery occurs in the upper Strait of Georgia, Jervis Inlet, and mainland inlets on the south coast of BC. Plankton trawl nets only fish the upper few metres of the water column and bycatch typically consists of Hake, Herring, and Dogfish (Krill IFMP). Unlikely to impact the RCA rockfish population. The annual total allowable harvest is 500 tonnes (DFO 2018l). However, there is minimal information on the krill fisheries, nor is there much information available on bycatch. The DFO 2007-2012 Euphausiid Integrated Fisheries Management Plan (IFMP) states that vessels in Canada “are requested to cease trawling in any location if the catch of larval or juvenile fish exceeds 10 per litre drained catch”. Information about the location, date and level of catch is to be reported to DFO so that “appropriate action can be taken to prevent any fishing of larval or juvenile fish” (DFO 2018l).
Smelt by gillnet			
Removal of biological material	1	4	Smelt by gillnet is permitted in RCAs. It is unlikely that smelt fishing with gillnets encounters large numbers of adult rockfish. However, juvenile rockfish in eelgrass beds may be vulnerable to this fishery (C. Wells, *pers. comm*., Feb 2018). Rockfish bycatch (may have similar bycatch rates to commercial techniques). Due to the small scale and location of this fishery it is unlikely that it encounters large

Stressor	Consequence	Uncertainty	Justification
			quantities of rockfish. A secondary effect (not assessed here) is the potential impact of prey reduction/removal with unknown impacts on rockfish.
Entrapment/ entanglement	1	4	Lost gear/ghost fishing frequency unknown, but presumed low. Juvenile rockfish would be susceptible. Occurs in unknown number of RCAs. Mod/High uncertainty.
Substrate disturbance (sediment resuspension)	1	3	Sediment resuspension from smelt gillnet fishing possible, but effects on rockfish unknown/undocumented. Impact unlikely to impact the population size or condition. High uncertainty.
Dual-FSC Groundfish fishing			
Removal of biological material	3	3	NB: Scored for dual fishing hook and line only. Other FSC fishing is discussed in the appendix, but not included in the assessment. Dual fishing hook and line trips are subject to audits to verify logbook accuracy via video analysis and dockside monitoring programs are in place. However, DFO’s capacity to conduct thorough assessments of all dual fishing trips is limited. The use of commercial scale groundfish gear in RCAs could impact the ability of rockfish populations to rebuild within RCAs. Rockfish removals (Hook and line, longline activity may actively remove large numbers of rockfish. Catch rates unknown.) Dual fishing documented in 32 RCAs (20%). Some First Nation groups request that their dual fishing vessels avoid fishing in RCAs. Precautionary scoring that this activity will have major impact on the RCA rockfish population with moderate uncertainty.
Entrapment/ entanglement	2	4	Amount of gear loss unknown, and impacts of ghost fishing from this fishery on rockfish not documented. Likely negligible impacts on the RCA rockfish community but scored using a precautionary approach due to lack of information. Mod/high uncertainty reflects this.

Stressor	Consequence	Uncertainty	Justification
Substrate disturbance (sediment resuspension)	1	3	Sediment plumes generated may travel large distances from the initial disturbance site, depending on the currents, plume size and particle size of the sediment (Auster 1998; Leys 2013). Elevated levels of sediment (over background levels) may harm fish through sub lethal effects, compromising well-being and survival (Birtwell 1999). It is unlikely that with the level of activity in RCAs that this stressor would negatively impact the RCA rockfish population. Uncertainty is moderate due to lack of knowledge of effects and sediment produced by this activity.
Finfish aquaculture			
Introductions (nutrients/biological material)	1	1	Biological material includes biochemical oxygen demanding (BOD) matter: fecal material coming from fish, dead fish, fish feed, and blood generated from harvest. Dead fish are removed from the marine environment regularly, and blood must be disposed of at land-based facilities, therefore the impact is mainly from fecal matter. Keeley et al. (2014), DFO Aquaculture management, and Science branch, have found that conditions beneath finfish cages can become anoxic and azoic. The majority of measureable effects are contained to within 125 from the cage edge, although sometimes traces of impacts can be found up to 250 m away if sites have very high bottom currents or other unique conditions (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm*., January 2019). Some older studies have found trace effects at distances of 900 m (Kutti et al. 2007), but such results may not reflect current practices. The aquaculture management framework attempts to constrain impacts within those boundaries (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm*., March 2018). The introduction of biological material from feed is not expected to have a direct negative impact on the RCA rockfish population. Uncertainty low.
Contaminants	2	2	Contaminants associated with finfish aquaculture that could potentially harm the marine environment include hydrocarbons and lubricants, disinfectants, formic acid (used as an ensiling agent), metals (antifoulants and feed), and drugs/medications. Management measures exist for all of these contaminants to reduce potential exposure and consequence, although accidental spills may occur and some contaminants may negatively impact the environment. Minor impacts anticipated for RCA rockfish populations. Uncertainty low/moderate.

Stressor	Consequence	Uncertainty	Justification
Removal of biological material	1	2	Incidental rockfish catch and mortality occurs in small numbers at finfish aquaculture tenures that overlap with RCA boundaries. Groundfish Management currently considers all incidentally caught rockfish to have 100% mortality even if released due to severe barotrauma effects. However, rockfish in aquaculture pens may be more acclimatized to shallower depths and subsequently less likely to suffer barotrauma when incidentally caught and released (S. Peterson*, pers. comm*., Feb 2018).
Shellfish aquaculture			
Introductions (nutrients/biological material)	1	2	Most shellfish facilities do not add additional nutrients to the surrounding area since most shellfish filter-feed from the natural environment. However, enrichment does occur, which may have a negative impact on some marine life. Negligible impacts expected on rockfish in RCAs.
Contaminants	2	2	Contaminants used in marine shellfish aquaculture include hydrocarbons and lubricants, wood treatment products, plastics, Styrofoam, and general chemicals used where humans live and work. The quantities and potential exposure to hydrocarbons and lubricants is expected to be lower than that for finfish aquaculture. As plastics and styrofoam breakdown, fish may ingest these particles resulting in a reduction in fitness or death. Impact on the overall RCA rockfish population expected to be low.
Substrate disturbance (sediment resuspension)	1	2	Sediment resuspension occurs at shellfish aquaculture sites, however, the volumes are unknown. Due to the nature of shellfish operations and the potential low spatial overlap with RCAs, impact is expected to e negligible, especially because rockfish are mobile and capable of moving away from a disturbance.
Invasive (bottom long-line) fishery surveys			
Removal of biological material	1	2	Between 2003-2017, 493 Inshore Rockfish were removed from the Estevan Point RCA IPHC longline sampling station and 123 Inshore rockfish removed from the North Danger Rocks RCA IPHC sampling station. Effects most likely injury or mortality but numbers low and would not effect at a population level across all RCAs. Impact on Inshore Rockfish population expected to be negligible.
Discharge			

Stressor	Consequence	Uncertainty	Justification
Substrate disturbance (sediment resuspension)	1	2	Justifications adapted from HS/QCS MPA Level 2 ERAF. The pressure wave from heavy debris impacting the seabed can cause a crater and a cloud of sediment (Wachsmann 2011), which can be transported on currents exposing a larger area. In this case, sediment re-suspension would be short term and only expected to occur upon the initial settlement of debris to the seabed. Solid debris would be unlikely to move around due to limited influence of storms, waves, surges and strong currents etc. at that depth. Though elevated levels of sediment (over background levels) may harm fish acutely (Birtwell 1999), it is expected that sediment re-suspension from discharged vessel debris would result in negligible mortality in the rockfish population due to the infrequent point source, expected low level and short term nature of the stressor as well as the ability of the fish to move away from sediment clouds. There are no documented cases of acute impacts to this SEC from sediment re-suspension from large vessel discharged debris.
Contaminants	2	4	Justification adapted from HS/QCS MPA Level 2 ERAF. Mobile species have the ability to move away from oil and contaminants. However, this stressor relates to low level chronic type pollution which may persist in the environment at low levels and is likely unavoidable. Examples of contaminants from vessels include POPs, PBDEs, PAHs and heavy metals, which have the potential to cause fish mortality (Debruyn et al. 2004; Terlizzi et al. 2001). Even low concentrations of Polycyclic Aromatic Hydrocarbons (PAHs) can have a deleterious effect on marine biota. Chronic releases of oil and contaminants by vessels are expected to cause immediate mortality to a negligible proportion of the rockfish population. With repeated exposure, rockfish could accumulate chronically discharged oil/contaminants with potential for sublethal effects. General sublethal effects from exposure to petroleum hydrocarbons include: impairment of feeding mechanisms, growth rates, development rates, energetics, reproductive output, recruitment rates and increased susceptibility to disease (Capuzzo 1987). Examples of contaminants from vessels include POPs, PBDEs, PAHs and heavy metals, which can result in sublethal effects on fish such as increased susceptibility to disease, reduced reproductive success, higher genetic mutation rates; reduced fitness for navigation/migration; reduced survival of eggs and juveniles (Debruyn et al. 2004; Terlizzi et al. 2001). Uncertainty due to lack of data on mortality effects of oil/contaminants on rockfish and their sensitivity to oil.
Movement underway			

Stressor	Consequence	Uncertainty	Justification
Noise disturbance	1	2	There is no evidence that noise from vessels under way can cause immediate mortality to rockfish. Effects would be expected to be more chronic in nature. Noise from shipping is pervasive throughout the marine environment especially at low (<300Hz) frequencies, this is a chronic stressor which can have deleterious effects on fish populations (Erbe et al. 2012; Merchant et al. 2012) such as disturbance, deterrence, reduced growth and reproduction, and can interfere with predator-prey interactions, communication and schooling behaviour (Sara et al. 2007; Slabbekorn et al. 2010). Though the whole population is likely exposed to this stressor, chronic impacts on a population scale are expected to be relatively low. There is associated high uncertainty with this score due to lack of literature specific to long term chronic effects on rockfish in this environment.
Oil spill			
Oil	4	3	Justification adapted from HS/QCS MPA Level 2 ERAF. How toxic a spill will be is related to the particular mix that is spilled, with more refined mixtures (e.g. the heavy fuel oil used in ships) being be more toxic that crude oils. Petroleum contaminants may enter fish through the skin or gills or through food webs, hydrocarbons taken through gills can accumulate in the liver and gall bladder and those ingested end up in the stomach (Lee et al. 1972; Teal 1977; Samiullah 1985). Most adult fish are able to detect and avoid contaminated areas unless limited in some way by behaviour or habitat. If extremely contaminated, gills of fish can become clogged, resulting in asphyxia and death, though in many cases, unless damaged by dispersants, the mucilaginous coat restricts oil adhesion (Samiullah 1985). Polycyclic aromatic hydrocarbons (PAHs) are one of the oil components for which a range of biological effects have been demonstrated including: acute toxicity (Batista et al. 2013; Yamada 2009). One study suggests that there are few long-term adverse effects on fish stocks attributed to oil, although it is stressed that short term local impacts can be extremely damaging (McIntyre 1982). In contrast, findings indicate that rockfish may be particularly affected by oil spills, as it has been well documented that demersal rockfish species were the only fish found dead in significant numbers after two major oil spills (The Amoco Cadiz spill in the English Channel in 1978 and the Exxon Valdez oil spill in Alaska in 1989) (Gundlach et al. 1983; Khan and Nag 1993; Marty et al. 2003). Based on these findings, and using the precautionary approach, a catastrophic oil spill from a vessel accident which spreads over a large area could be predicted to cause immediate mortality to a large proportion of the rockfish population.

Stressor	Consequence	Uncertainty	Justification
Movement and storage of logs			
Substrate disturbance (sediment resuspension)	1	2	Water-based log handling includes: log dumping, log booming, log transportation, log storage, and log sorting. Log dumps can cause serious bottom impacts and resuspend sediment. Bark and sawdust can accumulate under log dumps (up to 60 cm) and smother important juvenile and adult rockfish habitat like kelp beds and eelgrass (Van der Slagt et al. 2003). Logs can also cause bottom damage when they are dragged across the seafloor and rest on exposed intertidal flats during low tides, or when helicopters drop logs from great heights into storage areas (Levings and Northcote 2004). Rockfish are mobile and able to move away from suspended sediment. Negligible impacts to RCA rockfish population.
Contaminants	2	3	Log dumps can alter water quality in surrounding areas. Bark and sawdust can accumulate under log dumps (up to 60 cm) and smother important juvenile and adult rockfish habitat like kelp beds and eelgrass (Van der Slagt et al. 2003). Woody debris can create anaerobic conditions below and adjacent to log dump sites and alter ecosystem dynamics (Barker 1974). Logs stored in salt water can leach toxic acidic resin, which can contaminate the water column and substrate (Van der Slagt et al. 2003). Hemlock resin killed 50% of Pink Salmon test fish at 100–120 mg L^{-1} and Sitka Spruce was lethal at even lower levels (Buchanan et al. 1976). Key rockfish prey species like crabs and shrimp have also been shown to avoid habitats disturbed by woody debris. It takes several years for marine habitats to recover from log dump impacts and some areas never regain their original functionality (Levings and Northcote 2004). Minor impacts to rockfish population across RCAs.
Outfalls			
Introductions (nutrients/ biological material)	1	3	Effluent can include biological material/nutrients. Effluent dilution rates and plume areas are highly variable based on outfall design and local environmental conditions. However, due to the mobile nature of effluent, assessing only outfalls inside RCAs might underestimate potential effects of effluent outfalls in very close proximity to RCAs. A study of wastewater outfalls in southern California found that outfall plumes covered approximately16 km^2 (DiGiacomo et al. 2004). While nutrient input from sewage outfalls can increase food availability, which might benefit rockfish populations directly and indirectly, they can also create anoxic zones (Hindell et al. 2000). Expected negligible impact on RCA rockfish populations.

Stressor	Consequence	Uncertainty	Justification
Contaminants	2	4	Effluent can include sewage and waste from industry (e.g. oil processing, sawmills, etc.). We were unable to make a detailed assessment of the possible effects of these effluent outfalls on RCA habitats and rockfish populations given the available data. The effects of effluent on marine habitats are highly variable depending upon the type of effluent (e.g. sewage, pulp mill, oil processing), the amount of effluent being discharged, and the environment around the outfall. Municipal sewage effluent can cause eutrophication and changes to community assemblages in marine environments (Costanzo et al. 2001; Hindell et al. 2000). While nutrient input from sewage outfalls can increase food availability, which might benefit rockfish populations directly and indirectly, they can also create anoxic zones (Hindell et al. 2000). Sewage effluent can introduce pollutants into marine systems with a variety of potential effects. Pulp mill and oil processing effluent can also affect marine environments through the introduction of toxic chemicals (Yanko et al. 1999). Minor impacts on RCA rockfish population with high uncertainty.
Existing coastal infrastructure			
Contaminants	1	3	Contaminants associated with infrastructure include antifouling agents, which sensitive benthic organisms are particularly susceptible to. Contaminants associated with the vessels that use this infrastructure are included in vessel discharge and not included here. Expected to have a negligible impact on rockfish in RCAs.
Introduction of foreign material	1	2	Effects of floating structures in RCAs will be highly dependent upon the size, location, and popularity of these areas. A full assessment of the potential effects to RCAs from coastal infrastructure was not possible with available data. Some fixed coastal structures can create artificial reefs that may encourage rockfish assemblages in RCAs. However, certain construction materials do not support artificial reefs, and artificial structures can create unnatural habitats that are not always well suited to local species. For example, steep dock pilings or concrete walls can provide habitat for species like barnacles, tube worms, and anemones, but may lack crevices that provide habitat for rockfish species (Bulleri et al. 2010). Negligible impacts on rockfish population of RCAs.

F.2. ROCKY REEFS

Table F.2.1: Rocky reefs score overview. The Rocky Reef habitat SEC includes the biological communities associated with the habitat. When scoring Rocky Reefs, consideration is given to which species would be impacted by a stressor. Where multiple Rocky Reef species are impacted by a stressor, the most sensitive species is selected for scoring.

Activity	Stressor	Consequence	Uncertainty
Coastal_infrastructure	Contaminants	2	3
Coastal_infrastructure	Introductions_AIS	3	3
Crab_by_trap	Introductions_AIS	3	4
Crab_by_trap	Substrate_disturbance_crushing	2	3
Crab_by_trap	Substrate_disturbance_sediment_resuspension	2	3
Dual_FSC_groundfish_hook_and_line	Substrate_disturbance_sediment_resuspension	2	3
Finfish_aquaculture	Contaminants	2	2
Finfish_aquaculture	Introductions_AIS	2	2
Finfish_aquaculture	Introductions_nutrients_biological_material	1	1
Groundfish_by_midwater_trawl	Introductions_AIS	3	4
Groundfish_by_midwater_trawl	Substrate_disturbance_crushing	1	3
Groundfish_by_midwater_trawl	Substrate_disturbance_sediment_resuspension	1	3
Invasive_bottom_long_line_fishery_survey	Substrate_disturbance_crushing	1	2
Invasive_bottom_long_line_fishery_survey	Substrate_disturbance_sediment_resuspension	1	2
Outfalls	Contaminants	3	4

Activity	Stressor	Consequence	Uncertainty
Outfalls	Introductions_nutrients_biological_material	1	3
Prawn_and_shrimp_by_trap	Introductions_AIS	3	4
Prawn_and_shrimp_by_trap	Substrate_disturbance_crushing	2	3
Prawn_and_shrimp_by_trap	Substrate_disturbance_sediment_resuspension	2	3
Shellfish_aquaculture	Contaminants	2	2
Shellfish_aquaculture	Introductions_AIS	3	3
Shellfish_aquaculture	Introductions_nutrients_biological_material	1	3
Shellfish_aquaculture	Substrate_disturbance_sediment_resuspension	1	2
Smelt_by_gillnet_recreational	Substrate_disturbance_sediment_resuspension	1	3
Vessels_discharge	Contaminants	2	3
Vessels_discharge	Introductions_AIS	3	4
Vessels_discharge	Introductions_nutrients_biological_material	1	3
Vessels_discharge	Substrate_disturbance_crushing	1	2
Vessels_discharge	Substrate_disturbance_sediment_resuspension	1	4
Vessels_movement_underway	Substrate_disturbance_sediment_resuspension	2	4
Vessels_oil_spill	Oil	4	4

Table F.2.2: Consequence scores and justifcations for Rocky Reef habitat SEC by activity.

Stressor	Consequence	Uncertainty	Justifications
Prawn and shrimp trapping			
Substrate disturbance (crushing)	2	3	Target area for this fishery is rocky near-shore areas in depths of 40-100 m. Rocky reefs are in the target area of this fishery. Prawn traps could drag along rocky habitat and cause damage to sessile organisms such as anemones, which are important habitats for many demersal crustaceans (Lewis 2009). Damage to sessile benthic organisms could impact habitat features/complexity. Minor impact to rocky reef communities in RCAs due to size and weight of traps. Uncertainty moderate due to lack of studies specifically examining this.
Substrate disturbance (sediment resuspension)	2	3	Justification adapted from HS/QCS MPA Level 2 ERAF. Substrates are disturbed during demersal trap operations. Sediments can be re-suspended into the water column creating sediment plumes which can travel large distances from the initial disturbance site, depending on the currents and sediment particle size (Auster 1998; Leys 2013). However, due to the small size of prawn traps, the plume size is expected to be more restricted. Rocky reefs are in the target area of this fishery. Sedimentation can affect marine invertebrates inhabiting reefs through smothering, changes in behaviour, food limitation, reduced growth rates, recruitment and fertilization success, it can also affect early life stages by reducing larval survival and settlement and increasing abnormal larval development and mortality. However, studies on crabs indicate that they can frequently be unaffected by increases in sedimentation and are able to move away from affected areas (Gibbs 2004). Due to lack of information on the amount and movement of sediment suspended from trap operations in RCAs, precautionary scoring indicating minor impacts. This is justified by the high number of RCAs this fishery occurs in annually, the number of individual traps, and the proximity to rocky reefs.
Introductions (AIS)	3	4	Justification adapted from HS/QCS MPA Level 2 ERAF. Traps have crevices that could transport invasive species but this has been little studied. Perhaps the closest example is

Stressor	Consequence	Uncertainty	Justifications
			the movement of Green Crab megalopae and juveniles via clam bags left beach and then transported elsewhere (*pers. comm*. A. Dunham, DFO). It may be possible that a mobile AIS, or fragments of sessile invasive species such as ascidians could be transported on traps from infested areas previously fished. This would depend where traps were deployed previously and cleaning procedures, for which we have no information. This is a potential stressor and is scored using the precautionary approach.
Crab by trap			
Substrate disturbance (crushing)	2	3	Concerns about bottom impacts from crab trapping echo concerns from the commercial prawn trapping assessment. However, unlike prawn trapping, crab traps are typically deployed in subprime rockfish habitat (sandy or muddy substrates) preferred by Dungeness Crab (Harding and Reynolds 2014). However, commercial fishers deploy ~25-50 traps per buoy and it is very difficult to determine exactly where each trap lands within a particular area. Thus, although fishers may be targeting sandy and muddy substrates, some traps may drift into rocky areas and contact sessile organisms. A study of bottom contact lobster traps in the Florida Keys, USA showed that traps dragged up to 3.6 m during wind events exceeding 15 knots for more than two days (Lewis 2009). They also found this dragging reduced sessile organism coverage by up to 41%. These results are not directly comparable to BC crab trapping due to different gear, habitat, and depth. However, they do highlight the ability of bottom contact surface buoyed fishing gear to drag and damage habitat during “soak times”. Minor impacts to rocky reef communities in RCAs. Uncertainty moderate due to lack of studies specifically examining this.
Substrate disturbance (sediment resuspension)	2	3	Justification adapted from HS/QCS MPA Level 2 ERAF. Substrates are disturbed during demersal trap operations. Sediments can be re-suspended into the water column creating sediment plumes which can travel large distances from the initial disturbance site, depending on the currents and sediment particle size (Auster 1998; Leys 2013). Sedimentation can affect marine invertebrates inhabiting reefs through smothering, changes in behaviour, food limitation, reduced growth rates, recruitment and fertilization

Stressor	Consequence	Uncertainty	Justifications
			success, it can also affect early life stages by reducing larval survival and settlement and increasing abnormal larval development and mortality. However, studies on crabs indicate that they can frequently be unaffected by increases in sedimentation and are able to move away from affected areas (Gibbs 2004). Due to lack of information on the amount and movement of sediment suspended from trap operations in RCAs, precautionary scoring indicating moderate impacts (Maximum impact that still meets an objective (e.g. sustainable level of impact such as a full exploitation rate for a target species; maintaining levels of critical habitat).
Introductions (AIS)	3	4	Justification adapted from HS/QCS MPA Level 2 ERAF. Traps have crevices that could transport invasive species but this has been little studied. Perhaps the closest example is the movement of Green Crab megalopae and juveniles via clam bags left beach and then transported elsewhere (*pers. comm.* A. Dunham, DFO). It may be possible that a mobile AIS, or fragments of sessile invasive species such as ascidians could be transported on traps from infested areas previously fished. This would depend where traps were deployed previously and cleaning procedures, for which we have no information. This is a potential stressor and is scored using the precautionary approach.
Groundfish by mid-water trawl			
Substrate disturbance (sediment resuspension)	1	3	Damage to rockfish habitat in RCAs from mid-water trawl bottom contact is unknown. However, bottom contact is known to occur from mid-water trawl gear (Donaldson et al. 2010; Morgan and Chuenpagdee 2003; Zbicz and Short 2007). This stressor could impact rocky reefs if a large amount of sediment is resuspended by trawling close to the seabed in areas around rocky reefs. Sediment can affect marine invertebrates through smothering, changes in behaviour, food limitation, reduced growth rates, recruitment and fertilization success, it can also affect early life stages by reducing larval survival and settlement and increasing abnormal larval development and mortality. However, because this fishery avoids benthic contact, impact expected to be negligible. Uncertainties due to

Stressor	Consequence	Uncertainty	Justifications
			lack of knowledge on the frequency with which these trawls touch bottom, the impacts when they do and the amount of sediment suspended.
Substrate disturbance (crushing)	1	3	Damage to rockfish habitat in RCAs from mid-water trawl bottom contact is unknown. There are no data on the impact of mid-water trawls when the gear contacts the sea floor during Canadian fisheries (Fuller et al. 2008). However, direct impact between gear and rocky reefs could result in crushing of sensitive benthic communities on rocky reefs in RCAs. Due to the spatial and temporal scale of this activity, it is possible that minor impacts may occur to rocky reef communities of RCAs. High uncertainty due to a lack of information about exposure terms of this activity and studies of impacts on rocky reefs. The Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs MPA ERAF found that mid-water trawl gear can contact the bottom during fishing. When bottom contact does occur, the effect on habitats is similar to bottom trawling (Hannah et al. 2019). Mid-water trawling was identified as the third greatest human stressor to glass sponge reefs, sponge species, and motile indicator species (i.e. Squat Lobster and Boccaccio Rockfish) after vessel activities like oil spills and bottom trawling (Hannah et al. in press). Mid-water trawls can have significant active effects on benthic habitats as they, or parts of the gear, contacts the bottom. These effects are localized and less than that caused by active bottom gear, but could be significant if applied to patchy or sensitive habitats (Donaldson et al. 2010). Occasional contact with the sea floor can damage fragile ecosystems such as those containing corals and sponges, however, the problem has been little studied (Morgan and Chuenpagdee 2003; Zbicz and Short 2007). However, because this fishery avoids benthic contact, impact expected to be negligible. Uncertainties due to lack of knowledge on the frequency with which these trawls touch bottom, the impacts when they do and the amount of sediment suspended.

Stressor	Consequence	Uncertainty	Justifications
Introductions (AIS)	3	4	Justification adapted from HS/QCS MPA Level 2 ERAF. An AIS could potentially be introduced to rocky reefs in the RCAs via trawling. Fishing is typically a secondary anthropogenic vector which can move non-native species to new locations (from a previously fished area that is infested) through fishing gear (Ojaveer et al. 2014), for example the spread of the invasive alga (*Caulerpa taxifolia*) has been linked to transportation of fragments on bottom trawling gear (Relini 2000). Similar data was not found related to mid-water trawl. It is not known whether the vessels fishing in RCAs may have previously fished in infested areas. The non-native ascidian *Didemnum vexillum*, which has colonized at least 230 km^2 of pebble gravel habitat since it was introduced to east coast fishing grounds (Lengyel 2013; Valentine et. al. 2007). Its spread has been reasonably linked to trawl gear (pers. comm. I. Davidson, Smithsonian Institute). The invasion of *D. vexillum* has had significant impacts on the benthic community of Georges Bank, where it overgrows the benthos and sessile organisms. Its ability to colonize a wide variety of substrates and to reproduce through both sexually and asexually (Lengyel 2013) contributes to a potential for rapid expansion. There is the possibility of introduction and establishment of AIS, though at present none have been recorded in RCAs. This is a potential stressor and is scored using the precautionary approach.
Smelt by gillnet			
Substrate disturbance (sediment resuspension)	1	3	This fishery occurs in shallow, cobble, and gravel habitats near shore. Resuspended sediments from these areas could be transported to rocky reef areas, but is expected to have a negligible impact on the RCA rocky reef communities.
Dual-FSC Groundfish fishing			

Stressor	Consequence	Uncertainty	Justifications
Substrate disturbance (sediment resuspension)	2	3	Sediment plumes generated may travel large distances from the initial disturbance site, depending on the currents, plume size and particle size of the sediment (Auster 1998; Leys 2013). Elevated levels of sediment (over background levels) may harm benthic communities through sub lethal effects, compromising well-being and survival. There is data on groundfish dual fishing within RCAs from Electronic Monitoring. Dual fishing hook and line trips are subject to audits to verify logbook accuracy via video analysis and dockside monitoring programs are in place. However, DFO's capacity to conduct thorough assessments of all dual fishing trips is limited. Uncertainty is moderate due to lack of knowledge of effects and sediment produced by this activity.
Finfish aquaculture			
Introductions (nutrients/biological material)	1	1	Biological material includes biochemical oxygen demanding (BOD) matter: fecal material coming from fish, dead fish, and blood generated from harvest. The majority of measureable effects are contained to within 125 from the cage edge, although sometimes traces of impacts can be found up to 250 m away if sites have very high bottom currents or other unique conditions (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, pers. comm., January 2019). Some older studies have found trace effects at distances of 900 m (Kutti et al. 2007), but such results may not reflect current practices. The aquaculture management framework attempts to constrain impacts within those boundaries (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, pers. comm., March 2018). Typically, sites are located at depths of 80-120 m. The effects of aquaculture on rocky reefs, which can overlap with the 80-120 m depth range, are unknown. Finfish sites can be located on any kind of substrate, including rocky cliff faces. Some older studies have found trace effects at distances of 900 m (Kutti et al. 2007), but such results may not reflect current practices. The enrichment and possible small scale smothering by biological material could result in long term fitness effects. Due to the spatial overlap with few RCAs and the wide range of environments where this activity can occur, negligible impacts on rocky reefs in RCAs is expected.

Stressor	Consequence	Uncertainty	Justifications
Introductions (AIS)	2	2	The nutrient enrichment from this activity could result in habitat degradation and unnatural concentrations of species that could impact the sensitive communities associated with rocky reefs. If an AIS (e.g. tunicates) is introduced the impact on the rocky reef habitat could be moderate-high. However, due to the low spatial overlap between this activity and the SEC, minor impacts would be anticipated to the overall area of rocky reefs within RCAs. Uncertainty low/moderate. No historical incidences of AIS at finfish farms have been identified in the past. Flagged as a potential risk, rather than current snap-shot risk.
Contaminants	2	2	Contaminants associated with finfish aquaculture that could potentially harm the marine environment include hydrocarbons and lubricants, disinfectants, formic acid, metals (antifoulants and feed), and drugs/medications. Management measures exist for all of these contaminants to reduce potential exposure and consequence, although accidental spills may occur and some contaminants may negatively impact the environment. Due to the invertebrate and algal component of this habitat type, impacts on rocky reefs under or adjacent to finfish aquaculture sites expected to be moderate. However, on the scale of rocky reefs across all RCAs, the low spatial overlap between this SEC and stressor results in a minor impact. Uncertainty low/moderate.
Shellfish aquaculture			
Introductions (nutrients/biological material)	1	3	Most shellfish facilities do not add additional nutrients to the surrounding area since most shellfish filter-feed from the natural environment. However, enrichment does occur, which may have a negative impact on some marine life. Negligible impacts expected on rocky reefs in RCAs.
Introductions (AIS)	3	3	There are no documented cases of AIS from outside of BC in shellfish aquaculture areas. However, due to the year-round presence of these structures and the potential for nutrient input (although not common) and the associated habitat degradation, this could result in an unnatural concentration of organisms around these areas, which may impact this SEC. If AIS becomes introduced (e.g. tunicates, green crab) there is potential for major impacts

Stressor	Consequence	Uncertainty	Justifications
			to benthic habitats such as rocky reefs. Uncertainty moderate, as occurrence cannot be known.
Contaminants	2	2	Contaminants used in marine shellfish aquaculture include hydrocarbons and lubricants, wood treatment products, plastics, Styrofoam, and general chemicals used where humans live and work. The quantities and potential exposure to hydrocarbons and lubricants is expected to be lower than that for finfish aquaculture. Effects on invertebrate communities of rocky reefs minimal as target species of these sites are also invertebrates. Uncertainty low/mod.
Substrate disturbance (sediment resuspension)	1	2	Sediment resuspension occurs at shellfish aquaculture sites, however, the volumes are unknown. Due to the nature of shellfish operations and the potential low spatial overlap with RCAs, impact is expected to be negligible.
Invasive (bottom long-line) fishery surveys			
Substrate disturbance (crushing)	1	2	Extractive sampling injures and kills fish (e.g. long line fishing gear) and/or damages habitat such as rocky reefs. Limited extractive scientific sampling is currently permitted in RCAs (e.g. no trawl surveys, Outside Hard Bottom Longline (PHMC) surveys, Inside Hard Bottom Longline surveys; D. Haggarty, DFO, Pacific Biological Station, Nanaimo, *pers. comm*., Feb 2018). Impacts expected to be negligible to rocky reefs in RCAs due to load and overlap with few RCAs.
Substrate disturbance (sediment resuspension)	1	2	Sediment resuspended during this activity could result in smothering of rocky reef species or reduced fitness. However, it is unlikely that this would occur in volumes large enough to have more than a negligible impact on rocky reefs in RCAs.

Stressor	Consequence	Uncertainty	Justifications
Discharge			
Introductions (AIS)	3	4	Justifications adapted from HS/QCS MPA Level 2 MPA. Commercial shipping is recognized as a major vector for the spread of marine species (Davidson and Simkanin 2012). Invasive species introduced via discharge (dislodged vessel fouling) and established would be more likely to be chronic in nature. Invasive tunicates are an example of AIS that could impact rocky reef communities. For benthic invertebrates, chronic effects from invasive species could originate from the introduction of a competitor or a predator (unlikely to be introduced via this vector), or from a species that can impact the ability of the population to use the rocky reef habitat. Could have wider and longer-term impacts.
Substrate disturbance (crushing)	1	2	Justifications adapted from HS/QCS MPA Level 2 MPA. Solid debris discharged by vessels (e.g. deck debris, litter) could kill sessile benthic organisms of rocky reefs by directly crushing them during impact with the seafloor. Based on the expected small and infrequent amounts of solid debris discharged by vessels and reaching RCAs to crush this SEC, this stressor would be expected to affect only a negligible proportion of the population of this SEC.
Substrate disturbance (sediment resuspension)	1	4	Justifications adapted from HS/QCS MPA Level 2 MPA. In areas with unconsolidated sediments, the pressure wave from heavy sinking debris arriving at the seabed can cause a crater and a cloud of sediment (Wachsmann 2011). Sediment can be transported on currents exposing a larger area than the initial site of disturbance (Boutillier et al. 2013). Sediment re-suspension would be short term and produced only upon initial settlement of the solid debris on the seabed as debris would be unlikely to move around (due to limited influence of storms, waves, surges and strong currents etc.). In a worst case scenario (e.g. a shipping container from a cargo vessel) the cloud of sediment from large debris could cause some mortality to the population of reefs by smothering. However, based on the assumed small and infrequent discharges of solid debris from vessels, it is expected

Stressor	Consequence	Uncertainty	Justifications
			that re-suspension from discharged vessel debris would result in only a negligible impact on rocky reefs in RCAs.
Contaminants	2	3	Justifications adapted from HS/QCS MPA Level 2 MPA. Polycyclic aromatic hydrocarbons (PAHs), even in low concentrations, can have a deleterious effect on marine biota (National Research Council 2003). Chronic releases of oil and contaminants by vessels not expected to cause immediate mortality to rocky reefs in RCAs. Examples of general sublethal effects from exposure to petroleum hydrocarbons include: impairment of feeding mechanisms, growth rates, development rates, energetics, reproductive output, recruitment rates and increased susceptibility to disease (Capuzzo 1987). It is expected that chronic oil/contaminant discharges may result in minor impacts to rocky reefs in RCAs.
Introductions (nutrients/biological material)	1	3	Justifications adapted from HS/QCS MPA Level 2 MPA. The enrichment and possible small scale smothering by biological material could result in long term fitness effects. The expected low levels of black water discharges from vessels transiting RCAs suggest this stressor would have only negligible impacts on RCA rocky reefs.
Movement underway			
Substrate disturbance (sediment resuspension)	2	4	Sediment resuspended from vessel movements in RCAs could have minor effects (through smothering, reduced fitness) on rocky reef communities. Uncertainty high due to lack of data relating specifically to this stressor and rocky reefs in RCAs.
Oil spill			

Stressor	Consequence	Uncertainty	Justifications
Oil	4	4	Justifications adapted from HS/QCS MPA Level 2 MPA. A catastrophic oil spill from a vessel accident could result in a large loss in area of the rocky reef habitat through smothering and contamination. This benthic community could be exposed to a surface origin oil spill in a few ways: (i) Mixing during rough seas - lighter oil components mix the easiest, and are often the most toxic types of oil; (ii) Weathering or mixing of heavy oils with sediment, increasing oil density causing it to sink; (iii) The use of oil dispersants on a spill can cause oil to sink; (iv)The use of dense oil forms during transport, such as diluted bitumen (proposed for this area) and other oils with a specific gravity greater than 1.0 which may be neutrally buoyant or sink when spilled on water, or incorporation of sediments with oils (e.g. from river plumes) can make bitumen/oil more dense (*pers. comm.* DFO, K. Conway). It is also possible that a subsurface catastrophic oil spill could occur from a damaged vessel as it sinks, or upon impact with the seabed, which can crack the hull (Wachsmann 2011), releasing oil at depth. Stressor scored based on a large-scale spill.
Outfalls			
Introductions (nutrients/biological material)	1	3	The biological component/nutrients from outfalls would likely have a negligible impact on the rocky reefs of RCAs. Positive interactions not included in the scoring.
Contaminants	3	4	Effluent dilution rates and plume areas are highly variable based on outfall design and local environmental conditions. However, due to the mobile nature of effluent, assessing only outfalls inside RCAs might underestimate potential effects of effluent outfalls in very close proximity to RCAs. A study of wastewater outfalls in southern California found that outfall plumes covered approximately16 km^2 (DiGiacomo et al. 2004). The effects of effluent on marine habitats are highly variable depending upon the type of effluent (e.g. sewage, pulp mill, oil processing), the amount of effluent being discharged, and the environment around the outfall. Municipal sewage effluent can cause eutrophication and changes to community assemblages in marine environments (Costanzo et al. 2001,

Stressor	Consequence	Uncertainty	Justifications
			Hindell et al. 2000). While nutrient input from sewage outfalls can increase food availability, which might benefit marine organisms directly and indirectly, they can also create anoxic zones (Hindell et al. 2000). Sewage effluent can introduce pollutants into marine systems with a variety of potential effects. Pulp mill and oil processing effluent can also affect marine environments through the introduction of toxic chemicals (Yanko et al. 1999). Could have a moderate impact on RCA rocky reefs (particularly due to the high exposure of this stressor).
Existing coastal infrastructure			
Contaminants	2	3	Contaminants associated with infrastructure include antifouling agents, which sensitive benthic organisms are particularly susceptible to. Contaminants associated with the vessels that use this infrastructure are included in vessel discharge and not included here. Precautionary scoring - could have a minor impact on rocky reefs in RCAs.
Introductions (AIS)	3	3	Potential for AIS to become established as a result of coastal infrastructure (Iacella et al. 2018). Evidence of this occurring in BC (Iacella et al. 2018). This could impact rocky reef communities (particularly invertebrates’ communities from non-indigenous species, e.g. tunicates). Could have a moderate impact on rocky reef community, uncertainty mod, reflecting AIS as a potential stressor.

F.3. PREY

Table F.3.1: Overview of consequence scores for inshore rockfish prey SEC by activity. Inshore Rockfish prey include a range of species and sizes. Consequence scoring is based on the prey species impacted by the stressor. Where multiple prey species are being impacted by a single stressor, scoring is based on the most sensitive species. Consequence scoring is in part informed by terms of Exposure (specifically Load).

Activity	Stressor	Consequence	Uncertainty
Coastal_infrastructure	Contaminants	1	3
Coastal_infrastructure	Introductions_AIS	3	3
Coastal_infrastructure	Introductions_foreign_material	1	2
Crab_by_trap	Entrapment_entanglement	2	2
Crab_by_trap	Introductions_AIS	2	4
Crab_by_trap	Removal_of_biological_material	1	2
Crab_by_trap	Substrate_disturbance_sediment_resuspension	1	3
Dual_FSC_groundfish_hook_and_line	Entrapment_entanglement	1	3
Dual_FSC_groundfish_hook_and_line	Removal_of_biological_material	1	3
Dual_FSC_groundfish_hook_and_line	Substrate_disturbance_sediment_resuspension	1	3
Euphausiid_by_midwater_trawl	Introductions_AIS	2	4
Euphausiid_by_midwater_trawl	Removal_of_biological_material	2	3
Finfish_aquaculture	Contaminants	2	2
Finfish_aquaculture	Introductions_nutrients_biological_material	1	2
Finfish_aquaculture	Removal_of_biological_material	1	2

Activity	Stressor	Consequence	Uncertainty
Groundfish_by_midwater_trawl	Entrapment_entanglement	1	3
Groundfish_by_midwater_trawl	Introductions_AIS	2	4
Groundfish_by_midwater_trawl	Removal_of_biological_material	2	3
Groundfish_by_midwater_trawl	Substrate_disturbance_sediment_resuspension	1	3
Herring_by_gillnet	Entrapment_entanglement	1	3
Herring_by_gillnet	Removal_of_biological_material	2	4
Herring_seine_net	Entrapment_entanglement	1	4
Herring_seine_net	Removal_of_biological_material	2	3
Herring_spawn_on_kelp	Removal_of_biological_material	2	4
Invasive_bottom_long_line_fishery_survey	Removal_of_biological_material	1	2
Invasive_bottom_long_line_fishery_survey	Substrate_disturbance_sediment_resuspension	1	2
Movement_and_storage_of_logs	Contaminants	2	3
Movement_and_storage_of_logs	Substrate_disturbance_sediment_resuspension	1	2
Outfalls	Contaminants	2	4
Outfalls	Introductions_nutrients_biological_material	1	3
Prawn_and_shrimp_by_trap	Entrapment_entanglement	1	2
Prawn_and_shrimp_by_trap	Introductions_AIS	1	4
Prawn_and_shrimp_by_trap	Removal_of_biological_material	3	2

Activity	Stressor	Consequence	Uncertainty
Prawn_and_shrimp_by_trap	Substrate_disturbance_sediment_resuspension	1	2
Salmon_by_gillnet	Entrapment_entanglement	1	3
Salmon_by_gillnet	Removal_of_biological_material	1	3
Salmon_by_seine_net	Entrapment_entanglement	1	4
Salmon_by_seine_net	Removal_of_biological_material	1	3
Scallop_by_trawl	Entrapment_entanglement	1	3
Scallop_by_trawl	Introductions_AIS	1	4
Scallop_by_trawl	Removal_of_biological_material	1	2
Scallop_by_trawl	Substrate_disturbance_sediment_resuspension	1	2
Shellfish_aquaculture	Contaminants	2	2
Shellfish_aquaculture	Introductions_nutrients_biological_material	1	2
Shellfish_aquaculture	Substrate_disturbance_sediment_resuspension	1	2
Smelt_by_gillnet_recreational	Entrapment_entanglement	1	4
Smelt_by_gillnet_recreational	Removal_of_biological_material	2	3
Smelt_by_gillnet_recreational	Substrate_disturbance_sediment_resuspension	1	2
Vessels_discharge	Contaminants	2	4
Vessels_discharge	Introductions_AIS	2	4
Vessels_discharge	Substrate_disturbance_sediment_resuspension	1	2

Activity	Stressor	Consequence	Uncertainty
Vessels_movement_underway	Noise_disturbance	1	2
Vessels_movement_underway	Substrate_disturbance_sediment_resuspension	1	3
Vessels_oil_spill	Oil	4	3

Table F.3.2: Consequence scores and justifications for inshore rockfish prey SEC by activity.

Stressor	Consequence	Uncertainty	Justification
Prawn and shrimp trapping			
Removal of biological material	3	2	The direct removal of rockfish prey in prawn and shrimp traps is a documented occurrence. The target species is Spot Prawn (*Pandalus platyceros*), with a small incidental catch of other shrimp species and small commercial fisheries directed at Coonstripe Shrimp (*P. danae*) and Humpback Shrimp (*P. hypsinotus*). There are 246 commercial licences. The commercial fishery is managed by seasonal closures, in-season area closures, gear limits, gear marking requirements, trap mesh size requirements, minimum size limits, daily fishing time restrictions, and a daily single haul limit. The commercial prawn fishery is generally open for less than two months in spring - early summer. The directed Humpback Shrimp and Coonstripe Shrimp fisheries take place in Prince Rupert and Sooke, respectively, in the fall to the end of December (DFO 2018D) but there are no RCAs in these areas. From 2007 to 2017, on average about 17% of commercial prawn trap fishing representing 8,675 strings (9,940 days) occurred in RCAs annually. Prawn stocks are managed and assessed based on an escapement-based model (Boutillier and Bond 2000; Rutherford et al. 2004). Mesh size requirements allow undersize prawns to escape (Boutiller and Sloan (1991). Most non-target species are easily sorted and quickly returned to the water, resulting in presumed low mortality (Rutherford et al. 2010). Moderate impact on rockfish prey species (both as target and bycatch). Uncertainty = low/mod

Stressor	Consequence	Uncertainty	Justification
Entrapment/ entanglement	1	2	Lost trap gear can continue to catch and kill marine species until they become disabled by disintegration of escape (rot) cord, or lose their structural integrity (NRC 2008). There is no information available on annual commercial prawn trap losses in BC. However, commercial trap losses are common in the Dungeness Crab trap fishery and lost prawn traps have been located with submersibles in BC (Breen 1989). Replacement tags issued for lost traps are <1% of the annual trap hauls (Fisheries and Oceans Canada, Pacific Region, unpublished data, 2019). In Puget Sound, prawn trap loss from commercial sectors is believed to be very low (<0.1% of traps fished). The overall estimated density of derelict prawn traps was 14 traps per square kilometer in an average depth of 59 m (Antonelis et al. 2018). The commercial fishery is required to use side wall rot cord to facilitate escapements in the case of ghost fishing. Traps have escape tunnels also that do not rely on disintegration of rot cord or loss of structural integrity. Mesh size requirements allow undersize prawns to escape (Boutiller and Sloan 1991) and prawns leave traps as bait is used up. Catch rates of prawns decrease significantly for longer soak schedules greater than 6 hours (Boutillier 1986; Boutillier 1988). There is minimal diversity of bycatch (Rutherford et al. 2010). The majority of traps used in the prawn and shrimp trap fishery are mesh traps (DFO 2018D). The requirement for prawn and shrimp traps is 30 cm in length #30 untreated cotton twine in the side wall (DFO 2018D), such that on deterioration or parting produces an unrestricted opening. Deterioration of the twine allows the mesh to gape and fall (horizontal opening) open, i.e. immediately. Bycatch, small enough to have entered the trap through the tunnel and not yet found the way back out through the tunnel will be small enough to escape through the gape in the mesh that is larger than the entrance tunnel (L. Convey, DFO, *pers. comm.,* Jan 2019). This stressor includes impacts on both target (negligible impact) and bycatch. The use of rot cord and the low density of derelict traps is expected to have an insignificant impact on the prey species (in this case, prawns and shrimp) within RCAs. Non-target species are easily sorted and quickly returned to the water (Rutherford et al. 2010). Uncertainty low/mod
Substrate disturbance (sediment resuspension)	1	2	From 2007 to 2017, on average about 17% of commercial prawn trap fishing representing 8,675 strings (9,940 days) occurred in RCAs annually. Trap fishing causes temporary resuspension of bottom sediment. It is expected that sediment re-suspension in RCAs would not be sufficient to result in mortality in the rockfish prey population, which are mobile species

Stressor	Consequence	Uncertainty	Justification
			and able to move away from this stressor. This stressor is considered short term. There are no documented cases of acute impacts to rockfish prey from sediment re-suspension from traps.
Introductions (AIS)	1	4	Justification adapted from HS/QCS MPA Level 2 ERAF. Traps have crevices that could transport invasive species, but there is a lack of studies on transportation of AIS this way. It is unlikely that a trap could transport an invasive species that could impact the rockfish prey population directly (i.e. through predation). Precautionary scoring as negligible impact based on the incidence and type of AIS cannot be known and therefore the unknown impacts on rockfish prey. High uncertainty reflects this precautionary scoring.
Crab by trap			
Removal of biological material	1	2	Dungeness Crab (*Cancer magister*), and three other crab species (Red Rock (*Cancer productus*), Red King (*Paralithodes camtschatic*) and Golden King (*Lithodes aequispinus*)), are harvested with baited traps coast-wide in BC in the commercial fishery. According to logbook data, 17,000 commercial crab fishing events occurred in 103 RCAs (63%) between 2007 and 2017, and total fishing effort was 5,681,118 trap days. Inside waters had, by far, the greatest commercial crab trap effort in RCAs (5,047,031 trap days). Rockfish consume small juvenile crabs of many species including Red Rock Crab during their larval and post-larval stages (Murie 1995). Target of this fishery are crab too large to be rockfish prey. Negligible impact on rockfish prey in RCAs.

Stressor	Consequence	Uncertainty	Justification
Entrapment/ entanglement	2	2	Coastwide, 35,857 commercial crab traps were recorded lost in commercial logbooks between 2000-2014 (L. Barton, pers. comm., Feb 2018). A 1987 report found 11% of crab traps from the Dungeness Crab fishery were lost each year in the Fraser River Estuary with the ability to ghost fish ~7% of annual commercial hauls (Breen 1987). Target crab size is generally too large to be prey for rockfish, but trap bait or other bycatch may attract other prey species. The commercial fishery is now required to use rot cord to facilitate escapements in the case of lost traps. A study of the Dungeness Crab fishery in the USA found that rot cord is expected to take 90-130 days to disintegrate but often takes much longer (up to 2.5 years in Washington and over 6 years in Alaskan fisheries) (Arthur et al. 2014). Marine growth and metal fatigue often inhibit escape panels from opening (Arthur et al. 2014). Minor impact on rockfish prey population anticipated.
Substrate disturbance (sediment resuspension)	1	3	Trap fishing causes temporary resuspension of bottom sediment. It is expected that sediment re-suspension in RCAs would not be sufficient to result in mortality in the rockfish prey population, which are mobile species able to move away from this stressor. This stressor is a short-term stressor. There are no documented cases of acute impacts to rockfish prey from sediment re-suspension from traps. Negligible impacts on RCA rockfish prey populations. Uncertainty moderate due to lack of information specific to the fishery and rockfish prey.
Introductions (AIS)	2	4	Justification adapted from HS/QCS MPA Level 2 ERAF. Traps have crevices that could transport invasive species, but there is a lack of studies on transportation of AIS this way. It is not expected that traps would transport an invasive species that could impact the rockfish prey population (i.e. through predation or competition). It is expected that there are minor effects to the rockfish prey population through impacts such as competition or predation. Precautionary scoring based on unpredictable nature of the stressor and unknown impacts on rockfish prey population. High uncertainty reflects this precautionary scoring.

Stressor	Consequence	Uncertainty	Justification
Groundfish by mid-water trawl			
Substrate disturbance (sediment resuspension)	2	3	Justification adapted from HS/QCS MPA Level 2 ERAF. Mid-water trawls can touch bottom (Donaldson et al. 2010; Chuenpagdee et al. 2003) where they can temporarily resuspend bottom sediment as in a bottom trawl (Leys 2013). However, it is not expected that there will be sufficient sediment suspended to cause a change in population size of mobile prey species. Scored low uncertainty due to lack of knowledge on the degree of bottom interaction of this fishery in this area and amounts of sediment suspended.
Removal of biological material	2	3	There are no data on the impact of mid-water trawls when the gear contacts the sea floor during Canadian fisheries (Fuller et al. 2008; Donaldson et al. 2010). Prey species could be removed as both target and bycatch. Mid-water trawls are thought to have low bycatch percentages, but the actual numbers of individuals can be quite high (Morgan and Chuenpagdee 2003). Donaldson et al. (2010) highlighted the example: "the discard rate for the Pacific hake fishery (the largest fishery on the B.C. coast) is reported to be just 1%; however, this small percentage represents 900 tonnes of marine organisms discarded every year (Picco et al. 2008)".
Entrapment/ entanglement	1	3	Justifications adapted from HS-QCS MPA Level 2 ERAF. No information included in this assessment on incidents of gear loss for mid-water trawl. Lost mid-water trawl gear can cause seafloor damage if it sinks as a result of encrusting organisms and dying animals (Morgan and Chuenpagdee 2003). Death of trapped organisms from entanglement in derelict mid-water trawl gear could occur quickly from injury or predation and entangled fish may die from predation, starvation, and suffocation (Laist 1997). It is not known what the incidence of lost gear is but would be expected to be low and lost gear is likely to be speedily recovered as it is expensive (*pers. obs.* L. Yamanaka, DFO). Unlikely that enough gear would be lost to have a population scale impact. High uncertainty related to availability of information.

Stressor	Consequence	Uncertainty	Justification
Introductions (AIS)	2	4	Justification adapted from HS/QCS MPA Level 2 ERAF. It is not expected that trawl gear would transport an invasive species that could impact the rockfish prey population (i.e. through predation or competition). It is expected that there are minor effects to the rockfish prey population through impacts such as competition or predation (predation of crustaceans, etc.). Precautionary scoring based on unpredictable nature of the stressor and unknown impacts on rockfish population. Moderate/high uncertainty reflects this precautionary scoring.
Scallops by trawl			
Removal of biological material	1	2	The slow towing speed of scallop butterfly trawl nets (0.5 to 0.7 knots) allows most mobile organisms to avoid capture (DFO 2018F). This type of net is designed to remain approximately 20 cm off the bottom to catch swimming scallops, although occasional net contact can occur. This stressor is expected to have a negligible impact on RCA rockfish prey populations (precautionary scoring).
Entrapment/ entanglement	1	3	Death of trapped organisms from entanglement in derelict trawl gear could occur quickly from injury or predation and entangled organisms may die from predation, starvation, and suffocation (Laist 1997). Between 10 and 121 tows per year RCAs. Effort in all but two years since 2007; occurs in 2 RCAs (1%). This stressor likely has a negligible impact on the RCA rockfish population. Uncertainty due to lack of information on gear loss and impacts on the RCA rockfish prey population.

Stressor	Consequence	Uncertainty	Justification
Substrate disturbance (sediment resuspension)	1	2	This net is designed to remain ~20 cm off the bottom to catch swimming scallops, although occasional net contact can occur. This fishery is considered a bottom contact fishery as the net sits on several steel runners that roll across the bottom during tows. Bottom contact can temporarily resuspend bottom sediment. Elevated levels of sediment (over background levels) may harm fish and other prey organisms through sublethal effects, compromising well-being and survival (Birtwell 1999). However, it is not expected that there will be sufficient sediment suspended to cause a change in population size of mobile prey rockfish. Scored low with uncertainty due to lack of knowledge on the degree of bottom interaction of this fishery in this area and amounts of sediment suspended.
Introductions (AIS)	1	4	Justification adapted from HS/QCS MPA Level 2 ERAF. It is not expected that trawl gear would transport an invasive species that could impact the rockfish prey populations (i.e. through predation or competition). However, this stressor is scored using a precautionary approach due to the limited information available for this stressor. Scored as having a negligible impact on population/ habitat/ community structure or dynamics with high uncertainty.
Salmon by seine			
Removal of biological material	1	3	Prey species may be incidentally caught even when nets do not contact bottom habitats and accidental bottom contact does occur. Negligible impact on rockfish prey species anticipated. Mod uncertainty
Entrapment/ entanglement	1	4	It is expected that ghost fishing would have a negligible impact on the RCA rockfish prey population, but mod/high uncertainty reflects a lack of information about lost seine nets
Salmon by gillnet			

Stressor	Consequence	Uncertainty	Justification
Removal of biological material	1	3	It is expected that this fishery has a negligible impact on the RCA rockfish prey population. Specific reporting data on this fishery reduces the uncertainty.
Entrapment/ entanglement	1	3	The extent of lost fishing nets is unknown, but lost nets have been retrieved off rocky habitats in Area 24 with entangled rockfish prey species to feed on other entangled dead fish. These nets will continue to ghost fish until they are removed or degrade, which may take years. Fishery notices encourage fishers to report lost fishing gear to area managers or charter patrol (G. Hornby, DFO, Fisheries and Oceans Field Office, Campbell River, *pers. comm.*, March 2018) – but is not mandatory. This stressor is expected to have a negligible impact on the RCA rockfish prey community.
Herring seine net			
Removal of biological material	2	3	Scored based on direct removal of herring as a target. There is no location specific logbook information for this fishery to assess fishing effort inside RCAs. Vessels fish in deep water only and avoid bottom contact to prevent gear entanglement (B. Spence, *pers. comm*., Feb 2018). Moderate impact on RCA rockfish prey population
Entrapment/ entanglement	1	4	Ghost fishing is not considered a major concern in the fishery. However, rockfish prey could be impacted by lost gear. Negligible impact on the rockfish prey populations of RCAs.
Herring by gillnet			
Removal of biological material	2	4	Full extent unknown (known to overlap RCAs in Area 17 and Area 14); occurs in unknown # RCAs. Prey species are targeted in this fishery and other prey species are removed by bycatch. Stressor likely to have minor impact on the RCA rockfish prey population. Mod/High uncertainty.

Stressor	Consequence	Uncertainty	Justification
Entrapment/entanglement	1	3	Ghost fishing from lost nets is a concern in any RCA that overlaps with gillnet fishing locations. Area 17 and 14 are significant gillnet fishing locations and consultation on any proposed changes would be required (B. Spence, pers. comm., Feb 2018). Moderate uncertainty reflects lack of information.
Herring spawn-on-kelp			
Removal of biological material	2	4	The herring spawn-on-kelp fishery is permitted in RCAs; however, this fishery is highly selective and is harvested from the surface by hand with a knife (S. Groves, DFO, Fisheries and Oceans Field Office, Prince Rupert, *pers. comm*., September 2017). Although direct effects on rockfish appear to be small for Herring fisheries, juvenile herring are a major component of Inshore Rockfish diets. Effects of localized prey removals (e.g. removing herring spawn) to rockfish populations are unknown. Scored precautionary minor impacts on prey species (in this case, herring). Uncertainty linked to lack of specific data.
Euphausiid (krill) by mid-water trawl			
Removal of biological material	2	3	Plankton trawl nets only fish the upper few metres of the water column. Rockfish prey include both krill and bycatch. Due to slow towing speeds, which are a requirement for fine mesh planktonic nets, larger marine organisms generally can avoid nets during tows. Bycatch typically consists of hake, herring, and dogfish. Concerns about the removal of rockfish prey species are minimal since the krill fishery removes less than 1% of the estimated total krill biomass per year. Nevertheless, in low abundance years, localized depletions of krill could affect their availability to rockfish. Scored as minor impacts on rockfish prey in RCAs. Moderate uncertainty

Stressor	Consequence	Uncertainty	Justification
Introductions (AIS)	2	4	Justification adapted from HS/QCS MPA Level 2 ERAF. It is not expected that trawl gear would transport an invasive species that could impact the rockfish prey population (i.e. through predation or competition). Precautionary scoring based on unpredictable nature of the stressor and unknown impacts on rockfish prey population. High uncertainty reflects this precautionary scoring.
Smelt by gillnet			
Entrapment/ entanglement	1	4	Lost gear/ghost fishing frequency unknown, but presumed low. Rockfish prey species would be susceptible. Occurs in unknown number of RCAs. High uncertainty.
Substrate disturbance (sediment resuspension)	1	2	This fishery occurs in shallow, cobble, and gravel habitats near shore. Sediment resuspension from smelt gillnet fishing possible, but effects on rockfish prey unknown/undocumented. Impact unlikely to impact the population size or condition. High uncertainty.
Removal of biological material	2	3	Smelt by gillnet is permitted in RCAs. This stressor was identified as removing enough prey species to be a potential problem for rockfish (as a secondary effect). Minor impact on prey species.
Groundfish FSC dual fishing			
Entrapment/ entanglement	1	3	Amount of gear loss unknown, and impacts of ghost fishing from this fishery on rockfish prey not documented. Ghost fishing of hook and line gear expected to be very low, having a negligible impact on rockfish prey across RCAs. Moderate uncertainty.

Stressor	Consequence	Uncertainty	Justification
Substrate disturbance (sediment resuspension)	1	3	Sediment plumes generated may travel large distances from the initial disturbance site, depending on the currents, plume size and particle size of the sediment (Auster 1998, Leys 2013). Elevated levels of sediment (over background levels) may harm fish through sub lethal effects, compromising well-being and survival (Birtwell 1999). It is unlikely that with the level of activity in RCAs that this stressor would negatively impact the RCA rockfish prey population. Uncertainty is moderate due to lack of knowledge of effects and sediment produced by this activity.
Removal of biological material	1	3	NB: Scored for dual fishing hook and line only. Dual fishing hook and line trips are subject to audits to verify logbook accuracy via video analysis and dockside monitoring programs are in place. However, DFO's capacity to conduct thorough assessments of all dual fishing trips is limited. The use of commercial scale groundfish gear in RCAs could impact the ability of rockfish prey populations to rebuild within RCAs. Dual fishing documented in 32 RCAs (20%). Some First Nation groups request that their dual fishing vessels avoid fishing in RCAs. This fishery is known to catch cephalopods (prey for several species of Inshore Rockfish), but is unlikely to have more than a negligible impact on rockfish prey. Moderate uncertainty.
Finfish aquaculture			

Stressor	Consequence	Uncertainty	Justification
Introductions (nutrients/biological material)	1	2	Biological material includes biochemical oxygen demanding (BOD) matter: fecal material coming from fish, dead fish, fish feed, and blood generated from harvest. The majority of measureable effects are contained to within 125 from the cage edge, although sometimes traces of impacts can be found up to 250 m away if sites have very high bottom currents or other unique conditions (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm*., January 2019). Some older studies have found trace effects at distances of 900 m (Kutti et al. 2007), but such results may not reflect current practices. The aquaculture management framework attempts to constrain impacts within those boundaries (K. Shaw, DFO, Fisheries and Oceans Aquaculture Office, Campbell River, *pers. comm*., March 2018). The introduction of biological material from feed is not expected to have a direct negative impact on the RCA rockfish prey population. Uncertainty low/moderate.
Contaminants	2	2	Contaminants associated with finfish aquaculture that could potentially harm the marine environment include hydrocarbons and lubricants, disinfectants, formic acid, metals (antifoulants and feed), and drugs/medications. Deposition of SLICE under fish farms is a concern, as it targets invertebrates. Although research has been conducted on shrimp and prawn and direct mortality has not been observed in lab or field trials, there may be unknown sub-lethal effects on these rockfish prey species. Management measures exist for all of these contaminants to reduce potential exposure and consequence, although accidental spills may occur and some contaminants may negatively impact the environment. Minor impacts anticipated for rockfish prey populations. Uncertainty low/moderate.
Removal of biological material	1	2	Prey species could be caught as bycatch, but the impact on the rockfish prey population is expected to be negligible.
Shellfish aquaculture			

Stressor	Consequence	Uncertainty	Justification
Introductions (nutrients/biological material)	1	2	Shellfish facilities add additional nutrients to the surrounding area through the release of shells and pseudofaeces. However, since most shellfish filter-feed from the natural environment, there is often a net loss of nutrients rather than gain (*pers. comm*. K. Shaw, DFO, February 2019). The seabed enrichment that does occur may have a negative impact on some marine life, but is very dependent on type of species cultured, culture method, and site condition. Negligible impacts expected on rockfish prey in RCAs.
Contaminants	2	2	Contaminants used in marine shellfish aquaculture include hydrocarbons and lubricants, wood treatment products, plastics, Styrofoam, and general chemicals used where humans live and work. The quantities and potential exposure to hydrocarbons and lubricants is expected to be lower than that for finfish aquaculture. As plastics and styrofoam breakdown, fish may ingest these particles resulting in a reduction in fitness or death. Impact on the overall RCA rockfish prey expected to be low.
Substrate disturbance (sediment resuspension)	1	2	Sediment resuspension is rare at shellfish aquaculture sites, as the majority of culture is either raft structures with hanging product or beach culture of oyster that does not require sediment disturbance (*pers. comm.* K. Shaw, DFO, February 2019). Resuspension does occur from clam culture, which must be dug out of the sand. Due to the nature of shellfish operations and the potential low spatial overlap of soft sediment shellfish aquaculture with RCAs, impact is expected to be negligible, especially because most rockfish prey are mobile and capable of moving away from a disturbance.

Stressor	Consequence	Uncertainty	Justification
Invasive (bottom long-line) fishery surveys			
Substrate disturbance (sediment resuspension)	1	2	Extractive sampling injures and kills rockfish prey (e.g. long line fishing gear). Limited extractive scientific sampling is currently permitted in RCAs (e.g. no trawl surveys, Outside Hard Bottom Longline (PHMC) surveys, Inside Hard Bottom Longline surveys; D. Haggarty, DFO, Pacific Biological Station, Nanaimo, *pers. comm*., Feb 2018). This stressor is expected to have a negligible impact on rockfish prey in RCAs.
Removal of biological material	1	2	Effects most likely injury or mortality but numbers low and would not effect at a population level or geographic range. Has negligible impact on rockfish prey population.
Discharge			
Introductions (AIS)	2	4	It is not expected that AIS from discharge would transport an invasive species that could directly impact the rockfish prey population (i.e. through predation or competition). It is expected that there are negligible chronic effects to the rockfish population through impacts such as predation. Precautionary scoring based on unpredictable nature of the stressor and unknown impacts on rockfish prey population. High uncertainty reflects this precautionary scoring.

Stressor	Consequence	Uncertainty	Justification
Substrate disturbance (sediment resuspension)	1	2	Justifications adapted from HS/QCS MPA Level 2 ERAF. The pressure wave from heavy debris impacting the seabed can cause a crater and a cloud of sediment (Wachsmann 2011), which can be transported on currents exposing a larger area. In this case, sediment re-suspension would be short term and only expected to occur upon the initial settlement of debris to the seabed. Solid debris would be unlikely to move around due to limited influence of storms, waves, surges and strong currents etc. at that depth. Though elevated levels of sediment (over background levels) may harm fish acutely (Birtwell 1999), it is expected that sediment re-suspension from discharged vessel debris would result in negligible mortality in the rockfish population due to the infrequent point source, expected low level and short term nature of the stressor as well as the ability of the fish to move away from sediment clouds. There are no documented cases of acute impacts to this SEC from sediment re-suspension from large vessel discharged debris.

Stressor	Consequence	Uncertainty	Justification
Contaminants	2	4	Justification adapted from HS/QCS MPA Level 2 ERAF. Mobile species have the ability to move away from oil and contaminants. However, this stressor relates to low level chronic type pollution which may persist in the environment at low levels and is likely unavoidable. Examples of contaminants from vessels include POPs, PBDEs, PAHs and heavy metals, which have the potential to cause fish mortality (Debruyn et al. 2004; Terlizzi et al. 2001). Even low concentrations of Polycyclic Aromatic Hydrocarbons (PAHs) can have a deleterious effect on marine biota (National Research Council 2003). Chronic releases of oil and contaminants by vessels are expected to cause immediate mortality to a negligible proportion of the rockfish population. With repeated exposure, rockfish could accumulate chronically discharged oil/contaminants with potential for sublethal effects. General sublethal effects from exposure to petroleum hydrocarbons include: impairment of feeding mechanisms, growth rates, development rates, energetics, reproductive output, recruitment rates and increased susceptibility to disease (Capuzzo, 1987). Examples of contaminants from vessels include POPs, PBDEs, PAHs and heavy metals, which can result in sublethal effects on fish such as increased susceptibility to disease, reduced reproductive success, higher genetic mutation rates; reduced fitness for navigation/migration; reduced survival of eggs and juveniles (Debruyn et al. 2004; Terlizzi et al. 2001). Uncertainty due to lack of data on mortality effects of oil/contaminants on rockfish prey and their sensitivity to oil.
Movement underway			
Substrate disturbance (sediment resuspension)	1	3	Sediment resuspension from vessel movements is not expected to occur in volumes that would have a negative impact on the health of prey species. Impact is expected to be negligible across RCAs.

Stressor	Consequence	Uncertainty	Justification
Noise disturbance	1	2	There is no evidence that noise from vessels under way can cause immediate mortality to rockfish. Effects would be expected to be more chronic in nature. Noise from shipping is pervasive throughout the marine environment especially at low (<300Hz) frequencies, this is a chronic stressor which can have deleterious effects on fish populations (Erbe et al. 2012; Merchant et al. 2012) such as disturbance, deterrence, reduced growth and reproduction, and can interfere with predator-prey interactions, communication and schooling behaviour (Sara et al. 2007; Slabbekorn et al. 2010). Though the whole population is likely exposed to this stressor, chronic impacts on a population scale are expected to be relatively low. There is associated high uncertainty with this score due to lack of literature specific to long term chronic effects on rockfish prey in this environment.

Stressor	Consequence	Uncertainty	Justification
Oil spill			
Oil	4	3	Justification adapted from HS/QCS MPA Level 2 ERAF. How toxic a spill will be is related to the particular mix that is spilled, with more refined mixtures (e.g. the heavy fuel oil used in ships) being be more toxic that crude oils. Petroleum contaminants may enter fish through the skin or gills or through food webs, hydrocarbons taken through gills can accumulate in the liver and gall bladder and those ingested end up in the stomach (Lee et al. 1972; Teal 1977; Samiullah 1985). Most adult fish are able to detect and avoid contaminated areas unless limited in some way by behaviour or habitat. If extremely contaminated, gills of fish can become clogged, resulting in asphyxia and death, though in many cases, unless damaged by dispersants, the mucilaginous coat restricts oil adhesion (Samiullah 1985). Polycyclic aromatic hydrocarbons (PAHs) are one of the oil components for which a range of biological effects have been demonstrated including: acute toxicity (Batista et al. 2013; Yamada 2009. One study suggests that there are few long-term adverse effects on fish stocks attributed to oil, although it is stressed that short term local impacts can be extremely damaging (McIntyre 1982). In contrast, findings indicate that rockfish may be particularly affected by oil spills, as it has been well documented that demersal rockfish species were the only fish found dead in significant numbers after two major oil spills (The Amoco Cadiz spill in the English Channel in 1978 and the Exxon Valdez oil spill in Alaska in 1989) (Gundlach et al. 1983; Khan and Nag 1993; Marty et al. 2003). Based on these findings, and using the precautionary approach, a catastrophic oil spill from a vessel accident which spreads over a large area could be predicted to cause immediate mortality to a large proportion of the rockfish prey population.

Stressor	Consequence	Uncertainty	Justification
Movement and storage of logs			
Substrate disturbance (sediment resuspension)	1	2	Water-based log handling includes: log dumping, log booming, log transportation, log storage, and log sorting. Log dumps can cause serious bottom impacts and resuspend sediment. Bark and sawdust can accumulate under log dumps (up to 60 cm) and smother important juvenile and adult rockfish habitat like kelp beds and eelgrass (Van der Slagt et al. 2003). Logs can also cause bottom damage when they are dragged across the seafloor and rest on exposed intertidal flats during low tides, or when helicopters drop logs from great heights into storage areas (Levings and Northcote 2004). Rockfish are mobile and able to move away from suspended sediment. Negligible impacts to RCA rockfish prey population.
Contaminants	2	3	Log dumps can alter water quality in surrounding areas. Bark and sawdust can accumulate under log dumps (up to 60 cm) and smother habitats (Van der Slagt et al. 2003). Woody debris can create anaerobic conditions below and adjacent to log dump sites and alter ecosystem dynamics (Barker 1974). Logs stored in salt water can leach toxic acidic resin, which can contaminate the water column and substrate (Van der Slagt et al. 2003). Hemlock resin killed 50% of Pink Salmon test fish at 100–120 mg L^{-1} and Sitka Spruce was lethal at even lower levels (Buchanan et al. 1976). Key rockfish prey species like crabs and shrimp have also been shown to avoid habitats disturbed by woody debris. It takes several years for marine habitats to recover from log dump impacts and some areas never regain their original functionality (Levings and Northcote 2004). Minor impacts to rockfish prey population across RCAs.

Stressor	Consequence	Uncertainty	Justification
Outfalls			
Introductions (nutrients/biological material)	1	3	Effluent can include biological material/nutrients. Effluent dilution rates and plume areas are highly variable based on outfall design and local environmental conditions. However, due to the mobile nature of effluent, assessing only outfalls inside RCAs might underestimate potential effects of effluent outfalls in very close proximity to RCAs. A study of wastewater outfalls in southern California found that outfall plumes covered approximately16 km^2 (DiGiacomo et al. 2004). While nutrient input from sewage outfalls can increase food availability, which might benefit rockfish populations directly and indirectly, they can also create anoxic zones (Hindell et al. 2000). Expected negligible impact on RCA rockfish prey populations.
Contaminants	2	4	Effluent can include sewage and waste from industry (e.g. oil processing, sawmills, etc.). We were unable to make a detailed assessment of the possible effects of these effluent outfalls on RCA habitats and rockfish prey populations given the available data. The effects of effluent on marine habitats are highly variable depending upon the type of effluent (e.g. sewage, pulp mill, oil processing), the amount of effluent being discharged, and the environment around the outfall. Municipal sewage effluent can cause eutrophication and changes to community assemblages in marine environments (Costanzo et al. 2001; Hindell et al. 2000). While nutrient input from sewage outfalls can increase food availability, which might benefit rockfish populations directly and indirectly, they can also create anoxic zones (Hindell et al. 2000). Sewage effluent can introduce pollutants into marine systems with a variety of potential effects. Pulp mill and oil processing effluent can also affect marine environments through the introduction of toxic chemicals (Yanko et al. 1999). Minor impacts on RCA rockfish prey population with high uncertainty.

Stressor	Consequence	Uncertainty	Justification
Existing infrastructure			
Contaminants	1	3	Contaminants associated with infrastructure include antifouling agents, which sensitive benthic organisms are particularly susceptible to. Contaminants associated with the vessels that use this infrastructure are included in vessel discharge and not included here. Expected to have a negligible impact on rockfish prey in RCAs.
Introduction of foreign material	1	2	Effects of floating structures in RCAs will be highly dependent upon the size, location, and popularity of these areas. A full assessment of the potential effects to RCAs from coastal infrastructure was not possible with available data. Some fixed coastal structures can create artificial reefs that may encourage prey species assemblages in RCAs. However, certain construction materials do not support artificial reefs, and artificial structures can create unnatural habitats that are not always well suited to local species. For example, steep dock pilings or concrete walls can provide habitat for species like barnacles, tube worms, and anemones, but may lack crevices that provide habitat for rockfish species (Bulleri et al. 2010). Negligible impacts on rockfish prey population of RCAs.
Introductions (AIS)	3	3	Potential for AIS to become established as a result of coastal infrastructure (Iacella et al. 2018). This could impact rockfish prey species (particularly the invertebrates). Could have a moderate impact on rockfish prey species, uncertainty mod, reflecting AIS as a potential stressor

APPENDIX G: RISK RESULTS

Table G.1: Median risk scores and 10/90% Quantiles for Inshore Rockfish SEC.

Activity (Stressor)	Median $Risk_{sc}$	10% Quantile	90% Quantile
Dual_FSC_groundfish_hook_and_line (Removal_of_biological_material)	151.99	47.48	301.27
Crab_by_trap (Removal_of_biological_material)	101.91	46.43	172.90
Vessels_oil_spill (Oil)	95.60	10.17	220.76
Outfalls (Contaminants)	71.98	18.20	162.20
Movement_and_storage_of_logs (Contaminants)	71.18	23.53	119.60
Crab_by_trap (Entrapment_entanglement)	49.53	0.00	118.24
Prawn_and_shrimp_by_trap (Removal_of_biological_material)	48.14	21.01	78.06
Vessels_movement_underway (Noise_disturbance)	39.75	7.80	75.50
Finfish_aquaculture (Contaminants)	32.27	16.04	51.60
Dual_FSC_groundfish_hook_and_line (Entrapment_entanglement)	31.88	0.00	76.52
Prawn_and_shrimp_by_trap (Entrapment_entanglement)	30.31	3.49	55.80
Vessels_discharge (Contaminants)	27.29	0.41	68.42
Coastal_infrastructure (Introductions_foreign_material)	19.34	3.63	39.61
Movement_and_storage_of_logs (Substrate_disturbance_sediment_resuspension)	19.22	4.05	36.39
Outfalls (Introductions_nutrients_biological_material)	18.80	0.68	37.38
Shellfish_aquaculture (Contaminants)	17.00	6.04	29.28

Activity (Stressor)	Median $Risk_{sc}$	10% Quantile	90% Quantile
Crab_by_trap (Substrate_disturbance_sediment_resuspension)	13.77	1.69	27.19
Herring_seine_net (Removal_of_biological_material)	11.86	1.23	26.19
Salmon_by_seine_net (Removal_of_biological_material)	11.56	0.12	29.30
Dual_FSC_groundfish_hook_and_line (Substrate_disturbance_sediment_resuspension)	10.65	0.02	25.79
Coastal_infrastructure (Contaminants)	10.28	0.32	26.25
Finfish_aquaculture (Introductions_nutrients_biological_material)	8.93	4.77	14.23
Salmon_by_gillnet (Removal_of_biological_material)	8.30	0.14	20.01
Prawn_and_shrimp_by_trap (Substrate_disturbance_sediment_resuspension)	7.59	0.26	17.11
Smelt_by_gillnet_recreational (Entrapment_entanglement)	7.55	0.09	19.80
Smelt_by_gillnet_recreational (Removal_of_biological_material)	6.59	0.16	14.07
Euphausiid_by_midwater_trawl (Removal_of_biological_material)	5.87	0.00	15.61
Shellfish_aquaculture (Substrate_disturbance_sediment_resuspension)	4.95	0.76	10.23
Smelt_by_gillnet_recreational (Substrate_disturbance_sediment_resuspension)	4.87	0.03	13.45
Shellfish_aquaculture (Introductions_nutrients_biological_material)	4.36	0.65	9.70
Herring_by_gillnet (Entrapment_entanglement)	3.43	0.00	12.29
Finfish_aquaculture (Removal_of_biological_material)	3.32	0.81	7.31
Salmon_by_gillnet (Entrapment_entanglement)	3.05	0.00	9.56
Groundfish_by_midwater_trawl (Substrate_disturbance_sediment_resuspension)	2.90	0.19	7.63

Activity (Stressor)	Median $Risk_{sc}$	10% Quantile	90% Quantile
Scallop_by_trawl (Substrate_disturbance_sediment_resuspension)	2.59	0.05	7.28
Herring_by_gillnet (Removal_of_biological_material)	2.42	0.00	7.63
Scallop_by_trawl (Entrapment_entanglement)	2.32	0.02	5.84
Groundfish_by_midwater_trawl (Removal_of_biological_material)	2.13	0.29	4.94
Groundfish_by_midwater_trawl (Entrapment_entanglement)	1.25	0.00	2.79
Salmon_by_seine_net (Entrapment_entanglement)	1.20	0.00	3.62
Invasive_bottom_long_line_fishery_survey (Removal_of_biological_material)	1.20	0.21	2.33
Vessels_discharge (Substrate_disturbance_sediment_resuspension)	1.19	0.00	3.47

Table G.2: Median risk scores and 10/90% Quantiles for Prey SEC.

Activity (Stressor)	Median *Risk*$_{sc}$	10% Quantile	90% Quantile
Prawn_and_shrimp_by_trap (Removal_of_biological_material)	112.16	67.90	164.46
Coastal_infrastructure (Introductions_AIS)	106.97	50.66	169.77
Vessels_oil_spill (Oil)	86.04	20.01	157.63
Outfalls (Contaminants)	76.02	10.78	161.82
Movement_and_storage_of_logs (Contaminants)	75.86	17.71	140.01
Crab_by_trap (Entrapment_entanglement)	46.41	4.96	104.53
Herring_seine_net (Removal_of_biological_material)	37.16	2.72	74.26
Vessels_movement_underway (Noise_disturbance)	35.96	6.63	68.58
Finfish_aquaculture (Contaminants)	33.28	17.89	53.61
Crab_by_trap (Removal_of_biological_material)	26.53	4.94	54.97
Dual_FSC_groundfish_hook_and_line (Removal_of_biological_material)	26.14	1.32	53.43
Outfalls (Introductions_nutrients_biological_material)	26.10	1.38	57.08
Euphausiid_by_midwater_trawl (Removal_of_biological_material)	21.57	0.81	51.41
Vessels_discharge (Contaminants)	19.91	0.27	42.50
Coastal_infrastructure (Introductions_foreign_material)	18.33	3.98	39.46
Smelt_by_gillnet_recreational (Removal_of_biological_material)	17.68	0.55	48.26
Movement_and_storage_of_logs (Substrate_disturbance_sediment_resuspension)	17.05	4.63	32.90
Crab_by_trap (Substrate_disturbance_sediment_resuspension)	16.81	0.29	44.14

Activity (Stressor)	Median $Risk_{sc}$	10% Quantile	90% Quantile
Shellfish_aquaculture (Contaminants)	16.02	4.57	27.44
Salmon_by_seine_net (Removal_of_biological_material)	13.98	0.22	32.20
Dual_FSC_groundfish_hook_and_line (Substrate_disturbance_sediment_resuspension)	12.76	0.29	31.53
Salmon_by_gillnet (Removal_of_biological_material)	12.63	0.53	33.34
Vessels_movement_underway (Substrate_disturbance_sediment_resuspension)	11.81	-0.01	30.15
Herring_by_gillnet (Removal_of_biological_material)	11.50	-0.29	34.19
Coastal_infrastructure (Contaminants)	10.61	0.08	29.15
Herring_spawn_on_kelp (Removal_of_biological_material)	9.73	0.27	20.51
Finfish_aquaculture (Introductions_nutrients_biological_material)	9.18	1.22	18.64
Groundfish_by_midwater_trawl (Removal_of_biological_material)	8.80	2.32	17.29
Vessels_discharge (Introductions_AIS)	7.49	-0.42	20.57
Prawn_and_shrimp_by_trap (Substrate_disturbance_sediment_resuspension)	7.38	0.51	16.07
Dual_FSC_groundfish_hook_and_line (Entrapment_entanglement)	6.73	-0.07	16.39
Herring_seine_net (Entrapment_entanglement)	5.96	-0.64	20.85
Prawn_and_shrimp_by_trap (Entrapment_entanglement)	5.59	0.36	13.35
Smelt_by_gillnet_recreational (Substrate_disturbance_sediment_resuspension)	5.53	0.13	12.62
Smelt_by_gillnet_recreational (Entrapment_entanglement)	5.33	0.03	15.08
Euphausiid_by_midwater_trawl (Introductions_AIS)	5.11	0.00	11.51
Crab_by_trap (Introductions_AIS)	4.90	-0.62	13.84

Activity (Stressor)	Median $Risk_{sc}$	10% Quantile	90% Quantile
Shellfish_aquaculture (Substrate_disturbance_sediment_resuspension)	4.54	0.80	9.18
Shellfish_aquaculture (Introductions_nutrients_biological_material)	4.51	0.55	8.85
Finfish_aquaculture (Removal_of_biological_material)	3.53	0.83	6.59
Groundfish_by_midwater_trawl (Introductions_AIS)	3.49	-0.69	9.55
Salmon_by_gillnet (Entrapment_entanglement)	3.26	0.00	9.30
Scallop_by_trawl (Entrapment_entanglement)	3.07	0.16	6.64
Herring_by_gillnet (Entrapment_entanglement)	2.99	-0.18	8.71
Groundfish_by_midwater_trawl (Substrate_disturbance_sediment_resuspension)	2.57	0.30	5.77
Scallop_by_trawl (Removal_of_biological_material)	2.02	0.18	4.42
Scallop_by_trawl (Substrate_disturbance_sediment_resuspension)	1.93	0.15	4.35
Salmon_by_seine_net (Entrapment_entanglement)	1.85	-0.17	6.32
Groundfish_by_midwater_trawl (Entrapment_entanglement)	1.49	0.04	3.51
Prawn_and_shrimp_by_trap (Introductions_AIS)	1.47	-0.08	3.81
Scallop_by_trawl (Introductions_AIS)	1.41	-0.03	4.29
Vessels_discharge (Substrate_disturbance_sediment_resuspension)	1.31	-0.13	4.17
Invasive_bottom_long_line_fishery_survey (Removal_of_biological_material)	1.22	0.27	2.25
Invasive_bottom_long_line_fishery_survey (Substrate_disturbance_sediment_resuspension)	1.10	0.13	2.52

Table G.3: Median risk and 10/90% Quantiles scores for Rocky Reefs SEC.

Activity (Stressor)	**Median *Risk*$_{sc}$**	**10% Quantile**	**90% Quantile**
Outfalls (Contaminants)	141.87	53.57	242.05
Coastal_infrastructure (Introductions_AIS)	111.21	43.26	197.62
Vessels_oil_spill (Oil)	104.32	20.00	213.34
Crab_by_trap (Substrate_disturbance_sediment_resuspension)	62.03	7.41	115.73
Coastal_infrastructure (Contaminants)	38.46	8.15	85.33
Dual_FSC_groundfish_hook_and_line (Substrate_disturbance_sediment_resuspension)	37.99	6.73	83.59
Shellfish_aquaculture (Introductions_AIS)	37.07	10.40	69.82
Vessels_movement_underway (Substrate_disturbance_sediment_resuspension)	36.00	-0.54	93.15
Finfish_aquaculture (Contaminants)	32.83	17.44	50.47
Crab_by_trap (Substrate_disturbance_crushing)	31.87	5.02	65.03
Prawn_and_shrimp_by_trap (Substrate_disturbance_sediment_resuspension)	26.98	3.23	61.58
Prawn_and_shrimp_by_trap (Substrate_disturbance_crushing)	24.14	2.33	55.97
Outfalls (Introductions_nutrients_biological_material)	23.05	1.77	62.03
Vessels_discharge (Introductions_AIS)	20.74	-1.69	59.25
Vessels_discharge (Contaminants)	19.03	0.37	44.15
Shellfish_aquaculture (Contaminants)	16.31	6.90	26.96
Finfish_aquaculture (Introductions_AIS)	12.54	5.11	21.59

Activity (Stressor)	Median *Risk*$_{sc}$	10% Quantile	90% Quantile
Prawn_and_shrimp_by_trap (Introductions_AIS)	10.60	-0.39	27.74
Groundfish_by_midwater_trawl (Introductions_AIS)	9.87	-0.53	21.72
Finfish_aquaculture (Introductions_nutrients_biological_material)	8.40	4.30	13.33
Crab_by_trap (Introductions_AIS)	7.03	-1.80	20.62
Shellfish_aquaculture (Introductions_nutrients_biological_material)	5.50	0.27	12.77
Smelt_by_gillnet_recreational (Substrate_disturbance_sediment_resuspension)	4.94	0.07	13.98
Shellfish_aquaculture (Substrate_disturbance_sediment_resuspension)	4.71	0.68	9.81
Vessels_discharge (Introductions_nutrients_biological_material)	3.84	-0.12	14.40
Groundfish_by_midwater_trawl (Substrate_disturbance_crushing)	2.44	0.05	4.87
Groundfish_by_midwater_trawl (Substrate_disturbance_sediment_resuspension)	2.43	0.16	6.01
Vessels_discharge (Substrate_disturbance_crushing)	1.31	-0.06	2.98
Invasive_bottom_long_line_fishery_survey (Substrate_disturbance_crushing)	1.16	0.18	2.30
Vessels_discharge (Substrate_disturbance_sediment_resuspension)	1.12	-0.24	4.67
Invasive_bottom_long_line_fishery_survey (Substrate_disturbance_sediment_resuspension)	1.04	0.06	2.65

Table G.4: Exposure/Consequence Risk Results for all SEC-stressor interactions sorted by Exposure Calculated (R output) Exposure/Consequence scores for all SEC-stressor interactions sorted by Exposure Score (high to low).

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
Prey	Vessels_movement_underway (Noise_disturbance)	31.87	27.93	35.47	1.16	0.31	2.11
Rockfish	Vessels_movement_underway (Noise_disturbance)	31.46	26.56	36.62	1.26	0.27	2.44
Prey	Crab_by_trap (Removal_of_biological_material)	24.17	15.36	33.81	1.33	0.33	2.58
Rockfish	Crab_by_trap (Removal_of_biological_material)	23.84	13.51	35.08	4.16	2.52	6.37
Prey	Outfalls (Contaminants)	16.92	10.43	22.92	4.71	0.77	8.88
Rockfish	Outfalls (Contaminants)	16.87	9.79	23.97	4.97	1.07	9.87
Prey	Movement_and_storage_of_logs (Substrate_disturbance_sediment_resuspension)	16.71	8.85	24.57	1.07	0.30	2.01
Rockfish	Movement_and_storage_of_logs (Substrate_disturbance_sediment_resuspension)	16.48	9.69	23.31	1.14	0.27	1.87
Prey	Outfalls (Introductions_nutrients_biological_material)	16.48	9.19	22.29	1.10	0.07	2.44
Rockfish	Outfalls	16.46	9.42	22.94	1.37	0.09	3.25

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
	(Introductions_nutrients_biological_material)						
Rockfish	Movement_and_storage_of_logs (Contaminants)	16.31	9.44	24.61	4.07	1.27	6.63
Prey	Coastal_infrastructure (Introductions_foreign_material)	16.30	11.04	22.80	1.20	0.29	2.29
Rocky reef	Outfalls (Contaminants)	16.20	9.06	24.56	9.27	3.08	15.77
Rockfish	Dual_FSC_groundfish_hook_and_line (Removal_of_biological_material)	16.06	5.86	27.23	9.23	5.39	13.83
Prey	Movement_and_storage_of_logs (Contaminants)	16.06	9.89	21.78	4.75	1.70	8.20
Rocky reef	Outfalls (Introductions_nutrients_biological_material)	15.57	8.09	21.77	1.39	0.06	3.27
Prey	Dual_FSC_groundfish_hook_and_line (Removal_of_biological_material)	15.51	6.79	24.48	1.27	0.07	2.61
Rockfish	Coastal_infrastructure (Introductions_foreign_material)	15.40	10.30	21.62	1.17	0.30	2.35
Prey	Coastal_infrastructure (Introductions_AIS)	12.66	7.77	18.25	9.41	4.88	14.50
Rockfish	Prawn_and_shrimp_by_trap	12.50	8.96	15.93	4.25	2.05	6.60

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
	(Removal_of_biological_material)						
Rocky reef	Crab_by_trap (Substrate_disturbance_sediment_resuspension)	12.47	4.80	19.53	4.21	1.36	7.27
Rockfish	Crab_by_trap (Substrate_disturbance_sediment_resuspension)	12.07	2.58	20.60	1.14	0.18	2.67
Prey	Prawn_and_shrimp_by_trap (Removal_of_biological_material)	11.99	8.43	15.69	9.06	6.49	11.74
Prey	Crab_by_trap (Entrapment_entanglement)	11.80	1.50	24.66	4.33	2.16	6.92
Prey	Crab_by_trap (Substrate_disturbance_sediment_resuspension)	11.48	2.96	18.36	1.29	0.11	2.66
Rocky reef	Coastal_infrastructure (Introductions_AIS)	11.07	6.25	17.02	9.61	4.72	14.51
Prey	Salmon_by_seine_net (Removal_of_biological_material)	10.46	2.98	19.43	1.28	0.03	3.00
Rockfish	Crab_by_trap (Entrapment_entanglement)	10.45	-1.36	24.14	4.25	1.48	8.11
Rockfish	Salmon_by_gillnet (Removal_of_biological_material)	9.88	1.85	18.30	1.11	0.14	2.16
Prey	Herring_seine_net	9.63	1.74	20.94	4.48	2.15	7.38

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
	(Removal_of_biological_material)						
Prey	Vessels_movement_underway (Substrate_disturbance_sediment_resuspension)	9.48	-0.39	19.18	1.22	0.07	3.36
Rocky reef	Dual_FSC_groundfish_hook_and_line (Substrate_disturbance_sediment_resuspension)	8.79	2.24	18.47	4.46	1.42	8.42
Rockfish	Coastal_infrastructure (Contaminants)	8.48	3.48	13.74	1.29	0.07	3.25
Rocky reef	Crab_by_trap (Substrate_disturbance_crushing)	8.45	2.29	14.41	4.67	2.13	7.63
Rocky reef	Finfish_aquaculture (Introductions_nutrients_biological_material)	8.30	5.97	10.81	1.00	0.55	1.39
Rockfish	Finfish_aquaculture (Contaminants)	8.19	6.52	10.72	4.31	2.00	6.57
Rockfish	Dual_FSC_groundfish_hook_and_line (Substrate_disturbance_sediment_resuspension)	8.17	1.46	13.94	1.52	0.15	3.06
Rocky reef	Finfish_aquaculture (Contaminants)	8.12	5.82	10.69	4.00	2.17	6.05
Rockfish	Finfish_aquaculture (Introductions_nutrients_biological_material)	8.11	6.22	9.73	1.11	0.62	1.72
Prey	Finfish_aquaculture	8.02	5.74	10.38	4.03	2.09	6.39

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
	(Contaminants)						
Rockfish	Herring_seine_net (Removal_of_biological_material)	8.01	-0.38	17.30	1.08	0.19	2.11
Prey	Salmon_by_gillnet (Removal_of_biological_material)	7.99	1.85	15.77	1.43	0.06	3.45
Rocky reef	Coastal_infrastructure (Contaminants)	7.98	3.88	12.62	4.43	1.66	7.62
Prey	Coastal_infrastructure (Contaminants)	7.93	4.35	13.02	1.31	0.05	3.48
Prey	Finfish_aquaculture (Introductions_nutrients_biological_material)	7.90	5.68	10.24	1.04	0.22	2.12
Rockfish	Salmon_by_seine_net (Removal_of_biological_material)	7.86	0.23	16.25	1.29	0.07	3.30
Prey	Dual_FSC_groundfish_hook_and_line (Substrate_disturbance_sediment_resuspension)	7.70	1.68	14.31	1.44	0.18	3.03
Rocky reef	Vessels_movement_underway (Substrate_disturbance_sediment_resuspension)	7.15	-1.25	16.54	4.41	1.41	8.15
Rocky reef	Prawn_and_shrimp_by_trap (Substrate_disturbance_crushing)	6.94	1.74	11.47	4.61	1.83	7.63
Prey	Prawn_and_shrimp_by_trap	6.45	1.89	11.22	1.11	0.18	2.14

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
	(Entrapment_entanglement)						
Prey	Prawn_and_shrimp_by_trap (Substrate_disturbance_sediment_resuspension)	6.31	1.76	10.92	1.34	0.43	2.37
Rockfish	Dual_FSC_groundfish_hook_and_line (Entrapment_entanglement)	6.09	0.76	10.99	4.04	0.95	7.63
Rockfish	Vessels_oil_spill (Oil)	6.08	0.36	13.76	15.96	9.64	21.94
Rockfish	Prawn_and_shrimp_by_trap (Substrate_disturbance_sediment_resuspension)	5.94	1.41	11.12	1.23	0.31	2.46
Prey	Dual_FSC_groundfish_hook_and_line (Entrapment_entanglement)	5.87	-0.90	12.34	1.43	0.05	3.33
Rockfish	Prawn_and_shrimp_by_trap (Entrapment_entanglement)	5.86	1.69	10.38	4.28	2.73	6.03
Prey	Vessels_oil_spill (Oil)	5.84	1.56	12.11	16.49	11.27	22.77
Rocky reef	Vessels_oil_spill (Oil)	5.82	1.21	12.63	17.03	10.60	24.84
Rocky reef	Prawn_and_shrimp_by_trap (Substrate_disturbance_sediment_resuspension)	5.73	0.95	10.61	4.26	1.37	7.53
Rocky reef	Shellfish_aquaculture	4.55	0.96	8.38	8.94	5.35	13.36

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
	(Introductions_AIS)						
Prey	Smelt_by_gillnet_recreational (Substrate_disturbance_sediment_resuspension)	4.41	1.05	8.27	1.25	0.43	2.16
Rocky reef	Smelt_by_gillnet_recreational (Substrate_disturbance_sediment_resuspension)	4.27	0.80	8.44	1.32	0.05	3.08
Rocky reef	Vessels_discharge (Contaminants)	4.26	0.26	9.38	4.12	1.49	7.30
Rockfish	Smelt_by_gillnet_recreational (Substrate_disturbance_sediment_resuspension)	4.20	0.43	7.66	1.57	0.13	3.13
Rocky reef	Shellfish_aquaculture (Contaminants)	4.18	1.99	6.90	4.02	2.27	6.04
Prey	Vessels_discharge (Contaminants)	4.14	0.49	8.62	4.45	0.97	8.75
Rocky reef	Shellfish_aquaculture (Introductions_nutrients_biological_material)	4.12	1.97	6.68	1.48	0.04	3.42
Rockfish	Smelt_by_gillnet_recreational (Removal_of_biological_material)	4.09	0.68	9.23	1.72	0.08	4.25
Rockfish	Shellfish_aquaculture (Substrate_disturbance_sediment_resuspension)	4.01	1.89	6.97	1.18	0.21	2.33
Prey	Shellfish_aquaculture	3.98	1.93	6.30	1.09	0.23	2.06

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
	(Substrate_disturbance_sediment_resuspension)						
Rockfish	Shellfish_aquaculture (Introductions_nutrients_biological_material)	3.98	2.12	5.95	0.98	0.29	1.81
Rocky reef	Shellfish_aquaculture (Substrate_disturbance_sediment_resuspension)	3.94	1.82	6.32	1.33	0.29	2.28
Rockfish	Euphausiid_by_midwater_trawl (Removal_of_biological_material)	3.94	0.45	8.78	1.09	0.30	2.02
Prey	Shellfish_aquaculture (Introductions_nutrients_biological_material)	3.86	1.65	6.37	1.30	0.24	2.71
Rockfish	Shellfish_aquaculture (Contaminants)	3.82	1.88	5.80	4.41	2.42	6.35
Prey	Smelt_by_gillnet_recreational (Removal_of_biological_material)	3.82	0.67	8.56	4.18	1.55	7.38
Prey	Euphausiid_by_midwater_trawl (Removal_of_biological_material)	3.82	-0.47	8.36	3.86	1.60	6.45
Rockfish	Vessels_discharge (Contaminants)	3.74	-0.01	8.82	4.65	1.45	8.04
Prey	Shellfish_aquaculture (Contaminants)	3.73	1.70	5.73	4.27	2.33	6.06
Prey	Finfish_aquaculture	3.20	2.06	4.51	1.06	0.19	2.28

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
	(Removal_of_biological_material)						
Rocky reef	Finfish_aquaculture (Introductions_AIS)	3.08	1.46	4.70	4.33	2.24	6.37
Rockfish	Finfish_aquaculture (Removal_of_biological_material)	3.08	2.04	4.18	1.14	0.39	2.16
Prey	Smelt_by_gillnet_recreational (Entrapment_entanglement)	3.04	0.45	5.62	1.61	0.07	4.45
Prey	Herring_seine_net (Entrapment_entanglement)	3.01	-0.34	6.03	1.34	0.03	3.63
Rockfish	Smelt_by_gillnet_recreational (Entrapment_entanglement)	2.93	0.43	6.11	1.77	0.03	4.28
Rockfish	Salmon_by_gillnet (Entrapment_entanglement)	2.47	-0.40	6.15	1.51	0.11	3.44
Prey	Herring_by_gillnet (Entrapment_entanglement)	2.38	-0.28	5.63	1.41	0.08	3.75
Rockfish	Herring_by_gillnet (Removal_of_biological_material)	2.19	-0.44	6.11	1.53	0.07	4.11
Prey	Herring_spawn_on_kelp (Removal_of_biological_material)	2.17	0.20	4.77	4.63	0.60	9.23
Rockfish	Herring_by_gillnet	2.14	-0.14	5.21	1.57	0.05	3.69

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
	(Entrapment_entanglement)						
Prey	Scallop_by_trawl (Substrate_disturbance_sediment_resuspension)	2.11	0.87	3.56	1.23	0.34	2.08
Prey	Groundfish_by_midwater_trawl (Removal_of_biological_material)	2.05	1.11	3.07	4.14	1.92	6.89
Rocky reef	Groundfish_by_midwater_trawl (Substrate_disturbance_crushing)	2.05	0.77	3.40	1.36	0.10	3.18
Rockfish	Groundfish_by_midwater_trawl (Substrate_disturbance_sediment_resuspension)	2.01	0.54	3.94	1.28	0.10	2.56
Rockfish	Scallop_by_trawl (Substrate_disturbance_sediment_resuspension)	2.00	0.51	3.68	1.43	0.08	3.29
Rocky reef	Groundfish_by_midwater_trawl (Substrate_disturbance_sediment_resuspension)	1.99	0.70	3.30	1.08	0.11	2.48
Rockfish	Scallop_by_trawl (Entrapment_entanglement)	1.96	0.26	4.01	1.64	0.21	3.34
Rocky reef	Vessels_discharge (Introductions_AIS)	1.95	-0.22	4.72	10.41	4.17	17.27
Prey	Groundfish_by_midwater_trawl (Substrate_disturbance_sediment_resuspension)	1.93	0.79	3.37	1.50	0.05	3.67
Rockfish	Groundfish_by_midwater_trawl	1.89	1.06	2.92	1.13	0.24	1.96

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
	(Removal_of_biological_material)						
Prey	Scallop_by_trawl (Removal_of_biological_material)	1.87	0.88	2.97	1.16	0.30	2.32
Prey	Scallop_by_trawl (Entrapment_entanglement)	1.86	0.16	3.59	1.29	0.06	3.03
Rocky reef	Vessels_discharge (Introductions_nutrients_biological_material)	1.83	-0.57	5.73	1.20	0.06	2.85
Prey	Vessels_discharge (Introductions_AIS)	1.79	-0.04	4.62	4.17	1.10	7.60
Prey	Herring_by_gillnet (Removal_of_biological_material)	1.65	-0.40	4.68	5.35	0.94	10.92
Prey	Salmon_by_gillnet (Entrapment_entanglement)	1.54	-0.22	4.03	1.31	0.14	3.63
Prey	Prawn_and_shrimp_by_trap (Introductions_AIS)	1.23	-0.16	3.61	1.45	0.04	3.21
Rocky reef	Vessels_discharge (Substrate_disturbance_crushing)	1.20	-0.21	3.05	1.23	0.21	2.46
Rocky reef	Crab_by_trap (Introductions_AIS)	1.08	-0.07	2.82	10.24	3.74	16.42
Prey	Crab_by_trap	1.08	-0.05	3.23	4.54	1.16	9.82

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
	(Introductions_AIS)						
Prey	Scallop_by_trawl (Introductions_AIS)	1.06	-0.08	2.46	1.34	0.06	3.27
Prey	Euphausiid_by_midwater_trawl (Introductions_AIS)	1.03	-0.03	2.38	5.12	1.41	9.18
Prey	Salmon_by_seine_net (Entrapment_entanglement)	1.01	-0.40	3.36	1.58	0.08	3.79
Prey	Vessels_discharge (Substrate_disturbance_sediment_resuspension)	1.01	-0.10	2.79	1.26	0.32	2.39
Rockfish	Invasive_bottom_long_line_fishery_survey (Removal_of_biological_material)	1.01	0.61	1.53	1.17	0.24	2.52
Prey	Invasive_bottom_long_line_fishery_survey (Substrate_disturbance_sediment_resuspension)	1.01	0.34	1.77	1.02	0.20	1.90
Rocky reef	Invasive_bottom_long_line_fishery_survey (Substrate_disturbance_sediment_resuspension)	0.97	0.37	1.48	1.18	0.21	2.41
Rocky reef	Invasive_bottom_long_line_fishery_survey (Substrate_disturbance_crushing)	0.96	0.38	1.74	1.24	0.27	2.47
Prey	Invasive_bottom_long_line_fishery_survey (Removal_of_biological_material)	0.96	0.59	1.35	1.15	0.15	2.42
Prey	Groundfish_by_midwater_trawl	0.95	-0.24	2.40	3.93	0.37	7.65

SEC	Stressor	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
	(Introductions_AIS)						
Rocky reef	Groundfish_by_midwater_trawl (Introductions_AIS)	0.90	-0.18	2.54	9.71	3.94	15.33
Rockfish	Groundfish_by_midwater_trawl (Entrapment_entanglement)	0.90	0.09	2.01	1.40	0.06	3.25
Prey	Groundfish_by_midwater_trawl (Entrapment_entanglement)	0.86	0.07	1.85	1.31	0.04	3.29
Rockfish	Vessels_discharge (Substrate_disturbance_sediment_resuspension)	0.86	-0.12	2.59	1.07	0.25	1.94
Rockfish	Salmon_by_seine_net (Entrapment_entanglement)	0.82	-0.24	2.26	1.32	0.05	3.02
Rocky reef	Prawn_and_shrimp_by_trap (Introductions_AIS)	0.77	-0.28	2.57	9.05	2.84	15.00
Rocky reef	Vessels_discharge (Substrate_disturbance_sediment_resuspension)	0.74	-0.25	2.28	1.81	0.04	4.21

Table G.5: Exposure/Consequence Risk Results for all SEC-stressor interactions sorted by Consequence Calculated (R output) Exposure/Consequence scores for all SEC-stressor interactions sorted by Consequence Score (high to low)

SEC	Activity (Stressor)	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
Rocky reef	Vessels_oil_spill (Oil)	5.82	1.21	12.63	17.03	10.60	24.84
Prey	Vessels_oil_spill (Oil)	5.84	1.56	12.11	16.49	11.27	22.77
Rockfish	Vessels_oil_spill (Oil)	6.08	0.36	13.76	15.96	9.64	21.94
Rocky reef	Vessels_discharge (Introductions_AIS)	1.95	-0.22	4.72	10.41	4.17	17.27
Rocky reef	Crab_by_trap (Introductions_AIS)	1.08	-0.07	2.82	10.24	3.74	16.42
Rocky reef	Groundfish_by_midwater_trawl (Introductions_AIS)	0.90	-0.18	2.54	9.71	3.94	15.33
Rocky reef	Coastal_infrastructure (Introductions_AIS)	11.07	6.25	17.02	9.61	4.72	14.51
Prey	Coastal_infrastructure (Introductions_AIS)	12.66	7.77	18.25	9.41	4.88	14.50
Rocky reef	Outfalls (Contaminants)	16.20	9.06	24.56	9.27	3.08	15.77
Rockfish	Dual_FSC_groundfish_hook_and_line (Removal_of_biological_material)	16.06	5.86	27.23	9.23	5.39	13.83
Prey	Prawn_and_shrimp_by_trap (Removal_of_biological_material)	11.99	8.43	15.69	9.06	6.49	11.74
Rocky reef	Prawn_and_shrimp_by_trap (Introductions_AIS)	0.77	-0.28	2.57	9.05	2.84	15.00

SEC	Activity (Stressor)	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
Rocky reef	Shellfish_aquaculture (Introductions_AIS)	4.55	0.96	8.38	8.94	5.35	13.36
Prey	Herring_by_gillnet (Removal_of_biological_material)	1.65	-0.40	4.68	5.35	0.94	10.92
Prey	Euphausiid_by_midwater_trawl (Introductions_AIS)	1.03	-0.03	2.38	5.12	1.41	9.18
Rockfish	Outfalls (Contaminants)	16.87	9.79	23.97	4.97	1.07	9.87
Prey	Movement_and_storage_of_logs (Contaminants)	16.06	9.89	21.78	4.75	1.70	8.20
Prey	Outfalls (Contaminants)	16.92	10.43	22.92	4.71	0.77	8.88
Rocky reef	Crab_by_trap (Substrate_disturbance_crushing)	8.45	2.29	14.41	4.67	2.13	7.63
Rockfish	Vessels_discharge (Contaminants)	3.74	-0.01	8.82	4.65	1.45	8.04
Prey	Herring_spawn_on_kelp (Removal_of_biological_material)	2.17	0.20	4.77	4.63	0.60	9.23
Rocky reef	Prawn_and_shrimp_by_trap (Substrate_disturbance_crushing)	6.94	1.74	11.47	4.61	1.83	7.63
Prey	Crab_by_trap (Introductions_AIS)	1.08	-0.05	3.23	4.54	1.16	9.82
Prey	Herring_seine_net (Removal_of_biological_material)	9.63	1.74	20.94	4.48	2.15	7.38
Rocky reef	Dual_FSC_groundfish_hook_and_line (Substrate_disturbance_sediment_resuspension)	8.79	2.24	18.47	4.46	1.42	8.42
Prey	Vessels_discharge (Contaminants)	4.14	0.49	8.62	4.45	0.97	8.75

SEC	Activity (Stressor)	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
Rocky reef	Coastal_infrastructure (Contaminants)	7.98	3.88	12.62	4.43	1.66	7.62
Rocky reef	Vessels_movement_underway (Substrate_disturbance_sediment_resuspension)	7.15	-1.25	16.54	4.41	1.41	8.15
Rockfish	Shellfish_aquaculture (Contaminants)	3.82	1.88	5.80	4.41	2.42	6.35
Prey	Crab_by_trap (Entrapment_entanglement)	11.80	1.50	24.66	4.33	2.16	6.92
Rocky reef	Finfish_aquaculture (Introductions_AIS)	3.08	1.46	4.70	4.33	2.24	6.37
Rockfish	Finfish_aquaculture (Contaminants)	8.19	6.52	10.72	4.31	2.00	6.57
Rockfish	Prawn_and_shrimp_by_trap (Entrapment_entanglement)	5.86	1.69	10.38	4.28	2.73	6.03
Prey	Shellfish_aquaculture (Contaminants)	3.73	1.70	5.73	4.27	2.33	6.06
Rocky reef	Prawn_and_shrimp_by_trap (Substrate_disturbance_sediment_resuspension)	5.73	0.95	10.61	4.26	1.37	7.53
Rockfish	Prawn_and_shrimp_by_trap (Removal_of_biological_material)	12.50	8.96	15.93	4.25	2.05	6.60
Rockfish	Crab_by_trap (Entrapment_entanglement)	10.45	-1.36	24.14	4.25	1.48	8.11
Rocky reef	Crab_by_trap (Substrate_disturbance_sediment_resuspension)	12.47	4.80	19.53	4.21	1.36	7.27
Prey	Smelt_by_gillnet_recreational (Removal_of_biological_material)	3.82	0.67	8.56	4.18	1.55	7.38
Prey	Vessels_discharge (Introductions_AIS)	1.79	-0.04	4.62	4.17	1.10	7.60

SEC	Activity (Stressor)	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
Rockfish	Crab_by_trap (Removal_of_biological_material)	23.84	13.51	35.08	4.16	2.52	6.37
Prey	Groundfish_by_midwater_trawl (Removal_of_biological_material)	2.05	1.11	3.07	4.14	1.92	6.89
Rocky reef	Vessels_discharge (Contaminants)	4.26	0.26	9.38	4.12	1.49	7.30
Rockfish	Movement_and_storage_of_logs (Contaminants)	16.31	9.44	24.61	4.07	1.27	6.63
Rockfish	Dual_FSC_groundfish_hook_and_line (Entrapment_entanglement)	6.09	0.76	10.99	4.04	0.95	7.63
Prey	Finfish_aquaculture (Contaminants)	8.02	5.74	10.38	4.03	2.09	6.39
Rocky reef	Shellfish_aquaculture (Contaminants)	4.18	1.99	6.90	4.02	2.27	6.04
Rocky reef	Finfish_aquaculture (Contaminants)	8.12	5.82	10.69	4.00	2.17	6.05
Prey	Groundfish_by_midwater_trawl (Introductions_AIS)	0.95	-0.24	2.40	3.93	0.37	7.65
Prey	Euphausiid_by_midwater_trawl (Removal_of_biological_material)	3.82	-0.47	8.36	3.86	1.60	6.45
Rocky reef	Vessels_discharge (Substrate_disturbance_sediment_resuspension)	0.74	-0.25	2.28	1.81	0.04	4.21
Rockfish	Smelt_by_gillnet_recreational (Entrapment_entanglement)	2.93	0.43	6.11	1.77	0.03	4.28
Rockfish	Smelt_by_gillnet_recreational (Removal_of_biological_material)	4.09	0.68	9.23	1.72	0.08	4.25

SEC	Activity (Stressor)	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
Rockfish	Scallop_by_trawl (Entrapment_entanglement)	1.96	0.26	4.01	1.64	0.21	3.34
Prey	Smelt_by_gillnet_recreational (Entrapment_entanglement)	3.04	0.45	5.62	1.61	0.07	4.45
Prey	Salmon_by_seine_net (Entrapment_entanglement)	1.01	-0.40	3.36	1.58	0.08	3.79
Rockfish	Smelt_by_gillnet_recreational (Substrate_disturbance_sediment_resuspension)	4.20	0.43	7.66	1.57	0.13	3.13
Rockfish	Herring_by_gillnet (Entrapment_entanglement)	2.14	-0.14	5.21	1.57	0.05	3.69
Rockfish	Herring_by_gillnet (Removal_of_biological_material)	2.19	-0.44	6.11	1.53	0.07	4.11
Rockfish	Dual_FSC_groundfish_hook_and_line (Substrate_disturbance_sediment_resuspension)	8.17	1.46	13.94	1.52	0.15	3.06
Rockfish	Salmon_by_gillnet (Entrapment_entanglement)	2.47	-0.40	6.15	1.51	0.11	3.44
Prey	Groundfish_by_midwater_trawl (Substrate_disturbance_sediment_resuspension)	1.93	0.79	3.37	1.50	0.05	3.67
Rocky reef	Shellfish_aquaculture (Introductions_nutrients_biological_material)	4.12	1.97	6.68	1.48	0.04	3.42
Prey	Prawn_and_shrimp_by_trap (Introductions_AIS)	1.23	-0.16	3.61	1.45	0.04	3.21
Prey	Dual_FSC_groundfish_hook_and_line (Substrate_disturbance_sediment_resuspension)	7.70	1.68	14.31	1.44	0.18	3.03
Prey	Salmon_by_gillnet (Removal_of_biological_material)	7.99	1.85	15.77	1.43	0.06	3.45

SEC	Activity (Stressor)	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
Prey	Dual_FSC_groundfish_hook_and_line (Entrapment_entanglement)	5.87	-0.90	12.34	1.43	0.05	3.33
Rockfish	Scallop_by_trawl (Substrate_disturbance_sediment_resuspension)	2.00	0.51	3.68	1.43	0.08	3.29
Prey	Herring_by_gillnet (Entrapment_entanglement)	2.38	-0.28	5.63	1.41	0.08	3.75
Rockfish	Groundfish_by_midwater_trawl (Entrapment_entanglement)	0.90	0.09	2.01	1.40	0.06	3.25
Rocky reef	Outfalls (Introductions_nutrients_biological_material)	15.57	8.09	21.77	1.39	0.06	3.27
Rockfish	Outfalls (Introductions_nutrients_biological_material)	16.46	9.42	22.94	1.37	0.09	3.25
Rocky reef	Groundfish_by_midwater_trawl (Substrate_disturbance_crushing)	2.05	0.77	3.40	1.36	0.10	3.18
Prey	Prawn_and_shrimp_by_trap (Substrate_disturbance_sediment_resuspension)	6.31	1.76	10.92	1.34	0.43	2.37
Prey	Herring_seine_net (Entrapment_entanglement)	3.01	-0.34	6.03	1.34	0.03	3.63
Prey	Scallop_by_trawl (Introductions_AIS)	1.06	-0.08	2.46	1.34	0.06	3.27
Prey	Crab_by_trap (Removal_of_biological_material)	24.17	15.36	33.81	1.33	0.33	2.58
Rocky reef	Shellfish_aquaculture (Substrate_disturbance_sediment_resuspension)	3.94	1.82	6.32	1.33	0.29	2.28
Rocky reef	Smelt_by_gillnet_recreational (Substrate_disturbance_sediment_resuspension)	4.27	0.80	8.44	1.32	0.05	3.08

SEC	Activity (Stressor)	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
Rockfish	Salmon_by_seine_net (Entrapment_entanglement)	0.82	-0.24	2.26	1.32	0.05	3.02
Prey	Coastal_infrastructure (Contaminants)	7.93	4.35	13.02	1.31	0.05	3.48
Prey	Salmon_by_gillnet (Entrapment_entanglement)	1.54	-0.22	4.03	1.31	0.14	3.63
Prey	Groundfish_by_midwater_trawl (Entrapment_entanglement)	0.86	0.07	1.85	1.31	0.04	3.29
Prey	Shellfish_aquaculture (Introductions_nutrients_biological_material)	3.86	1.65	6.37	1.30	0.24	2.71
Prey	Crab_by_trap (Substrate_disturbance_sediment_resuspension)	11.48	2.96	18.36	1.29	0.11	2.66
Rockfish	Coastal_infrastructure (Contaminants)	8.48	3.48	13.74	1.29	0.07	3.25
Rockfish	Salmon_by_seine_net (Removal_of_biological_material)	7.86	0.23	16.25	1.29	0.07	3.30
Prey	Scallop_by_trawl (Entrapment_entanglement)	1.86	0.16	3.59	1.29	0.06	3.03
Prey	Salmon_by_seine_net (Removal_of_biological_material)	10.46	2.98	19.43	1.28	0.03	3.00
Rockfish	Groundfish_by_midwater_trawl (Substrate_disturbance_sediment_resuspension)	2.01	0.54	3.94	1.28	0.10	2.56
Prey	Dual_FSC_groundfish_hook_and_line (Removal_of_biological_material)	15.51	6.79	24.48	1.27	0.07	2.61
Rockfish	Vessels_movement_underway (Noise_disturbance)	31.46	26.56	36.62	1.26	0.27	2.44

SEC	Activity (Stressor)	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
Prey	Vessels_discharge (Substrate_disturbance_sediment_resuspension)	1.01	-0.10	2.79	1.26	0.32	2.39
Prey	Smelt_by_gillnet_recreational (Substrate_disturbance_sediment_resuspension)	4.41	1.05	8.27	1.25	0.43	2.16
Rocky reef	Invasive_bottom_long_line_fishery_survey (Substrate_disturbance_crushing)	0.96	0.38	1.74	1.24	0.27	2.47
Rockfish	Prawn_and_shrimp_by_trap (Substrate_disturbance_sediment_resuspension)	5.94	1.41	11.12	1.23	0.31	2.46
Prey	Scallop_by_trawl (Substrate_disturbance_sediment_resuspension)	2.11	0.87	3.56	1.23	0.34	2.08
Rocky reef	Vessels_discharge (Substrate_disturbance_crushing)	1.20	-0.21	3.05	1.23	0.21	2.46
Prey	Vessels_movement_underway (Substrate_disturbance_sediment_resuspension)	9.48	-0.39	19.18	1.22	0.07	3.36
Prey	Coastal_infrastructure (Introductions_foreign_material)	16.30	11.04	22.80	1.20	0.29	2.29
Rocky reef	Vessels_discharge (Introductions_nutrients_biological_material)	1.83	-0.57	5.73	1.20	0.06	2.85
Rockfish	Shellfish_aquaculture (Substrate_disturbance_sediment_resuspension)	4.01	1.89	6.97	1.18	0.21	2.33
Rocky reef	Invasive_bottom_long_line_fishery_survey (Substrate_disturbance_sediment_resuspension)	0.97	0.37	1.48	1.18	0.21	2.41
Rockfish	Coastal_infrastructure (Introductions_foreign_material)	15.40	10.30	21.62	1.17	0.30	2.35

SEC	Activity (Stressor)	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
Rockfish	Invasive_bottom_long_line_fishery_survey (Removal_of_biological_material)	1.01	0.61	1.53	1.17	0.24	2.52
Prey	Vessels_movement_underway (Noise_disturbance)	31.87	27.93	35.47	1.16	0.31	2.11
Prey	Scallop_by_trawl (Removal_of_biological_material)	1.87	0.88	2.97	1.16	0.30	2.32
Prey	Invasive_bottom_long_line_fishery_survey (Removal_of_biological_material)	0.96	0.59	1.35	1.15	0.15	2.42
Rockfish	Movement_and_storage_of_logs (Substrate_disturbance_sediment_resuspension)	16.48	9.69	23.31	1.14	0.27	1.87
Rockfish	Crab_by_trap (Substrate_disturbance_sediment_resuspension)	12.07	2.58	20.60	1.14	0.18	2.67
Rockfish	Finfish_aquaculture (Removal_of_biological_material)	3.08	2.04	4.18	1.14	0.39	2.16
Rockfish	Groundfish_by_midwater_trawl (Removal_of_biological_material)	1.89	1.06	2.92	1.13	0.24	1.96
Rockfish	Salmon_by_gillnet (Removal_of_biological_material)	9.88	1.85	18.30	1.11	0.14	2.16
Rockfish	Finfish_aquaculture (Introductions_nutrients_biological_material)	8.11	6.22	9.73	1.11	0.62	1.72
Prey	Prawn_and_shrimp_by_trap (Entrapment_entanglement)	6.45	1.89	11.22	1.11	0.18	2.14
Prey	Outfalls (Introductions_nutrients_biological_material)	16.48	9.19	22.29	1.10	0.07	2.44

SEC	Activity (Stressor)	Exposure Median	10% Quantile	90% Quantile	Consequence Median	10% Quantile	90% Quantile
Prey	Shellfish_aquaculture (Substrate_disturbance_sediment_resuspension)	3.98	1.93	6.30	1.09	0.23	2.06
Rockfish	Euphausiid_by_midwater_trawl (Removal_of_biological_material)	3.94	0.45	8.78	1.09	0.30	2.02
Rockfish	Herring_seine_net (Removal_of_biological_material)	8.01	-0.38	17.30	1.08	0.19	2.11
Rocky reef	Groundfish_by_midwater_trawl (Substrate_disturbance_sediment_resuspension)	1.99	0.70	3.30	1.08	0.11	2.48
Prey	Movement_and_storage_of_logs (Substrate_disturbance_sediment_resuspension)	16.71	8.85	24.57	1.07	0.30	2.01
Rockfish	Vessels_discharge (Substrate_disturbance_sediment_resuspension)	0.86	-0.12	2.59	1.07	0.25	1.94
Prey	Finfish_aquaculture (Removal_of_biological_material)	3.20	2.06	4.51	1.06	0.19	2.28
Prey	Finfish_aquaculture (Introductions_nutrients_biological_material)	7.90	5.68	10.24	1.04	0.22	2.12
Prey	Invasive_bottom_long_line_fishery_survey (Substrate_disturbance_sediment_resuspension)	1.01	0.34	1.77	1.02	0.20	1.90
Rocky reef	Finfish_aquaculture (Introductions_nutrients_biological_material)	8.30	5.97	10.81	1.00	0.55	1.39
Rockfish	Shellfish_aquaculture (Introductions_nutrients_biological_material)	3.98	2.12	5.95	0.98	0.29	1.81