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A REGIONAL ASSESSMENT OF ECOLOGICAL ATTRIBUTES IN ROCKFISH CONSERVATION AREAS IN BRITISH COLUMBIA

There are 37 species of rockfish in British Columbia. Inshore rockfish include Quillback (*Sebastes maliger*), Yelloweye (*S. rubberimus*), Copper (*S. caurinus*), Tiger (*S. nigrocinctus*), China (*S. nebulosus*), Black (*S. melanops*), Brown (*S. auriculatus*), and Deacon (*S. diaconus*; often mistakenly considered to be Blue [*S. mystinus*]; Frable et al. 2015). These eight rockfish species aggregate throughout the Pacific Region over rocky areas in nearshore waters generally shallower than 200 m, and have recently experienced precipitous declines in population sizes. This assessment focuses on these eight inshore rockfish species. Rockfish Conservation Areas (RCAs) are harvest refuges (fishery closures or marine refuges) where commercial and recreational fisheries with direct and incidental catch of inshore rockfish have been restricted. Resource managers are interested in knowing whether the RCA network is achieving its conservation objectives, select RCAs can contribute to Canada's 2020 marine conservation targets by meeting Other Effective Area Based Conservation Measure (OEABCM) criteria, and the conservation benefit of certain RCAs might be improved by altering configurations or relocating them.

Context

The Inshore Rockfish Conservation Strategy was developed by Fisheries and Oceans Canada (DFO) in 2001 to help address the precipitous decline of inshore rockfish species. The Strategy focused on improving four areas of rockfish fisheries management:

1. account for all inshore rockfish catch,
2. decrease fishing mortality on inshore rockfish,
3. establish areas closed to fishing, and
4. improve inshore rockfish stock assessment and monitoring.

Under the Fisheries Act, DFO designated RCAs as harvest refuges (fishery closures or marine refuges) where commercial and recreational fisheries with direct and incidental catch of inshore rockfish were restricted to decrease fishing mortality of exploited inshore rockfish populations within RCA boundaries and provide opportunities for these species to rebuild. In addition, RCAs protect rockfish habitat from impacts of fishing activities caused by certain types of bottom contact fishing gear. All 164 RCAs, totaling approximately 4,800 km^2, were established by 2007 and they protected 28% and 15% of modelled rockfish habitats in the Inside and Outside Management Areas (Figure 1), respectively (Yamanaka and Logan 2010). The design was considered to be a 'network'; it was believed many smaller areas located close together would facilitate movements of larvae and adults between protected areas, and provide spillover to adjacent areas open to fishing.

In 2010, the Government of Canada agreed to conserve 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; Government of Canada 2011). Since then, Canada has reaffirmed this international commitment for Canada. In 2016, the Minister of Fisheries and Oceans Canada announced a plan to reach our domestic marine conservation targets of protecting five percent of Canada's marine and coastal areas by 2017 and ten percent by 2020. Five areas of action to support reaching Canada's marine conservation targets have been laid out, 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 (International Union for Conservation of Nature and Convention on Biological Diversity; Convention on Biological Diversity 2010), domestic discussions, and DFO science advice (Canadian Council of Ecological Areas; DFO 2016b), and identifies five criteria that area-based management measures must meet in order to be considered 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, and
5. the ecological components of interest (the important habitat and species identified) are effectively conserved.

In 2016, DFO Fisheries Management conducted a preliminary review of RCAs to evaluate them against OEABCM criteria; however, limited time and data were available and a formal risk assessment was not completed. Consequently, RCAs were initially screened out of the OEABCM process and therefore did not contribute to the 2017 marine conservation targets of five percent protection. Nevertheless, RCAs have the potential to meet the 2020 marine conservation targets of ten percent protection if they can meet all OEABCM criteria. Furthermore, it has been at least 11 years since RCAs were first implemented and it is therefore timely to review their conservation effectiveness and assess whether conservation benefits of particular RCAs can be enhanced by changing configurations or locations. Such changes in boundaries or locations, along with other management tools and measures, may help some RCAs meet all OEABCM criteria.

In 2016, DFO Fisheries Management requested Science Branch identify RCAs that might benefit from changes to their boundaries or locations to better protect inshore rockfish and their habitats. Specifically, they asked Science to "re-evaluate RCA locations given new habitat information / ground-truthing / modeling methods / etc. to estimate the percent coverage of inshore rockfish habitat in Inside and Outside waters (Figure 1), and to identify RCAs that could be moved, altered, or eliminated in order to better protect inshore rockfish habitat." Given the diversity of RCAs throughout the region and the lack of survey data in many areas, additional assessments need to be conducted on an individual RCA basis. As such, this assessment of ecological attributes in RCAs is considered to be the first phase of this request. Complimentary research is a qualitative risk assessment that identified those permitted human activities which may inhibit RCAs from fulfilling their conservation objectives.

Advice arising from this Canadian Science Advisory Secretariat (CSAS) Science Response and Research Document will be used to inform the management of RCAs to ensure conservation objectives are being met. The evaluation will help identify potential measures that may be implemented to support RCAs in achieving their conservation goals and also allow certain RCAs to meet all OEABCM criteria by 2020 and, thus, contribute to marine conservation targets. Results from this research will help inform consultations with First Nations and stakeholders regarding potential changes to existing RCAs.

This Science Response Report results from the Science Response Process of July 2018 on the Assessment of ecological attributes in Rockfish Conservation Areas in British Columbia.

Background

When RCAs were established, rockfish habitat was identified in multiple phases between 2002 and 2006. In 2002, marine charts were used during consultations with stakeholders where participants identified habitat for Quillback and Yelloweye Rockfishes. Areas of socioeconomic importance to fishers (other groundfish, salmon, herring, and shellfish) were also identified using this method so these areas would remain open. Other factors considered included ease of description in fishery regulations, clear recognition by the public, and ease of monitoring and enforcement. In 2003, DFO conducted an internal review of the proposed area closures identified from consultations and compared them to catch data to determine areas of high or medium rockfish value. In 2004, a rockfish habitat model (100×100 m resolution) was developed in GIS using commercial and recreational Quillback and Yelloweye Rockfish catch data from logbooks, and bathymetry data. The model combined fishery catch-per-unit-effort density analysis to highlight areas of high rockfish catch, and a complexity analysis to identify high slope. These two metrics combined were used as a surrogate for rockfish habitat coast-wide. Proposed RCA locations and boundaries were made available for comment during public consultations between 2003 and 2006.

As of 2018, a coast-wide monitoring program has not yet been formally established for the RCA network. Various researchers from governments (federal and First Nations), academia, and NGOs have collected monitoring data related to rockfish and RCAs using Remotely Operated Vehicles (ROV), scuba, and hook-and-line surveys, and also conducted genetic analyses (see Haggarty 2014 for a review of these research initiatives). In general, these studies compared data collected inside RCAs to nearby sites that are open to fishing because no data were collected before RCAs were established, and this, unfortunately, makes it impossible to track whether there are more fish in RCAs since these areas were closed. An important baseline dataset is the first study published on RCAs by Marliave and Challenger (2009) in Howe Sound in 2006 using scuba surveys. More recently there has been some research to study the effectiveness of RCAs in rebuilding inshore rockfish populations (Frid et al. 2016, Haggarty 2015). Recreational (non) compliance in RCAs has been studied in the south coast using aerial surveys (Haggarty et al. 2016), dock-side interviews (Lancaster et al. 2015), and shore-based remote cameras (Lancaster et al. 2017). Having no cohesive monitoring program and very little baseline data, combined with the unique life histories of inshore rockfish (e.g. long-lived), creates challenges when trying to determine the effectiveness of the RCA network.

Analysis and Response

We conducted a regional assessment of four ecological attributes of RCAs (size, rockfish habitat, depth, and connectivity) and their associated metrics using GIS data to provide some indication as to how effective RCAs are as a spatial protection measure for inshore rockfish.

The ecological attributes are:

1. Size:
    a. Minimum size criteria - minimum size recommended for marine protected areas (MPAs); minimum size in relation to the range of movements of adult rockfish.
    b. Distance to nearest boundary - measured from the center of the RCA to the nearest water boundary (not against the shore).
2. Rockfish habitat (rocky reef, kelp forest, eelgrass bed, glass sponge reef):
    a. Proportion (%) of RCA that contains rockfish habitat.
    b. Area (km2) of rockfish habitat in RCA.
    c. Isolation
        i. Boundary to area ratio
        ii. Boundary intersecting habitat ratio.
3. Depth: area in RCAs which encompasses the depth range of inshore rockfish (0 to 200 m), in 50 m depth categories.
4. Connectivity: water distances between RCAs compared to distances larvae disperse.

Spatial analyses were conducted using a GIS with ESRI ArcGIS Desktop software (minimum version 10.4.1). An Albers Equal Area Conic projection (NAD_1983_BC_Environment_Albers) was used. Datasets used for this research are listed in Table 1.

Rockfish habitat was calculated from a GIS layer created using a combination of rocky reef (substrate [20×20m resolution] and multi-beam [5×5m resolution] habitat models), kelp canopy, eelgrass bed, and sponge reef layers.

There are several data caveats, and for the following reasons all calculations should be considered as approximate.

- Islands and lakes in RCAs that would inflate RCA size were removed before calculating areas. RCAs that were adjusted include Broken Group Islands, Copeland Islands, Discovery – Chatham Islands, Duntze Head (Royal Roads), Kanish Bay, Nelson Island, Salmon Channel, Smith Sound, and Viscount Island.
- Coastlines used at the time of creation of the official version of RCAs do not always align with coastlines used in other datasets derived from various sources and compiled at different scales.
- Original rockfish habitat files were digitized at different scales, projections, and used different coastline files for reference, and therefore do not necessarily line up with RCA coastline boundaries. Concerted effort was made to align habitats with RCA boundaries in order to obtain the most accurate results; however, there are still discrepancies.
- The higher resolution (5×5m) rocky reef habitat model does not cover the entire BC coast. In areas where data are unavailable, the lower resolution (20×20m) rocky reef habitat model was used instead. Due to its coarser resolution, the 20×20m model generally overestimates the amount of rocky reef habitat in RCAs compared to the higher resolution model.
- Kelp and eelgrass datasets have not been systematically ground-truthed and may be somewhat outdated.

- Two RCAs are divided between bioregions and management areas. Walken Island to Hemming Bay RCA exists in both the Strait of Georgia and Northern Shelf Bioregions, and Carmanah RCA exists in both the Inside and Outside Management Areas. For this assessment, Walken Island to Hemming Bay RCA is included in the Strait of Georgia Bioregion and Carmanah RCA is included in the Outside Management Area.

Table 1. Datasets used for the regional assessment of RCAs.

Dataset	Source and Date Last Modified
RCAs	DFO 2018[1]
Rocky Reef Habitat Models (5×5m and 20×20m)	DFO 2018 Haggarty and Yamanaka 2018
Eelgrass Bed	BCMCA 2006-2013[2] CRIMS (Province of BC) 2017[3] Harper and Morris 2014
Kelp Canopy	BCMCA 2006-2013 CRIMS (Province of BC) 2017 Harper and Morris 2014
Sponge Reef	DFO 2018 NRCan 2018[4]
Marine Bioregions	DFO 2016[5]
Pacific Fishery Management Areas	DFO 2007[6]
Conservation Areas Reporting and Tracking System (CARTS)	CCEA 2017
Derived 20 m DEM Bathymetry	Davies et al. in prep[7]
80 m DEM Bathymetry	NOAA 2013

BCMCA = BC Marine Conservation Analysis
CCEA = Canadian Council on Ecological Areas
CRIMS = BC's Coastal Resource Information Management System
DFO = Fisheries and Oceans Canada
NOAA = National Oceanic and Atmospheric Administration
NRCan = Natural Resources Canada

[1] DFO 2018. Rockfish Conservation Areas

[2] British Columbia Marine Conservation Analysis. 2006-2013. The British Columbia Marine Conservation Analysis.

[3] Ministry of Forests, Lands and Natural Resource Operations. GeoBC. 2017. Eelgrasses – Coastal Resource Information Management System (CRIMS).

[4] Natural Resources Canada (NRCan). 2018. West Coast Sponge Reefs. Provided by Kung, R (Geological Survey of Canada, NRCan, 2018).

[5] DFO 2016. Federal Marine Bioregions

[6] DFO 2007. Pacific Fishery Management Area Regulations

[7] Davies, S.C., Gregr, E.J., Lessard, J., Bartier, P., and Wills, P. In prep. Development of bathymetric elevation models for ecological analyses in Pacific Canadian coastal waters. Can. Tech. Rep. Fish. Aquat. Sci.

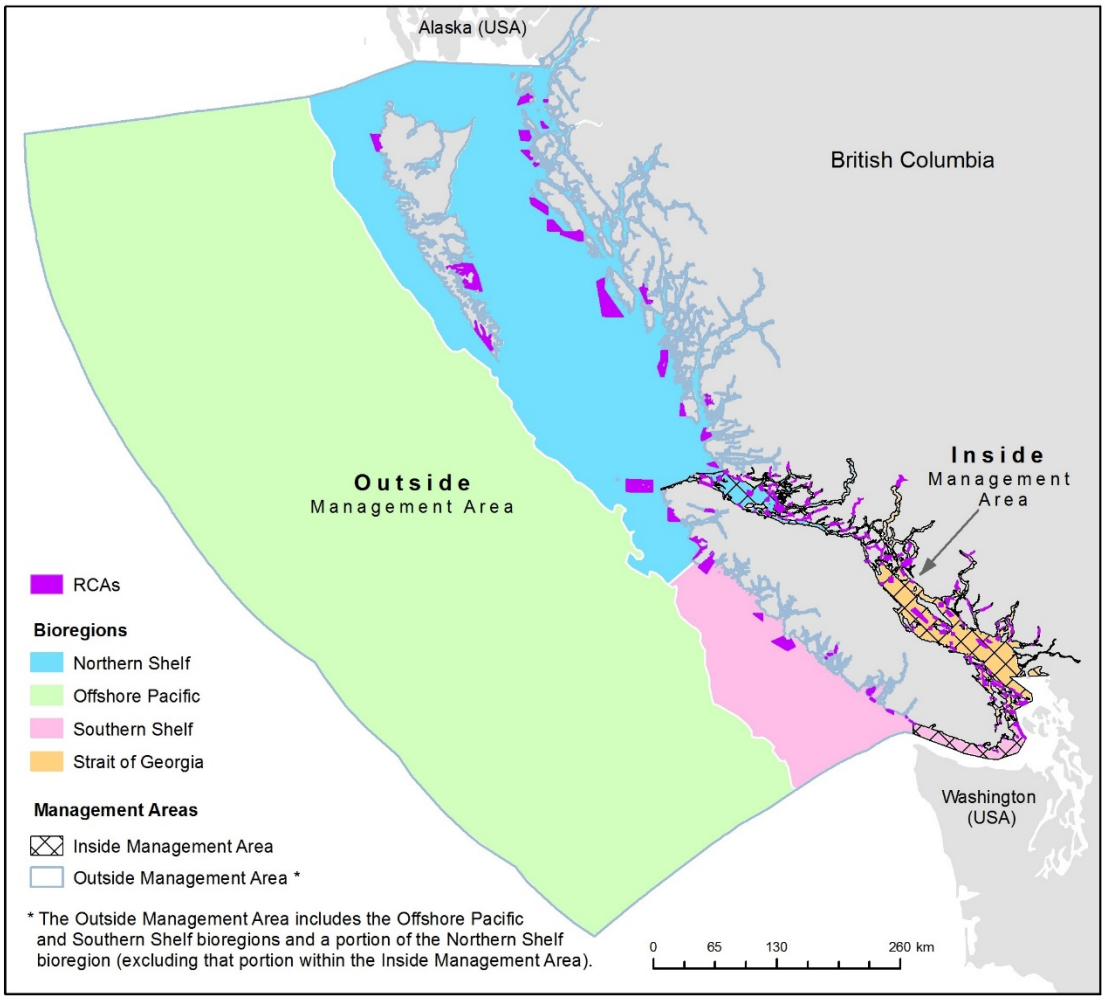

Figure 1. RCAs in relation to bioregions and Inside and Outside Management Areas.

The Inside Management Area includes Pacific Fishery Management Areas (PFMAs) 12 (except Subarea 12-14) to 20, 28, and 29 (Figure 1). The Outside Management Area includes PFMAs 1-11, 21-27, 101-111, 121-127, 130, 142 and Subarea12-14.

Attribute thresholds were derived from the literature and authors' expertise. We took three approaches to our analyses:

1. RCAs were ranked according to individual attributes.
2. RCAs were ranked according to a single index of overall status that is an additive (unweighted) score based on most attributes.
3. RCAs were ranked according to ideal attribute criteria to evaluate how the current network compares to a best case scenario.

RCA Size

Most RCAs (125 or 76%) are smaller than 25 km^2. The median and mean sizes of RCAs are 10.8 km^2 and 29.4 ± 4.7 km^2 (range 0.13 to 493.1 km^2). RCAs are generally smaller in the Strait of Georgia Bioregion and the Inside Management Area.

Sizes of RCAs were compared to recommended MPA sizes (3.4, 5, 10, 12.6, 23-80, >100 km^2; DFO 2017, Burt et al. 2014, Edgar et al. 2014, Hannah and Rankin 2011, California MLPA Advisory Team 2006) and movements/home ranges of adult rockfish (<1, 2.8, 5 km; Burt et al. 2014, Freiwald 2012, Starr and Green 2007, Buonaccorsi et al. 2002, Lea et al. 1999, Matthews 1990, Culver 1986, Love 1980, Miller and Geibel 1973, Gotshall et al. 1965). Mean home range values for six of the eight inshore rockfish species (not Brown and Deacon Rockfishes) are less than 0.5 km (Burt et al. 2014), a distance we used as the threshold minimum distance from the center of the RCA to the nearest fished boundary. Distances rockfish move translate into potential relevant areas necessary to protect them (0.8, 3.4, 5, 6.2, 78.5 km^2).

The number/proportion of RCAs smaller than minimum sizes recommended for MPAs (3.4, 5, 10, 12.6, 23, 100 km^2) is, respectively, 38/23%, 54/33%, 78/48%, 89/54%, 124/76%, and 152/93%. Three RCAs (2%; Hardy Bay – Five Fathom Rock, Bentinck Island, and Passage Island) are smaller than 0.8 km^2, a suggested minimum size for RCAs. Nineteen RCAs (12%) have fished boundaries closer than 0.5 km and may experience high spillover of mature fish (Table 3 in Dunham et al. 2019).

Rockfish Habitat

Rockfish habitat is defined as benthic areas (rocky reef, kelp forest, eelgrass bed, and glass sponge reef) important to the various life stages of inshore rockfish (Frid et al. 2018, Dunham et al. 2018). Two substrate models were used to predict the presence of rocky reef habitat. One model utilized multi-beam data at 5×5m resolution, the other model utilized coast-wide bathymetry data at 20×20m resolution. Multi-beam modeled data do not encompass the entire BC Coast and cover only certain areas in the South Coast. Multi-beam data have been collected in 96 RCAs and are not available for 68 RCAs, 48 of which are located in the South Coast and 20 in the Central and North Coast. For the 68 RCAs with no coverage of high resolution multi-beam modeled data, we used the coast-wide lower resolution data to conduct our analysis.

Kelp forest and eelgrass bed linear features were converted to areas using a 20 m buffer (the rationale for this buffer size is the rocky reef model used 20×20m resolution bathymetry data). Areas of kelp and eelgrass may be under- or overestimated as the linear extent might have captured presence/absence, but not areal extent. There are 20 RCAs with buffered kelp features and 14 RCAs with buffered eelgrass bed features.

Glass sponge reefs have been mapped using high resolution multi-beam bathymetry data. The presence of sponge reefs were confirmed in most cases by ROVs and/or acoustic methods (NRCan 2018). We also incorporated a dataset included as part of a DFO Science Response (DFO 2018) which consists of 22 sponge aggregations (bioherms and gardens) recently identified in Howe Sound.

We considered three metrics for rockfish habitat:

1. the proportion of individual RCAs comprised of rockfish specific habitat,
2. the total area (km^2) of rockfish habitat in individual RCAs, and
3. habitat isolation and spillover.

Two metrics were used to determine habitat isolation: the boundary to area ratio, and the length of boundary intersecting rockfish habitat ratio. Biodiversity objectives are better served by reserves that have higher area and minimized edges, and where boundaries conform to natural habitat edges rather than intersect habitats (Fernandes et al. 2012, Gaines et al. 2010, McLeod et al. 2009, Bartholomew et al. 2008).

The following equations were used from Bartholomew et al. (2008):

1. Boundary to area ratio = Reserve Perimeter (RP) / Total reserve Area (RA)
2. Length of boundary intersecting habitat = Reserve boundary that intersects reef habitat (HI) / reef habitat area within the reserve (HA)

Higher ratio values may indicate less habitat isolation and potentially more spillover from closed to harvested areas.

The total area of rockfish habitat protected in all RCAs is 1,253.9 km^2. The proportion of RCA area that is rockfish habitat is 26%. Considerably more rockfish habitat and RCA area are protected in the Northern Shelf Bioregion (957.9 km^2 and 28.8%) and Outside Management Area (970 km^2 and 29.7%). The least amount of habitat is protected in the Strait of Georgia Bioregion (142.5 km^2 and 15.2%) %) which has, compared to other bioregions, the smallest area of rockfish habitat.

Thirty-four RCAs (21%) contain less than 10% rockfish habitat and therefore by definition (California MLPA Advisory Team 2006) may contain a small amount of habitat and may not support high abundances of fish which would limit population rebuilding efforts (Table 6 in Dunham et al. 2019[9]).

One hundred and twenty-three RCAs (75%) contain, on average, 1.5 ± 0.12 km^2 (mean ± SE) of rockfish habitat. Fifty-one RCAs (31%) contain less than 0.8 km^2 of rockfish habitat within their boundaries (Table 8 in Dunham et al. 2019[9]) and 105 RCAs (64%) contain less than 3.4 km^2 of rockfish habitat.

Fifteen RCAs (9%) have a combined total of 7.9 km^2 of documented biologically significant glass sponge reefs within their boundaries (Table 9 in Dunham et al. 2019[9]).

RCAs where spillover of adult fish may be higher, as indicated by the boundary to area ratio and the length of boundary that intersects habitat ratio, are listed in Tables 10 and 11 in Dunham et al. (2019[9]).

Depth

DEM bathymetry rasters (20 and 80 m) were converted to polygon layers and depth values reclassified using 50 m intervals. The total area for each depth class was calculated in each RCA.

RCAs are more often situated in shallow compared to deep water. The mean size of RCAs is 29 km^2, and almost half of this area (47%) is shallower than 50 m, and 76% of this area is shallower than 100 m. Most of the area in RCAs (88%) is less than 150 m deep.

Twenty RCAs (12%) are not deeper than 50 m and 19 more have less than 10% of their area deeper than 50 m (Table 14 in Dunham et al. 2019[9]). Therefore, 39 RCAs (24%) generally do not protect depths greater than 50 m and would be preferred by Black, Copper, and China Rockfishes. Fifty-nine RCAs (36%) are not deeper than 100 m and do not provide optimal depth coverage for Yelloweye, Quillback, and Tiger Rockfishes.

In contrast, 13 RCAs (8%) essentially incorporate no areas shallower than 50 m and therefore do not provide optimum depth coverage for Black, China, and Copper Rockfishes (Table 15 in Dunham et al. 2019[9]).

Connectivity

We considered two key distances (100 and 50 km) related to fish larvae and juvenile dispersal and the nearest distance between adjacent protected areas (Lotterhos et al. 2014, Burt et al. 2014, CDFG 2008, OSPAR 2007, Shanks et al. 2003). Connectivity between RCAs was

determined using the distance over water between nearby RCAs (Haggarty 2014, Lotterhos et al. 2014). Hydrodynamic distance was not considered which may increase uncertainty in the results. The analysis of connectivity included only RCAs and not other protected areas.

The most isolated RCA is Frederick Island on the northwestern tip of Haida Gwaii. The closest RCAs on Haida Gwaii (South Moresby) and the mainland (Dunira) are 217 and 165 km away, respectively. South Moresby RCA is 93 km from the nearest RCA on Haida Gwaii (Lyell Island) which is, in turn, 86 km from the nearest RCA on the mainland.

A barrier to connectivity in the central coast might exist between McMullin Group RCA and Kitasu Bay/Aristazabal Island RCAs. These RCAs are separated by Milbanke Sound (a distance of 53 km). Furthermore, both McMullin Group/Goose Island RCAs and Kitasu Bay RCA are 20-50 km from only one nearby RCA.

Three connectivity gaps may exist on the west coast of Vancouver Island. Along the southern shore of Vancouver Island in the Juan de Fuca Strait, Sooke Bay RCA and Carmanah RCA are separated by a distance of 71 km. The Broken Group Islands RCA is 59 km from three small, more inland RCAs near Tofino, and 93 km from Estevan Point RCA. Although the West of Bajo Reef RCA is connected to Estevan Point RCA to the south, it is 65 km from Checleset Bay RCA to the north, separated by Esperanza Inlet and Kyuquot Sound. West of Bajo Reef RCA is somewhat isolated because only one RCA lies within 20-50 km away.

In general, RCAs located at the heads of inlets tend to be further away from other RCAs and may experience less larvae input from other areas. Bute Inlet North RCA is 77 km from the nearest RCA (Octopus Islands to Hoskyn Channel). Three RCAs (Queens Reach East and West, and Princess Louisa Inlet) clustered at the head of Jervis Inlet are collectively 56 km from the nearest RCA. Similarly, Holberg Inlet RCA is 53 km from the nearest RCA.

Index of Overall Conservation Status

By assigning scores to the various attributes, the authors were able to combine attributes into a single index which allowed us to rank and prioritize RCAs. Attributes, their associated metrics, and key values are summarized in Table 2.

Each attribute category, derived from key values, was assigned a score (Table 3). The attribute “overall size” was not included in the additive scoring, the rationale being RCA size is highly correlated with “area of rockfish habitat”. Attributes were not weighted, but can be weighted in the future if particular ones are determined to be higher priority for management.

Each attribute and its corresponding metrics were scored between zero and one, with zero being the least desirable (Table 3). Scores were based on corresponding bin values which were determined from the literature or calculations (in Table 2). Scores assigned between zero and one for a particular metric reflect the number of bins and how bin values correlate to rockfish conservation.

Additive scores could theoretically range from zero to seven, with zero being undesirable (assumed to have lower conservation benefit to rockfish) and seven being the most desirable (assumed to have higher conservation benefit). The mean score is 4.1 (range = 1.63 to 6.01). Scores are highest in the Northern Shelf Bioregion (mean = 4.68) and lower in the Southern

Shelf (mean = 3.79) and Strait of Georgia (mean = 3.77) Bioregions. These scores suggest RCAs in the Northern Shelf Bioregion may provide higher conservation benefit to rockfish compared to RCAs in other bioregions. Values for all RCAs are listed by bioregion in Table 4 in rank order beginning with the lowest scoring RCA (1.63), Hardy Bay – Five Fathom Rock in the Northern Shelf Bioregion. This RCA, and others near the top of the list, scored poorly on most

attributes except connectivity. In general, these RCAs are small and shallow with potentially fished boundaries not far from the center, and contain little rockfish habitat that may not be well isolated within their boundaries meaning there may be a high degree of spillover. RCAs with the lowest scores in the Southern Shelf and Strait of Georgia Bioregions are Bentinck Island (2.0) and Mariners Rest (1.85), respectively.

Table 2. Key values used to provide thresholds for scoring attributes and their metrics. Bolded values are used as ideal attribute criteria.

Attribute	Metric		Key Values	Rationale	Comments
Size	Minimum MPA	-	**5**, 10, 13, 23-80, 100 km^2	DFO (2017), Burt et al. (2014), Edgar et al. (2014), California MLPA Advisory Team (2006)	5 km^2 is based on fish movements; other values are related to biodiversity
	Rockfish movements	-	3.4-15, 6.2, 78.5 km^2	Hannah and Rankin (2011)	Minimum size of MPAs that provide some protection to rockfish = 3.4 A circle with a diameter of 2.8 km (home ranges of various rockfish species; radius 1.4 km) = 6.2 A circle with a radius of 5 km = 78.5
	Distance to fished boundary	-	**≥0.5** km from center to nearest boundary **0.8** km^2	Dunham (2018)	Minimum RCA size might be 0.8 km^2 (area of a circle with radius = 0.5 km; mean home ranges for rockfish)
Rockfish Habitat	Proportion	-	**≥10%**	California MLPA Advisory Team (2006)	-
	Area	-	0.8, **3.4**, 5, 6.2 km^2	Hannah and Rankin (2011), California MLPA Advisory Team (2006)	-
	Spillover	Boundary to area ratio	1.42, **1.58**, 1.92, 3.93	C/A	Based on area (A) and circumference (C) of circles with Area Key Values
		Boundary intersecting habitat ratio	**0.28**, 0.7, 1.24	Quartiles	Derived from calculated RCA ratio values
Depth	50 m depth categories	-	% RCA in each depth category **0-200** m	Frid et al. (2016), Haggarty et al. (2016), Burt et al. (2014), Lotterhos and Markel (2012), Markel (2011), Love et al. (2002)	-
Connectivity	Distance to nearest RCA	-	20, **50**, 75, 100 km	Lotterhos et al. (2014), Burt et al. (2014), CDFG (2008), OSPAR (2007)	-

Table 3. Scores assigned to ecological attribute categories and used to calculate an index of overall conservation status for Rockfish Conservation Areas. Scores range between 0 and 1.

Distance (km) from the center to nearest fished boundary: Score Bin 0 < 0.5 0.50 = 0.5 to 0.99 0.75 = 1 to 1.49 0.90 = 1.5 to 2.0 1 > 2 • mean home ranges of six rockfish species <0.5 km • used 0.5 km categories	***Proportion (%) of rockfish habitat:*** Score Bin 0 < 10% 0.10 = 10 to 20 0.30 = 20.1 to 30 0.40 = 30.1 to 40 0.50 = 40.1 to 50 0.60 = 50.1 to 60 0.70 = 60.1 to 70 0.80 = 70.1 to 80 0.90 = 80.1 to 90 1 = 90.1 to 100 • 10% or less considered virtually absent • used 10% categories
Area (km^2) of rockfish habitat: Score Bin 0 < 0.8 0.25 = 0.81 to 3.39 0.75 = 3.4 to 4.99 0.90 = 5 to 6.19 1 > 6.2 • four key small protected area sizes (km^2): 0.8, 3.4, 5.0, 6.2; see Table 2 for rationale	***Boundary to area ratio:*** Score Bin 0 > 3.93 0.25 = 1.92 to 3.93 0.50 = 1.58 to 1.91 0.75 = 1.42 to 1.57 1 < 1.42 • Based on areas and circumferences of circles 0.8, 3.4, 5.0, and 6.2 km^2; see Table 2 for rationale
Boundary intersecting habitat ratio: Score Bin 0 > 1.24 0.33 = 0.70 to 1.24 0.66 = 0.28 to 0.69 1 < 0.28 • quartiles (25% = 0.28, 50% = 0.70, 75% = 1.24) derived from calculated RCA ratios	***Depth (m):*** Score Bin 0-0.20 = 0 to 50 0-0.20 = 50 to 100 0-0.20 = 100 to 150 0-0.20 = 150 to 200 0-0.20 > 200 • most RCAs have more than one depth category • score assigned is equal to the % of area in each category; maximum score for each category is 0.20 even if the % of area in the depth category is >20% • final score is sum of all categories
Connectivity (km): Score Bin 0 > 100 0.25 = 75 to 100 0.50 = 50 to 74.9 0.75 = 20 to 49.9 1 < 20 • values between 20 and 100 km with a focus on two key distances, 50 and 100 km	

Table 4a. Ecological attribute values, additive scores, and rank for RCAs in the Northern Shelf Bioregion. RCAs are listed in rank order beginning with the lowest score to highlight those areas which may have lower conservation benefit to rockfish.

RCA	Overall Size (km^2)	Distance to Fished Boundary (km)	Habitat %	Habitat Area (km^2)	Ratio Boundary to Area	Ratio Boundary Intersect Habitat	Depth (%<100 m)	Distance to nearest RCA (km)	Score	Rank	Habitat Model
Hardy Bay - Five Fathom Rock	0.1	0.2	12.7	0.0	9.7	0.9	100	15.5	1.63	133	5
Haddington Passage	2.5	0.6	16.5	0.4	3.3	3.5	99	10.3	2.10	126	20
Cracroft Point South - Sophia Islands	2.7	0.5	38.2	1.0	1.6	2.7	94	4.9	2.44	122	5
Gull Rocks North	5.9	0.9	8.7	0.5	1.9	1.1	66	21.0	2.51	120	20
Bond Sound	3.8	0.5	6.0	0.2	1.9	1.9	37	4.3	2.58	117	20
Forward Harbour	3.3	3.0	3.0	0.1	0.2	1.7	89	1.6	3.20	98	20
Hodgson Reefs	11.5	1.3	19.2	2.2	0.9	1.4	92	12.0	3.30	94	20
Port Elizabeth	6.0	1.4	4.6	0.3	0.1	0.6	96	12.4	3.66	82	5
Browning Passage - Hunt Rock	10.0	1.0	33.3	3.3	0.9	1.5	71	3.5	3.75	79	5
Mackenzie - Nimmo	4.0	1.7	13.2	0.5	0.5	0.6	74	2.9	3.86	74	20
Havannah Channel	32.1	0.4	18.4	5.9	0.4	0.8	61	3.8	4.06	68	5
Eden-Bonwick-Midsummer-Swanson Islands	68.7	0.4	35.6	24.4	0.6	0.7	97	1.6	4.14	65	5
Kwatsi Bay	3.4	1.4	8.4	0.3	0.4	0.6	39	4.3	4.19	64	20
Drury Inlet - Muirhead Islands	11.7	1.8	11.7	1.4	0.2	0.1	92	20.9	4.20	63	20
Lower Clio Channel	13.9	2.6	15.9	2.2	0.2	0.4	94	4.7	4.21	62	5
Thompson Sound	14.0	2.5	5.1	0.7	0.5	0.4	23	6.1	4.22	61	20
Frederick Island	113.9	3.2	36.1	41.1	0.3	0.3	99	165.0	4.26	60	20
Wakeman Sound	12.5	2.4	2.8	0.4	0.2	0.6	24	13.0	4.32	58	20
Viscount Island	21.9	3.0	9.6	2.1	0.3	1.2	41	1.7	4.34	57	5
Nowell Channel	12.5	0.8	33.0	4.1	0.7	0.7	96	1.6	4.40	56	20
West Cracroft Island - Boat Bay	3.6	0.6	51.9	1.9	1.4	1.2	64	4.9	4.44	54	5
Chancellor Inlet East	3.5	2.1	27.1	0.9	0.5	0.6	94	2.8	4.53	52	20

RCA	Overall Size (km^2)	Distance to Fished Boundary (km)	Habitat %	Habitat Area (km^2)	Ratio Boundary to Area	Ratio Boundary Intersect Habitat	Depth (%<100 m)	Distance to nearest RCA (km)	Score	Rank	Habitat Model
Brooks Bay	72.3	0.9	12.3	8.9	0.4	0.6	95	9.9	4.53	52	5
Belleisle Sound	5.1	2.0	10.0	0.5	0.0	0.3	43	13.0	4.54	51	20
Browning Island to Raynor Group	17.4	0.9	49.3	8.6	0.8	0.8	95	3.6	4.59	49	20
Wellborne	23.0	1.7	12.0	2.7	0.2	0.3	65	1.6	4.64	48	20
Burley Bay - Nepah Lagoon	10.7	2.3	11.6	1.2	0.2	0.3	88	2.9	4.76	43	20
South Moresby	132.9	3.3	31.1	41.3	0.2	0.3	94	93.0	4.76	43	20
Greenway Sound	17.9	1.9	8.0	1.4	0.1	0.1	53	13.7	4.91	39	20
Topknot	96.1	4.2	10.4	10.0	0.3	0.4	98	21.2	4.91	39	5
Susquash	8.1	0.6	44.2	3.6	1.1	0.2	94	11.7	4.95	37	20
Dickson - Polkinghorne Islands	15.9	1.4	47.6	7.6	0.6	0.7	96	3.8	4.99	35	20
Upper Call Inlet	21.1	7.5	5.5	1.2	0.0	0.1	52	3.8	5.01	34	20
Bate - Shadwell Passage	17.8	1.5	25.1	4.5	0.5	0.6	95	3.2	5.01	34	5
Shelter Bay	15.6	1.4	27.1	4.2	0.7	0.7	68	1.4	5.06	33	5
Salmon Channel	14.1	1.6	28.3	4.0	1.1	1.2	41	2.1	5.06	33	20
Lyell Island	331.8	8.3	18.2	60.5	0.2	0.1	68	86.0	5.07	32	20
Loughborough Inlet	37.1	13.1	2.8	1.1	0.0	0.2	44	12.8	5.10	30	20
McMullin Group	68.8	3.6	56.8	39.1	0.5	0.5	94	53.0	5.12	29	20
Scott Islands	339.2	6.5	9.3	31.5	0.2	0.1	94	24.0	5.20	27	5
Fish Egg Inlet	28.2	1.0	23.8	6.7	0.1	0.1	84	27.0	5.22	26	20
Chancellor Inlet West	13.9	3.0	17.6	2.4	0.3	0.2	46	2.8	5.23	25	20
Numas Islands	28.9	2.3	14.3	4.1	0.8	0.3	17	7.7	5.24	24	20
Holberg Inlet	22.5	4.5	27.1	6.1	0.1	0.1	77	52.8	5.29	22	20
Storm Islands	37.3	1.9	38.2	14.2	0.7	0.9	52	5.5	5.29	22	20
Bolivar Passage	16.7	1.4	58.1	9.7	0.9	0.9	70	4.2	5.33	21	5
Weynton Passage	17.6	1.6	43.4	7.6	1.1	1.2	75	7.6	5.34	20	5
Smith Sound	69.8	3.8	31.6	22.0	0.4	0.3	83	27.0	5.36	19	20

RCA	Overall Size (km^2)	Distance to Fished Boundary (km)	Habitat %	Habitat Area (km^2)	Ratio Boundary to Area	Ratio Boundary Intersect Habitat	Depth (%<100 m)	Distance to nearest RCA (km)	Score	Rank	Habitat Model
Otter Passage	162.5	3.7	23.8	38.7	0.3	0.3	50	44.0	5.50	17	20
Goschen	14.5	1.7	58.9	8.5	0.8	0.4	100	10.0	5.56	14	20
North Danger Rocks	128.8	4.3	15.1	19.5	0.4	0.1	76	5.0	5.63	12	20
Goletas Channel	36.7	7.2	19.7	7.2	0.2	0.1	19	1.4	5.64	11	5
Gull Rocks South	20.9	1.9	24.7	5.2	0.9	0.1	80	17.0	5.64	11	20
West Calvert	57.1	2.4	42.0	24.0	0.4	0.1	99	27.0	5.65	10	20
Stephens Island	112.0	5.1	34.1	38.2	0.4	0.3	76	10.0	5.70	9	20
West Aristazabal Island	493.1	5.5	42.9	211.5	0.2	0.1	85	29.0	5.80	7	20
Goose Island	105.5	3.9	52.8	55.6	0.5	0.2	93	33.0	5.81	6	20
Kitasu Bay	64.8	2.3	22.4	14.5	0.3	0.2	63	29.0	5.81	6	20
Porcher Peninsula	50.1	2.1	61.5	30.8	0.5	0.2	100	4.0	5.90	4	20
West Banks Island	154.5	3.6	48.0	74.2	0.4	0.1	98	5.0	5.92	3	20
Dunira	79.0	3.3	39.4	31.1	0.4	0.3	69	12.0	6.01	1	20

Table 4b. Ecological attribute values, additive scores, and rank for RCAs in the Southern Shelf Bioregion. RCAs are listed in rank order beginning with the lowest score to highlight those areas which may have lower conservation benefit to rockfish.

RCA	Overall Size (km^2)	Distance to Fished Boundary (km)	Habitat %	Habitat Area (km^2)	Ratio Boundary to Area	Ratio Boundary Intersect Habitat	Depth (%<100m)	Distance to nearest RCA (km)	Score	Rank	Habitat Model
Bentinck Island	0.6	0.4	28.5	0.2	1.7	3.6	96	0.9	2.00	130	20
Becher Bay East	1.0	0.4	56.5	0.6	3.2	3.1	96	4.7	2.05	128	20
Trial Island	0.8	0.4	83.8	0.7	4.6	2.7	100	4.2	2.10	126	5
Duntze Head (Royal Roads)	0.9	0.3	62.2	0.6	2.8	2.6	99	8.8	2.15	125	5
Sooke Bay	3.4	0.3	57.1	1.9	2.0	2.2	98	10.8	2.30	124	20
Discovery - Chatham Islands	3.2	0.8	47.4	1.5	2.3	3.3	89	3.3	2.70	114	5
Vargas Island to Dunlap Island	2.8	0.9	30.1	0.9	1.7	2.1	100	2.8	2.85	109	20
Race Rocks	2.8	0.6	97.9	2.7	3.0	2.8	100	0.9	3.20	98	5
Saranac Island	10.9	1.0	11.0	1.2	0.8	1.2	99	1.2	3.58	84	20
Dare Point	3.5	0.8	51.0	1.8	1.4	1.0	99	3.0	3.88	73	20
Carmanah	8.2	0.6	54.2	4.5	1.3	1.7	96	3.0	4.05	69	20
Bedwell Sound	15.4	3.7	12.2	1.9	0.2	0.3	99	1.2	4.41	55	20
West of Bajo Reef	41.8	2.1	18.9	7.9	0.8	1.0	100	23.2	4.58	50	20
Pachena Point	19.3	1.2	45.3	8.7	0.7	0.7	99	12.4	4.78	42	20
Folger Passage	17.0	1.3	26.5	4.5	1.1	0.5	89	1.8	4.87	41	5
Checleset Bay	149.4	4.7	14.3	21.4	0.2	0.3	98	9.9	5.51	16	5
Estevan Point	186.3	5.1	30.8	57.4	0.3	0.2	100	23.2	5.55	15	20
Broken Group Islands	39.7	2.0	60.4	23.9	0.5	0.5	99	1.8	5.56	14	5
D'Arcy Island to Beaumont Shoal	53.9	1.2	21.0	11.3	0.9	0.2	49	3.3	5.93	2	5

Table 4c. Ecological attribute values, additive scores, and rank for RCAs in the Strait of Georgia Bioregion. RCAs are listed in rank order beginning with the lowest score to highlight those areas which may have lower conservation benefit to rockfish.

RCA	Overall Size (km^2)	Distance to Fished Boundary (km)	Habitat %	Habitat Area (km^2)	Ratio Boundary to Area	Ratio Boundary Intersect Habitat	Depth (%<100m)	Distance to nearest RCA (km)	Score	Rank	Habitat Model
Mariners Rest	1.9	0.5	9.3	0.2	2.0	1.3	66	3.6	1.85	132	5
Patey Rock	0.9	0.4	41.2	0.4	4.3	1.5	100	9.3	1.90	131	5
Mid Finlayson Arm	1.9	0.3	8.8	0.2	2.5	2.0	47	5.5	2.03	129	5
Passage Island	0.8	0.4	36.3	0.3	3.8	4.1	91	0.4	2.08	127	5
Danger Reefs	1.5	0.4	29.2	0.9	3.6	1.5	99	0.7	2.15	125	20
McNaughton Point	2.2	0.4	37.0	0.8	2.8	2.0	92	3.0	2.34	123	5
Russell Island	2.4	0.8	26.0	0.6	1.6	2.5	96	2.5	2.50	121	5
Savoie Rocks - Maude Reef	1.7	0.4	34.8	0.6	2.1	0.6	98	3.0	2.51	120	20
Departure Bay	2.7	0.9	6.1	0.2	1.7	0.9	99	3.1	2.53	119	5
West Vancouver	2.8	0.6	19.1	0.5	1.9	1.9	62	0.4	2.57	118	5
Baynes Sound - Ship Point	2.5	0.5	1.0	0.0	2.8	0.0	100	4.5	2.65	116	5
Oyster Bay	9.1	1.1	2.9	0.3	1.6	1.3	96	5.0	2.69	115	5
West Bay	1.1	0.7	9.4	0.1	0.7	2.6	83	3.0	2.70	114	5
Reynolds Point - Link Island	4.3	0.7	18.3	0.8	1.5	2.5	98	5.7	2.75	113	20
Chrome Island	3.9	0.7	18.7	0.7	1.4	1.2	97	3.0	2.80	112	20
Upper Centre Bay	1.1	0.6	12.0	0.1	0.8	2.7	93	3.0	2.80	112	5
Pam Rock	5.7	0.3	18.2	1.0	2.1	1.0	49	1.2	2.81	111	5
Maud Island	3.1	0.5	9.9	0.3	1.1	2.7	91	1.9	2.83	110	5
Bedwell Harbour	2.5	0.7	17.3	0.4	1.0	2.0	94	2.2	2.89	108	5
Portland Island	3.0	0.6	60.5	1.8	2.8	2.3	93	2.2	2.90	107	5
Eastern Burrard Inlet	2.8	0.6	2.3	0.1	1.7	0.3	99	5.9	2.92	106	5
Domett Point	2.1	0.6	8.5	0.2	2.6	0.7	13	3.7	2.95	105	5
Coffin Point	4.3	0.9	17.9	0.8	1.4	1.6	98	0.8	3.00	104	20
De Courcy Island North	4.0	0.8	17.1	0.7	1.4	1.0	97	1.2	3.02	103	20

RCA	Overall Size (km^2)	Distance to Fished Boundary (km)	Habitat %	Habitat Area (km^2)	Ratio Boundary to Area	Ratio Boundary Intersect Habitat	Depth (%<100m)	Distance to nearest RCA (km)	Score	Rank	Habitat Model
Brentwood Bay	3.4	0.8	17.2	0.6	1.3	2.4	94	5.5	3.04	102	5
Burgoyne Bay	2.6	0.9	9.4	0.2	0.9	2.2	67	3.1	3.11	101	5
Menzies Bay	3.9	0.9	10.5	0.4	0.7	0.9	84	1.9	3.13	100	20
Walken Island to Hemming Bay	13.6	0.2	23.1	3.1	1.3	1.5	71	2.2	3.19	99	5
Coal Island	3.1	0.6	25.6	0.8	1.4	1.7	99	2.2	3.25	97	5
Heriot Bay	5.1	0.7	21.1	1.1	1.9	1.1	6	4.4	3.27	96	5
Queen's Reach East	4.5	0.4	17.1	0.8	1.7	0.3	20	1.4	3.27	96	5
Woolridge Island	3.8	0.9	17.3	0.7	1.6	0.8	43	3.6	3.29	95	5
Indian Arm - Twin Islands	2.9	0.9	14.1	0.4	1.0	1.7	44	3.7	3.34	93	5
Maple Bay	3.3	0.7	12.4	0.4	0.5	1.1	93	2.5	3.35	92	5
Thurston Bay	6.6	0.5	11.1	0.7	0.5	1.2	84	2.2	3.41	91	5
Trincomali Channel	21.7	0.7	7.7	1.7	0.5	1.2	99	0.9	3.48	90	5
Dinner Rock	6.7	0.8	4.3	0.3	1.1	0.9	47	7.5	3.49	89	5
Thormanby Island	3.3	0.9	30.3	1.0	1.5	2.6	72	3.0	3.52	88	5
Bowyer Island	3.2	0.6	20.7	0.7	3.0	0.4	44	1.1	3.53	87	5
Ballenas Island	5.8	1.1	22.0	1.3	1.6	1.3	31	2.4	3.55	86	5
Deepwater Bay	1.8	0.7	9.3	0.2	0.7	0.6	95	6.8	3.56	85	5
Galiano Island North	9.8	0.9	3.5	0.3	0.9	0.4	97	9.4	3.56	85	5
Ruxton - Pylades Island	6.8	0.6	29.3	2.0	1.8	0.3	99	1.6	3.61	83	20
Prevost Island North	9.1	1.6	20.0	1.8	1.4	1.3	94	2.5	3.67	81	5
Kanish Bay	8.0	2.2	2.8	0.2	0.3	1.0	94	7.4	3.70	80	5
Skookumchuck Narrows	13.2	0.4	15.6	2.1	1.1	0.3	45	8.7	3.75	79	20
Lasqueti South - Young Point	9.3	1.5	4.2	0.4	1.3	1.0	9	2.4	3.76	78	5
Gabriola Passage	2.7	1.0	49.5	1.3	0.6	0.8	93	1.2	3.78	77	5
Queen's Reach West	3.5	0.5	16.6	0.6	1.3	0.8	43	3.5	3.83	76	5
Nanoose - Schooner Cove	12.0	1.2	15.7	1.9	0.9	1.0	97	2.4	3.84	75	5

RCA	Overall Size (km^2)	Distance to Fished Boundary (km)	Habitat %	Habitat Area (km^2)	Ratio Boundary to Area	Ratio Boundary Intersect Habitat	Depth (%<100m)	Distance to nearest RCA (km)	Score	Rank	Habitat Model
McCall Bank	13.4	1.0	6.3	0.8	1.5	0.6	44	4.6	3.89	72	5
Northumberland Channel	14.8	1.2	7.4	1.1	0.7	0.8	68	3.1	3.93	71	5
Pasley Island	12.0	1.5	19.6	2.4	0.9	1.1	77	5.3	4.03	70	5
Lions Bay	4.8	0.8	17.1	0.8	1.2	0.7	32	1.1	4.10	67	5
Halibut Bank	33.0	1.2	4.9	1.6	1.0	0.8	27	4.6	4.13	66	5
Saltspring Island North	8.5	1.8	17.2	1.5	0.6	0.5	97	0.0	4.19	64	20
Navy Channel	8.3	1.8	14.8	1.2	0.6	0.5	98	2.9	4.31	59	5
Valdes Island East	10.1	1.0	19.8	2.0	0.9	0.5	71	7.2	4.40	56	5
Davie Bay	10.2	0.9	12.0	1.2	0.9	0.5	40	5.7	4.41	55	5
Nelson Island	8.7	1.5	25.2	2.2	0.5	0.3	87	3.6	4.49	53	20
Hardy Island	16.0	0.9	11.3	1.8	0.7	0.1	27	4.0	4.54	51	5
Copeland Islands	15.3	1.0	22.8	3.5	1.3	1.5	56	3.8	4.64	48	5
Bell Chain Islets	13.0	0.9	45.8	6.0	1.0	0.9	95	2.9	4.67	47	5
Bute Inlet North	46.2	5.7	9.7	4.5	0.1	0.1	32	77.4	4.70	46	5
Thetis-Kuper Islands	25.7	1.0	22.0	5.7	0.9	0.9	95	0.7	4.71	45	5
Malaspina Strait	28.3	1.7	10.5	3.0	0.8	0.1	0	3.6	4.72	44	5
Mayne Island North	7.1	0.6	54.3	3.8	1.5	0.7	94	0.0	4.72	44	5
Sinclair Bank	19.2	2.1	11.9	2.3	0.9	0.6	16	3.8	4.76	43	5
Indian Arm - Crocker Island	9.0	3.2	11.9	1.1	0.3	0.3	50	3.7	4.88	40	5
Sabine Channel-Jervis-Jedediah Islands	22.4	1.6	20.0	4.5	0.7	1.0	67	2.4	4.94	38	5
Sisters Islets	10.7	1.6	19.4	2.1	1.2	0.2	12	4.3	4.97	36	5
Mitlenatch Island	24.9	2.3	8.9	2.2	0.8	0.2	20	5.0	4.99	35	5
Brethour,Domville,Forrest,Gooch Islands	18.8	1.5	32.3	6.1	0.9	0.9	85	2.7	5.08	31	5
Pendrell Sound	15.3	5.4	16.3	2.5	0.1	0.1	35	6.7	5.19	28	5
Teakerne Arm	8.4	2.6	15.6	1.3	0.2	0.1	42	8.6	5.19	28	5

RCA	Overall Size (km^2)	Distance to Fished Boundary (km)	Habitat %	Habitat Area (km^2)	Ratio Boundary to Area	Ratio Boundary Intersect Habitat	Depth (%<100m)	Distance to nearest RCA (km)	Score	Rank	Habitat Model
Read - Cortes Islands	30.3	2.2	15.7	4.7	0.4	0.3	28	4.4	5.20	27	5
Ajax / Achilles Bank	73.9	1.8	4.7	3.5	0.7	0.1	27	4.3	5.28	23	5
Hotham Sound	22.4	3.0	18.6	4.2	0.2	0.1	25	9.0	5.46	18	5
Princess Louisa Inlet	6.3	4.1	41.7	2.6	0.0	0.0	52	1.4	5.46	18	20
Octopus Islands to Hoskyn Channel	35.9	7.2	15.7	5.6	0.1	0.2	87	4.5	5.51	16	5
Lasqueti Island South	18.5	1.6	21.0	3.9	0.7	0.6	35	6.2	5.55	15	5
South Saturna	30.9	2.3	12.6	3.9	0.5	0.3	48	2.2	5.60	13	5
Salmon Inlet	17.5	5.7	22.1	3.9	0.1	0.1	27	8.7	5.79	8	20
Desolation Sound	60.0	3.6	13.8	8.3	0.2	0.2	33	3.8	5.84	5	5

Table 5. Based on additive scores (≤3) of select ecological attributes, the following RCAs ranked 104 to 133 may have lower conservation benefit for rockfish and their habitats.

Strait of Georgia	***Southern Shelf***	***Northern Shelf***
Mariners Rest	Bentinck Island*	Hardy Bay - Five Fathom Rock*
Patey Rock*	Becher Bay East	Haddington Passage*
Mid Finlayson Arm	Trial Island	Cracroft Point South – Sophia Islands
Passage Island*	Duntze Head (Royal Roads)	Gull Rocks North
Danger Reefs	Sooke Bay*	Bond Sound
McNaughton Point	Discovery – Chatham Islands	-
Russell Island*	Vargas Island to Dunlap Island	-
Savoie Rocks – Maude Reef	-	-
Departure Bay	-	-
West Vancouver	-	-
Baynes Sound – Ship Point	-	-
Oyster Bay	-	-
West Bay	-	-
Reynolds Point – Link Island	-	-
Chrome Island	-	-
Upper Center Bay	-	-
Pam Rock	-	-
Maud Island*	-	-
Bedwell Harbour	-	-
Portland Island	-	-
Eastern Burrard Inlet	-	-
Domett Point	-	-
Coffin Point	-	-

*RCAs identified as having low conservation scores by Haggarty (2015)

More RCAs in the Northern Shelf Bioregion may provide higher conservation benefit to rockfish than in other bioregions (Table 6).

Table 6. The twenty highest ranked RCAs according to their additive attribute scores. These RCAs may provide more conservation benefit to rockfish.

RCA	Bio-region	Overall Size (km^2)	Distance to Fished Boundary (km)	Habitat %	Habitat Area (km^2)	Ratio Boundary to Area	Ratio Boundary Intersect Habitat	Depth (% <100m)	Distance to nearest RCA (km)	Score	Rank	Habitat Model
Dunira	NS	79.0	3.3	39.4	31.1	0.4	0.3	69	12.0	6.01	1	20
D'Arcy Island to Beaumont Shoal	SS	53.9	1.2	21.0	11.3	0.9	0.2	49	3.3	5.93	2	5
West Banks Island	NS	154.5	3.6	48.0	74.2	0.4	0.1	98	5.0	5.92	3	20
Porcher Peninsula	NS	50.1	2.1	61.5	30.8	0.5	0.2	100	4.0	5.90	4	20
Desolation Sound	StG	60.0	3.6	13.8	8.3	0.2	0.2	33	3.8	5.84	5	5
Goose Island	NS	105.5	3.9	52.8	55.6	0.5	0.2	93	33.0	5.81	6	20
Kitasu Bay	NS	64.8	2.3	22.4	14.5	0.3	0.2	63	29.0	5.81	6	20
West Aristazabal Island	NS	493.1	5.5	42.9	211.5	0.2	0.1	85	29.0	5.80	7	20
Salmon Inlet	StG	17.5	5.7	22.1	3.9	0.1	0.1	27	8.7	5.79	8	20
Stephens Island	NS	112.0	5.1	34.1	38.2	0.4	0.3	76	10.0	5.70	9	20
West Calvert	NS	57.1	2.4	42.0	24.0	0.4	0.1	99	27.0	5.65	10	20
Goletas Channel	NS	36.7	7.2	19.7	7.2	0.2	0.1	19	1.4	5.64	11	5
Gull Rocks South	NS	20.9	1.9	24.7	5.2	0.9	0.1	80	17.0	5.64	11	20
North Danger Rocks	NS	128.8	4.3	15.1	19.5	0.4	0.1	76	5.0	5.63	12	20
South Saturna	StG	30.9	2.3	12.6	3.9	0.5	0.3	48	2.2	5.60	13	5
Goschen	NS	14.5	1.7	58.9	8.5	0.8	0.4	100	10.0	5.56	14	20
Broken Group Islands	SS	39.7	2.0	60.4	23.9	0.5	0.5	99	1.8	5.56	14	5
Estevan Point	SS	186.3	5.1	30.8	57.4	0.3	0.2	100	23.2	5.55	15	20
Lasqueti Island South	StG	18.5	1.6	21.0	3.9	0.7	0.6	35	6.2	5.55	15	5
Checleset Bay	SS	149.4	4.7	14.3	21.4	0.2	0.3	98	9.9	5.51	16	5
Octopus Islands to Hoskyn Channel	StG	35.9	7.2	15.7	5.6	0.1	0.2	87	4.5	5.51	16	5
Otter Passage	NS	162.5	3.7	23.8	38.7	0.3	0.3	50	44.0	5.50	17	20
Hotham Sound	StG	22.4	3.0	18.6	4.2	0.2	0.1	25	9.0	5.46	18	5
Princess Louisa Inlet	StG	6.3	4.1	41.7	2.6	0.0	0.0	52	1.4	5.46	18	20
Smith Sound	NS	69.8	3.8	31.6	22.0	0.4	0.3	83	27.0	5.36	19	20
Weynton Passage	NS	17.6	1.6	43.4	7.6	1.1	1.2	75	7.6	5.34	20	5

Evaluating the Network Against Ideal Attribute Criteria

Based on literature reviews and authors' expertise, we evaluated RCAs against the following ideal ecological attribute criteria (see also Table 2):

- minimum size is 5 km^2
- distance to the nearest fished boundary is greater than 0.5 km
- minimum area of rockfish habitat is 3.4 km^2
- boundary to area ratio is less than 1.59
- boundary intersecting rockfish habitat ratio is less than 0.28
- depth ranges from 0 to 200 m
- distance to the nearest RCA is less than 50 km.

Fourteen RCAs (8.5%) meet all of the ideal attribute criteria; five in the Strait of Georgia Bioregion (Ajax/Achilles Bank, Desolation Sound, Hotham Sound, Salmon Inlet, South Saturna), one in the Southern Shelf Bioregion (D'Arcy Island to Beaumont Shoal), and eight in the Northern Shelf Bioregion (Dunira, Fish Egg Inlet, Goletas Channel, Goose Island, Kitasu Bay, North Danger Rocks, West Aristazabal Island, West Banks Island). These are highly ranked RCAs with all but three scoring in the top ten.

Thirty-four RCAs (21%) meet all but one ideal criteria and consequently are good candidates for realistic improvement (Table 21 in Dunham et al. 2019[9]). Minimum area of rockfish habitat is an important criterion; RCAs without significant areas of rockfish habitat will not likely protect many rockfish. Ten RCAs do not have the minimum amount of rockfish habitat; six are in the Strait of Georgia Bioregion (Hardy Island, Mitlenatch Island, Pendrell Sound, Princess Louisa Inlet, Sisters Islets, Teakerne Arm) and four are in the Northern Shelf Bioregion (Chancellor Inlet West, Greenway Sound, Loughborough Inlet, Upper Call Inlet). The conservation benefit of these RCAs would be increased if they protected more rockfish habitat. Fourteen RCAs, five in the Strait of Georgia and nine in the Northern Shelf, may experience higher spillover and might benefit from having their boundaries aligned better with habitat edges. Eight RCAs, one in the Strait of Georgia (Octopus Islands), two in the Southern Shelf (Checleset Bay and Estevan Point), and five in the Northern Shelf, may benefit from increasing the range of depth they cover, if possible. Two RCAs, Bute Inlet North and Lyell Island, might benefit from having other RCAs located closer.

Thirty-six RCAs (22%) meet five out of seven criteria (Table 22 in Dunham et al. 2019[9]). Most of these RCAs might benefit from having their boundaries aligned better with habitat features to limit spillover of adult fish. Furthermore, many of these RCAs would benefit from increasing the amount of habitat they protect in deeper waters.

By improving the above mentioned 70 RCAs, plus the 14 RCAs which already meet the ideal criteria, then 84 RCAs (51%) could potentially provide considerable conservation benefit to rockfish, as long as permitted human activities are having negligible impacts and compliance is high.

Twenty-nine RCAs (18%) meet four out of seven ecological attribute criteria. Twenty-eight RCAs (17%) meet three out of seven criteria. Twenty-three RCAs (14%) meet only one or two of the ideal criteria (Table 23 in Dunham et al. 2019[9]). Essentially the best quality of these RCAs is they are well connected and within 50 km from another RCA. Although one third of these RCAs

are sufficiently wide, most still likely experience high spillover of adult fish. In addition, many are small in size and contain little rockfish habitat that does not extend to an appropriate depth.

Protected Areas Other Than RCAs

To determine the amount of rockfish habitat outside RCAs that is within other protected areas, we used the coast-wide 20×20m rockfish habitat layer, as well as the CARTS dataset which contains protected areas data from all federal, provincial, and territorial jurisdictions (CCEA 2017).

There are 169 protected areas under provincial and federal jurisdiction that contain rockfish habitat (total area within these protected areas is 1,941 km^2; Table 25 in Dunham et al. 2019[9]). Of the provincial protected areas, conservancies contain the largest overall area of rockfish habitat (690 km^2). Of the federal protected areas, Hecate Strait/Queen Charlotte Sound Glass Sponge Reefs MPA, Gwaii Haanas National Marine Conservation Area (NMCA), and Scott Islands Marine National Wildlife Area (mNWA) encompass the most rockfish habitat (420, 290, and 160 km^2, respectively).

Twenty-three protected areas contain more than 10 km^2 of rockfish habitat and account for approximately 1,760 km^2 or 91% of rockfish habitat available in protected areas outside RCAs (Table 26 in Dunham et al. 2019[9]). Fourteen of the 23 protected areas are provincial conservancies. Thirty-eight areas contain at least 3.4 km^2 of rockfish habitat (total 1,856 km^2) and 73 protected areas have at least 1 km^2 of habitat.

The Province of BC does not have the jurisdiction to manage fisheries; therefore, rockfish and their habitat are not protected from fishing pressure in provincial protected areas. In contrast, rockfish and their habitat are somewhat protected in Fisheries and Oceans glass sponge reef protected areas, which is a significant area of rockfish habitat (431 km^2). In total, federal MPAs, NMCAs, mNWAs, and OEABCMs provide some protection to approximately 880 km^2 of rockfish habitat outside RCAs (Table 27 in Dunham et al. 2019[9]), which increases the amount of protected habitat from 1,254 km^2 to 2,134 km^2.

RCAs and federal areas that contribute to achieving the marine conservation targets (MCT) have management measures in place to protect inshore rockfish and their habitat. Therefore, 19.6% and 26.7% of rockfish habitat in Inside and Outside waters, respectively, is afforded some protection (Table 27 in Dunham et al. 2019[9]). Overall, RCAs (14.9%) and federal MCT areas (10.5%) currently protect 25.4% of total rockfish habitat.

Conclusions

RCA Size

Inshore rockfish have small home ranges; therefore, small RCAs may provide conservation benefits to them. Nevertheless, some RCAs may be too small resulting in many mature fish moving beyond boundaries into fished areas. RCAs smaller than 3.4 km^2 (38 RCAs or 23%), and especially 0.8 km^2 (3 RCAs or 2%), and those where fished boundaries are closer than 0.5 km (19 RCAs or 12%), may experience high spillover which might negate conservation benefits.

Even though most inshore rockfish have small home ranges, tagging studies provide evidence rockfish often move beyond their home ranges (Green et al. 2014, Parker et al. 2007). Larger RCAs are precautionary and provide numerous conservation benefits.

Rockfish Habitat

RCAs need to protect significant areas of high quality rockfish habitat (rocky reef, kelp forests, eelgrass beds, glass sponge reefs). No matter their size, RCAs which contain very little rockfish habitat will likely provide limited conservation benefit to inshore rockfish. For this reason the amount of high quality rockfish habitat in RCAs is an important ecological attribute.

Considerably more rockfish habitat and overall area is protected in the Northern Shelf Bioregion and Outside Management Area. RCAs in the Outside Management Area protect 14% of available rockfish habitat which is less than the desired 20% target (from Yamanaka and Logan 2010). RCAs in the Inside Management Area protect 19% of rockfish habitat, considerably less than the desired 30% target (from Yamanaka and Logan 2010).

Many RCAs might contain very little rockfish habitat. According to habitat models, 75% of RCAs contain, on average, 1.5 km^2 of rockfish habitat. Approximately 31% of RCAs contain less than 0.8 km^2 of rockfish habitat compared to 2% whose overall size is less than 0.8 km^2. Most of the rockfish habitat in RCAs is rocky reef; we did not differentiate the types of rocky reef, whether it is complex reefs or smooth bedrock, the former being much more important to rockfish. Consequently, many RCAs might contain very little high quality rocky reef habitat and, therefore, may not support high abundances of fishes which would limit population rebuilding efforts.

The conservation benefit of some RCAs may increase by having their boundaries adjusted to incorporate more rockfish habitat. Smaller RCAs with limited areas of rockfish habitat may have a higher proportion of habitat, yet spillover could be occurring where RCA boundaries intersect habitat patches and fish can move back and forth between protected and fished areas. Boundaries of these RCAs could be adjusted to incorporate entire habitats. Similarly, boundaries of some RCAs could be adjusted to encompass nearby glass sponge reefs which are important habitat for rockfish.

The conservation benefit of RCAs which contain very little rockfish habitat, and none exists nearby, might increase if they are moved to different locations where there is more habitat. Rockfish likely do not live in RCAs where there is no rockfish habitat. In contrast, RCAs with a higher proportion of rockfish habitat, but contain few fish may have been overexploited and fish may return in the future.

Depth

Black, Copper, and China Rockfishes are normally found at depths shallower than 50 m; Quillback, Yelloweye, Tiger, Brown, and Deacon Rockfishes are often found at depths greater than 50 m.

Deeper depths are important to inshore rockfish as size, age, and fecundity of particular rockfish species increase with depth (McGreer and Frid 2017, Frid et al. 2016, Johnson et al. 2003). Rockfish also require a range of depths for feeding opportunities and to survive changing environmental conditions (Green et al. 2014).

RCAs more often protect shallower areas which are prime habitat for Black, Copper, and China Rockfishes. At least 24% of RCAs do not protect habitat in deeper waters utilized by Quillback, Yelloweye, Tiger, Brown, and Deacon Rockfishes.

Depth analyses included all areas within RCA boundaries and were not restricted to rockfish habitat. Recall much of the area in RCAs is not suitable rockfish habitat. RCAs that meet depth criteria may actually not meet the criteria if analyses were constrained to rockfish habitat only.

Connectivity

Demographic connectivity is an important consideration for network design; it depends on the relative contributions of immigrants and local recruitment to population growth rates (Lowe and Allendorf 2010) and requires many more settlers than what is needed to maintain genetic connectivity. The RCA network is well connected at distances of 100 km; however, at 50 km several gaps exist in Haida Gwaii, the central coast, along the west coast of Vancouver Island, and in three long inlets (Bute, Holberg, Jervis). The three RCAs on Haida Gwaii are generally isolated from each other as well as from the mainland. RCAs located at the heads of inlets tend to be isolated from other RCAs and likely will experience less larvae input from other areas.

Connectivity of rockfish habitat is important as breaks in habitat caused by oceanographic features like upwelling, extensive sandy areas, and headlands may be barriers to dispersal for adults and larvae (Lotterhos et al. 2014, Lotterhos et al. 2012).

Index of Overall Conservation Status

Although low scoring RCAs are generally well connected in the network, they are often small and shallow, with potentially fished boundaries not far from the center, and contain very little rockfish habitat that may not be well isolated within their boundaries meaning there may be a high degree of spillover of mature fish. Of those RCAs scoring three or lower or ranked higher than 103, 23 are located in the Strait of Georgia Bioregion, seven are in the Southern Shelf Bioregion, and five are in the Northern Shelf Bioregion. These 35 RCAs (21%) may have lower conservation benefit for rockfish. RCAs in the Northern Shelf Bioregion generally scored higher suggesting these RCAs might be providing more protection to inshore rockfish.

Evaluating the RCA Network Against Ideal Attribute Criteria

Eighty-four RCAs (51%) could potentially provide considerable conservation benefit to rockfish, as long as permitted human activities are having negligible impacts and compliance is high. In contrast, 23 RCAs (14%) may require boundary adjustments or relocation to improve their conservation benefit to rockfish. Many of these RCAs likely experience high spillover of adult fish and are small in size and contain little rockfish habitat that does not extend to an appropriate depth.

Potential Changes to RCAs to Improve their Conservation Benefit to Rockfish

Lower ranked RCAs should be evaluated further to determine whether their conservation benefit to rockfish might be increased through a strategic change, such as adjusting configurations or by relocation. The shape and/or size of a RCA can be modified by adjusting boundaries. A more drastic measure might involve moving a particular RCA to a new location.

The conservation benefit to rockfish of all attributes in RCAs, except connectivity, can be improved by adjusting boundaries and changing configurations. Specifically, increasing the size of RCAs is an effective way to potentially resolve concerns with most attributes. In principle, the size of RCAs should not be decreased where possible.

RCAs with very little rockfish habitat may need to be relocated if additional habitat does not exist at their current locations. Generally, for those RCAs that score poorly for multiple attributes, and these concerns cannot be resolved at their current locations by adjusting boundaries, then they should be moved, or possibly removed from the network.

It might be beneficial to remove the poorest performing RCAs and compensate for their loss by increasing the size of other promising RCAs, or by adding new RCAs. Ideally any changes to

existing RCAs ultimately should not produce a net decrease in the collective area currently protected in the network.

Concerns about connectivity may be resolved by creating new RCAs and strategically locating them throughout the network where gaps exist.

Protected Areas Other Than RCAs

Considerable rockfish habitat exists in other types of protected areas outside the RCA network, especially in federal protected areas such as MPAs, NMCAs, and mNWAs where there is some protection afforded to rockfish and their habitats. Rockfish and their habitat are somewhat protected in Fisheries and Oceans glass sponge reef protected areas, which is a significant area of rockfish habitat (431 km^2). In the Strait of Georgia and Howe Sound Glass Sponge Reef Conservation Areas (OEABCM area), bottom contact fishing gear are prohibited, but salmon trolling and hook and line are permitted. Approximately 16-17% of Gwaii Haanas NMCA provides some protection to rockfish and their habitat (14% is designated as RCAs and 2-3% [six areas, two which overlap with one RCA] is closed to commercial and recreational fishing; Gwaii Haanas NMCA Management Plan 2010). There are four small areas in the NMCA outside RCAs, or approximately 2% (up to 5.8 km^2), that provide some protection to rockfish. In total, federal MPAs, NMCAs, mNWAs, and OEABCMs provide some protection to approximately 880 km^2 of rockfish habitat outside RCAs, which increases the amount of protected habitat from 1,254 km^2 to 2,134 km^2.

The amount of rockfish habitat in Inside waters (19.6%) afforded some protection is considerably less than the desired conservation target of 30%. In contrast, the amount of rockfish habitat protected in Outside waters (26.7%) is higher than the desired conservation target of 20%. Rockfish habitat is also prevalent in provincial conservancies; however, the Province of BC does not have the jurisdiction to manage fisheries and, therefore, rockfish and their habitat are not protected from fishing pressure in provincial protected areas.

Recommendations

RCA Size

1. Consider increasing the size of the smallest RCAs, especially those less than 0.8 km^2. A precautionary minimum RCA size might be at least 3.4 km^2 to conserve inshore rockfish.
2. Based on rockfish movements, a minimum distance from the center to the nearest fished boundaries should be at least 0.5 km, and possibly further to be precautionary. Consider adjusting boundaries in RCAs to ensure they meet the minimum distance.

Rockfish Habitat

1. Consider increasing the area of rockfish habitat protected in RCAs in the Inside and Outside Management Areas to achieve the desired conservation targets of 30% and 20%, respectively. Please refer to “Protected Areas Other Than RCAs” for further refinement related to this recommendation.
2. Consider adjusting boundaries or moving RCAs confirmed to contain less than a threshold minimum area of rockfish habitat.
3. Consider adjusting boundaries of seven RCAs (Hodgson Reefs, Goose Island, Passage Island, West Vancouver, Lions Bay, Ajax/Achilles Bank, Stephens Island) to encompass nearby glass sponge reefs.

4. Strengthen management restrictions in RCAs related to bottom contact fishing gear to provide better protection for sensitive benthic habitats such as glass sponge reefs and gardens, and corals.
5. Consider increasing the size of RCAs that have comparatively higher boundary to area ratio values. Furthermore, consider adjusting the boundaries of RCAs whose boundaries intersect with rockfish habitat so boundaries conform better with habitat edges.

Depth

To improve protection of inshore rockfish species found in deeper water (>50 m), consider adjusting boundaries, and possibly increasing the size, of suitable RCAs to incorporate additional high quality rockfish habitat located at a greater range of depths (at least to 200 m), and isolate continuous habitat within boundaries. Prioritize those RCAs that currently do not protect depths greater than 50 m, and those where less than 10% of their area encompasses depths deeper than 50 m. If particular shallow RCAs are considered to be acceptable, then it should be acknowledged they may not support the recovery of the largest and most fecund individuals for Quillback and Yelloweye Rockfishes (and likely other species).

Connectivity

1. Consider strengthening protection measures for isolated RCAs where it may be more challenging for fish larvae to disperse to, in particular the three RCAs in Haida Gwaii, especially Frederick Island, and RCAs located near the heads of long inlets such as Bute (Bute Inlet North), Holberg (Holberg Inlet), and Jervis (Queen's Reach East and West, and Princess Louisa Inlet) Inlets.
2. Consider creating additional RCAs or integrate other protected areas to ensure distances between RCAs are no more than 50 km to facilitate larval dispersal for many species of inshore rockfish between protected areas:
    a. on the west side of Haida Gwaii between South Moresby Island and Frederick Island RCAs,
    b. in the central coast in Milbanke Sound between McMullin Group and Aristazabal Island RCAs,
    c. on the WCVI:
        i. along the north shore of the Juan de Fuca Strait between Sooke and Carmanah,
        ii. between the Broken Group Islands and Estevan Point,
        iii. between Bajo Reef and Checleset Bay.

Index of Overall Conservation Status

Use existing survey data to test whether the ranking system used in this report accurately describes the conservation status or effectiveness of RCAs.

Evaluating the RCA Network Against Ideal Attribute Criteria

1. Consider improving the conservation benefits of particular RCAs to rockfish, including those listed in:
    a. Table 21 in Dunham et al. (2019[9]) which meet all but one ideal criteria. Consider prioritizing those ten RCAs that do not have the minimum amount of rockfish habitat.

b. Table 22 in Dunham et al. (2019[9]) which meet five of seven criteria.

2. Further evaluation is warranted for, at minimum, the 23 RCAs listed in Table 23 in Dunham et al. (2019[9]) to determine how to improve their conservation benefit to rockfish. These RCAs might be improved by having their boundaries adjusted, moving them to better locations, or possibly removing them from the network.

Potential Changes to RCAs to Improve their Conservation Benefit to Rockfish

1. Further evaluate those RCAs which have the lowest attribute scores to determine how to improve their conservation benefit to rockfish.
2. Before implementing boundary changes or relocating RCAs, consider improving compliance and conducting ecological monitoring.
3. Consider adjusting configurations of low ranking RCAs to improve their conservation benefit to rockfish and their habitat. Strategically increasing RCA size is a good option for resolving concerns with most attributes. Incorporating more rockfish habitat over a broader range of depths and encompassing entire habitat areas to limit spillover of mature fish may also help.
4. Consider moving those RCAs that contain very little rockfish habitat inside and nearby, or score poorly for multiple attributes. Such RCAs can also be removed from the network and their lost area added to more promising RCAs.
5. Any changes to the existing RCA network should not produce a net decrease in the collective area currently protected.
6. Consider creating new RCAs and strategically locate them throughout the network where gaps exist.

Protected Areas other than RCAs

1. Consider protecting an additional 156 km^2 of rockfish habitat in the Inside Management Area if protecting 30% of rockfish habitat is the desired conservation target. One way to achieve this is to adequately protect rockfish habitat that already exists in all protected areas outside RCAs.
2. Consider increasing protection for rockfish and their habitat in protected areas outside RCAs. To prioritize, consider the following:
   a. Sites in the Inside Management Area.
   b. Federal areas in Gwaii Haanas NMCA, Scott Islands mNWA, and Pacific Rim National Park.
   c. Provincial areas in conservancies (especially Duu Guusd, Hakai Luxvbalis, Daawuuxusda), Checleset Bay Ecological Reserve, Boundary Bay Wildlife Management Area, and Broughton Archipelago Provincial Park. If applying management changes to a type of protected area is more preferable than to single protected areas of various types, then increase protection for rockfish in all provincial conservancies using fisheries closures.
   d. Select sites listed in Table 26 (Dunham et al. 2019[9]) to fill gaps and improve connectivity of the RCA network.

Knowledge Gaps

Having no consistent monitoring plan in place since RCAs were established, and limited baseline data, make it more challenging to assess the effectiveness of the RCA network. In our

assessment, we relied on habitat models which are inferior to site-specific ecological monitoring data. The resolution of modelled rockfish habitat we used can be improved in 68 RCAs; in 20 RCAs in the Northern Shelf Bioregion multi-beam data exist, but have not yet been incorporated into habitat models, in 48 RCAs multi-beam data do not exist and need to be collected.

RCAs should be ground-truthed using non-invasive visual survey methods (ROV, tow/drop cameras, scuba) to collect relevant ecological data. Data can also be obtained from sponge reef research and other DFO programs that have used ROVs. Ground-truthing RCAs is important for:

1. increasing our understanding how rockfish associate with different types of habitats,
2. determining the presence, quality, and degree of patchiness of rockfish habitat at various depth categories. RCAs should be evaluated not just based on the presence/absence of rocky habitat, but also on the quality/structural complexity of that habitat,
3. verifying the predictive capabilities of rockfish habitat models and improve them as new data become available, and
4. determining the presence and abundance of rockfish (species, size, sex), as required by OEABCM criteria for conservation and stock management objectives.

A better understanding of the minimum size of RCAs, the minimum distance to fished boundaries, and the minimum area of high quality rockfish habitat is necessary to determine optimal RCA size in relation to rockfish density and diversity.

RCA connectivity analysis can be improved by incorporating:

1. rockfish habitat rather than simply water pathways,
2. other protected areas which effectively conserve rockfish,
3. locations of barriers (sandy areas, upwelling regions, headlands) to the dispersal of adult rockfish and larvae,
4. oceanographic models that describe water movement patterns and,
5. dispersal distances of inshore rockfish species.

The merit of the attributes considered in this research with regard to rockfish conservation and RCA effectiveness could be evaluated using existing survey data from RCAs. In addition, other relevant criteria could be incorporated into RCA conservation scores, such as rockfish bycatch, compliance, and external risks including pollution and climate change.

The RCA network can be improved by identifying locations outside the existing network where there are excellent rockfish habitat and high densities of rockfish.

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This Science Response Report results from the Science Response Process of July 2018 on the Assessment of ecological attributes in Rockfish Conservation Areas in British Columbia.

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