Rockfish conservation areas in B.C.:

Our current state of knowledge

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Table of Contents

Executive summary

Rockfish biology and rockfish conservation area (RCA) research

Inshore rockfish are part of the genus *Sebastes*, a group of fish characterized by extreme longevity, slow growth, relatively large size, old age at maturity, localized movement patterns and poor survival after being discarded. These characteristics make inshore rockfish inherently vulnerable to being overfished and also good candidates for protection in marine protected areas (MPAs) or fishery reserves.

In response to conservation concerns for inshore rockfish, Fisheries and Oceans Canada implemented a system of 164 rockfish conservation areas (RCAs) in British Columbia as part of the Rockfish Conservation Strategy. RCAs were established between 2004 and 2007. RCAs are not marine protected areas (MPAs) since they were not designated though any MPA legislative tool such as Canada's Ocean Act, but rather through a fishery closure using the Fisheries Act. They can, however, be considered harvest refugia.

Evaluations of the performance of RCAs have recently been undertaken by government agencies, academics, non-governmental organizations (NGOs) and First Nations. This report describes the most recent scientific research on RCAs. Research has been done using remotely operated vehicles (ROVs), scuba surveys, hook-and-line fishing surveys, genetic analysis and compliance monitoring.

Although some empirical research shows some RCAs are demonstrating an effect, most have not shown statistical differences in rockfish density among RCAs and non-RCA sites. One reason for this might be that RCAs are still considered to be "new" or "young" and it is thought that rockfish will take numerous years to respond to protection.

Study designs are limited by a lack of data from before the establishment of RCAs, which would allow temporal comparison of populations in RCAs. Other factors impacting the ability to detect change between RCAs and non-RCA sites are low fishing effort adjacent to many RCAs, continued recreational fishing and sub-optimal habitat in some RCAs.

New rockfish habitat modelling work is currently underway and should be applied to an assessment of the effectiveness of RCAs.

Genetic work conducted on rockfish indicates that most RCAs are well-distributed and placed on the coast to allow for connectivity of populations in reserves through larval dispersal. A few RCAs in the system may, however, be isolated. Rockfish populations in inlets have also been shown to be genetically distinguishable from populations on the open coast.

RCA compliance

It was found that recreational compliance in RCAs is low and overall recreational effort in the areas of RCAs did not change between 2003 (pre-establishment) and 2011. Continued recreational fishing effort within RCAs might also be affecting the performance of some RCAs. Education, outreach and enforcement of RCAs should be ameliorated.

Fishing sectors' acceptance of RCAs

Acceptance of RCAs by the commercial, recreational and First Nations fishing sectors was researched for this report.

Representatives of the fishing sectors affected by RCAs were approached and asked questions about their opinions on RCAs and on the health of inshore rockfish populations. Most respondents from all sectors support RCAs and felt they are at least a good form of insurance for rockfish management despite acknowledging there is not any concrete evidence that RCAs are having a positive benefit.

There are anecdotal accounts suggesting that some RCAs may be working but it is difficult to separate the effects of RCAs without considering the effects of other management changes to the commercial and recreational fisheries that were brought in at the same time as RCAs under the Rockfish Conservation Strategy.

Depending on the geographic region they were familiar with, respondents perceived the health of rockfish populations as improving, steady, poor or unknown.

All sectors wanted additional information about the effectiveness of RCAs and felt RCAs must be monitored and evaluated. Most respondents from all sectors also felt additional education about RCAs and much greater enforcement are required.

Commercial and First Nations respondents remarked that sport fishers are still fishing in RCAs. Recreational and commercial fishers felt First Nations fisheries for food, social and ceremonial purposes in RCAs may undermine the conservation objectives.

First Nations fishers felt that the public requires greater education that it is an aboriginal right to fish in RCAs and that First Nations members require more education about rockfish conservation concerns. Respondents from all sectors felt the need to use an adaptive management approach to monitor, evaluate and reassess objectives, and update the RCA strategy, including siting of RCAs.

RCAs as part of a broader MPA network

Planning processes to better manage human activities in the marine environments of British Columbia are currently underway. Some of these processes aim to create a network of MPAs. The system of RCAs was designed as a fisheries management tool and not with a broader MPA network in mind. However, given the high degree of protection these areas already receive from commercial fishing, their broad coverage along the B.C. coast and their existence for almost a decade, there is a need to determine the potential of RCAs to be integrated into a MPA network.

Rockfish are important ecological components of marine systems in B.C. that are still in need of conservation. Rockfish can be considered "flagship species" whose protection will confer protection on other species and habitats that are associated with them.

Habitats other than rocky reefs represented in RCAs include kelp forests, eelgrass beds and soft substrates that often form the majority of RCAs (58 per cent). Numerous species of fish and invertebrates in addition to rockfish have been observed in RCAs, as well as seabirds and marine mammals. Many of the fish species are juvenile stages of important commercial groundfish species. RCAs may, therefore, protect critical juvenile rearing habitats. RCAs should be considered in the development of an MPA network in B.C. RCAs are logical candidates for inclusion in an MPA network since they have been designated and protected from some types of fishing now for almost a decade.

Long-term monitoring of MPAs is necessary to determine their effectiveness. Monitoring data and reserve assessments is also necessary to gain and retain buy in from fishing communities.

Foreword

Much of the empirical research described in this report is in the pre-published or draft stages. The research has been described here to inform participants of the ongoing planning process about RCAs and to allow common access to the most recent scientific research available. When citing this work, please refer back to the original works or contact the primary authors for the most recent versions of their work. Some of the results presented in this report might change with further analysis and with peer review. I want to thank all of the scientists who contributed data to this report and allowed me to summarize their projects and data. I would also like to thank Isabelle Côté for her thoughtful review of this document.


Photo credit: Janna Nichols

Introduction

Fishing is a major human impact to marine ecosystems (Norse 1993, Botsford, Castilla et al. 1997, Pauly, Christensen et al. 1998, Jackson 2001, Lotze, Lenihan et al. 2006). Fishing reduces the abundance of the target species and can erode the age and size structure of fish populations (Pauly, Christensen et al. 2002). The loss of older and larger fish in a population leads to greater variation in recruitment success and increased vulnerability to environmental effects (Pauly, Christensen et al. 2002, Anderson, Hsieh et al. 2008). There is a growing awareness that the high fecundity of marine fish does not make them immune to the threat of extinction and some formerly abundant commercial fish species have even been considered for protection under endangered species legislation (Hutchings 2001, Pauly, Christensen et al. 2002, Dulvy, Sadovy et al. 2003, Dulvy, Ellis et al. 2004, Hutchings and Reynolds 2004). There has also recently been wide acceptance that "fisheries products cannot be extracted from the sea without ecosystem effects" such as reductions of non-target species through bycatch, changes in predator-prey dynamics that cascade through ecosystems and the alteration or destruction of habitats by fishing practices (NRC 2006). These fishery impacts occur simultaneously with large-scale oceanographic events such as El Niño, decadal-scale oscillation and long-term climate change, and the resilience to such effects can be hampered by the effects of fishing, making fish stocks less predictable and more difficult to manage (Pauly, Christensen et al. 2002, Hsieh, Yamauchi et al. 2010, Thrush and Dayton 2010).

A combination of major reductions in fishing capacity, reductions in catch and the use of areas closed to fishing, or Marine Protected Areas (MPAs), is necessary to rebuild fisheries and reverse declines in marine biodiversity (Pauly, Christensen et al. 2002, Worm, Hilborn et al. 2009). Although MPAs may not be a panacea for marine conservation (Allison, Lubchenco et al. 1998), they are considered to be an effective way to conserve rockfish populations (Carr and Reed 1993, Yoklavich 1998, Parker, Berkeley et al. 2000). Many populations of Pacific rockfish (*Sebastes* spp.), have been overfished along the west coast of the United States and British Columbia (Parker, Berkeley et al. 2000, Love, Yoklavich et al. 2002, Williams, Levin et al. 2010, Yamanaka and Logan 2010). MPAs have been established to protect rockfish and other marine life in California, Oregon and Washington State, and a system of reserves, termed Rockfish Conservation Areas (RCAs), has been established in British Columbia (Yamanaka and Logan 2010). Determining if reserves are an effective means of rebuilding rockfish populations is essential to adaptive management and the conservation of rockfish (Babcock, Shears et al. 2010).

At present, there is a planning process being undertaken to better manage human activities in the marine environments of British Columbia's north coast. Part of that planning process is to create a network of MPAs. The system of RCAs was designed as a fisheries management tool and never intended to be a component of a MPA network. However, given the high degree of protection these areas already receive from fishing, their broad coverage along the B.C. coast and their existence for a decade, there is a need to determine the potential of RCAs to be integrated into a MPA network as part of the broader planning process.

In this report, I summarize the most recent scientific research into the effectiveness of the system of RCAs to conserve rockfish in British Columbia. Next, I describe research evaluating the level of acceptance of RCAs from the commercial, recreational and First Nations fisheries sectors. Lastly, I discuss the potential of RCAs to be incorporated into a network of MPAs in British Columbia.

Background

Marine protected areas

MPAs are defined as "any area of inter-tidal or sub-tidal terrain, together with its overlying water and associated flora, fauna, historical, or cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (Kelleher and Kenchington 1992), while the term "marine reserve" is usually used for complete "no-take" reserves (Council 2001, Agardy, Bridgewater et al. 2003). Harvest refugia have been defined as "a location of restricted harvesting of targeted species for the purpose of replenishing exploited populations through larval recruitment" (Carr and Reed 1993). MPAs are a major component of ecosystem-based management (Halpern, Lester et al. 2010, Thrush and Dayton 2010). MPAs have been shown to be a successful strategy to increase the size, abundance and diversity of species protected within and sometimes adjacent to them (Allison, Lubchenco et al. 1998, Mosqueira, Cote et al. 2000, Halpern and Warner 2002, Halpern 2003, Alcala, Russ et al. 2005, Claudet, Osenberg et al. 2008, Lester, Halpern et al. 2009, Babcock, Shears et al. 2010). Interconnected networks of reserves may protect species with dispersing larvae as well as promote spillover effects that support fisheries (Gaines, Lester et al. 2010, Gaines, White et al. 2010).

Although MPAs can be effective tools for conservation, improperly placed reserves or poorly designed networks of MPAs can lead to a false sense of security and could detract from other forms of management (Allison, Lubchenco et al. 1998, Carr and Raimondi 1999, Crowder, Lyman et al. 2000). The potential economic and ecological implications of MPAs have led to the development of a theory of reserve design (Roberts 2000, Airamé, Dugan et al. 2003, Gaines, Gaylord et al. 2003, Hastings and Botsford 2003, Leslie, Ruckelshaus et al. 2003, Roberts, Andelman et al. 2003, Roberts, Branch et al. 2003, Gaines, Lester et al. 2010, Gaines, White et al. 2010). Although the design of an MPA or network of MPAs varies according to the goals of the reserves (i.e., protection of biodiversity versus fishery management) (Carr and Reed 1993, Hastings and Botsford 2003, Gaines, White et al. 2010) and the species targeted, the design criteria include the following considerations: location, shape, size, spacing and the proportion of area protected (Yoklavich 1998, Gaines, Gaylord et al. 2003, Roberts, Andelman et al. 2003, Roberts, Branch et al. 2003, Gaines, White et al. 2010).

The most important criteria for situating the location of an MPA appears to be the quality and diversity of habitats protected, since a diversity of habitats are required to support different species and ontogenetic stages (Yoklavich 1998, Carr and Raimondi 1999, Crowder, Lyman et al. 2000, Roberts, Andelman et al. 2003, Parnell, Dayton et al. 2006). Oceanographic criteria such as currents and upwelling regimes should also be considered in addition to benthic habitats (Gaines, Gaylord et al. 2003). The placement also depends on the goal of a reserve, since boundaries placed within continuous habitat will allow spillover of adults, benefiting fisheries, while boundaries placed beyond the edge of habitats should retain adults (Chapman and Kramer 2000, Gaines, White et al. 2010). The shape of the reserve also affects adult and larval spillover since greater edges or a greater area-to-perimeter ratio increases reserve "leakiness" (Yoklavich 1998) and provides greater opportunity for fishers to exploit the edge of a reserve by "fishing the line" (Kellner, Tetreault et al. 2007). The size of reserves is another important criterion. Although positive effects have been shown for reserves of all sizes (Claudet, Osenberg et al. 2008), larger reserves are usually recommended since small reserves may not be large enough to accommodate viable or persistent populations (Crowder, Lyman et al. 2000, Halpern 2003), larger reserves are required for species with large home ranges (Yoklavich 1998, Carr and Raimondi 1999, Gaines, White et al. 2010) and larger reserves may be less susceptible to environmental or human disturbance and can be easier to enforce (Roberts, Andelman et al. 2003, Kritzer 2004). The shape of the reserve also effects its enforceability since law enforcement officers must be able to clearly identify and prove if people are fishing within a reserve (Yamanaka and Logan 2010).

Networks of MPAs, rather than single reserves, are recommended because most marine populations are open due to pelagic larval dispersal stages. Benefits from multiple reserves may be synergistic so networks are thought to outperform single reserves (Murray, Ambrose et al. 1999, NRC 2000, Botsford, Hastings et al. 2001, Botsford, Micheli et al. 2003, Palumbi 2003, Roberts, Branch et al. 2003, Gaines, White et al. 2010). The spacing of the reserves in a network is, therefore, a key factor determining connectivity among reserves in a network (Gaines, Gaylord et al. 2003, Palumbi 2003, Botsford, Brumbaugh et al. 2009) and should match the larval dispersal distance of the target species (Botsford, Hastings et al. 2001, Gaines, Gaylord et al. 2003, Largier 2003, Gaines, White et al. 2010).

The total proportion of marine habitat to be placed in MPAs is another subject of debate. Modelling studies of this question have found that reserve benefits will be maximized when 20 to 50 per cent of habitat is protected (NRC 2000, Roberts, Branch et al. 2003). More than 1,600 scientists and conservationists called for 20 per cent of marine waters to be protected by 2020 (MCBI 1998). Canada signed the Convention on Biological Diversity which includes a commitment to protect a minimum of 10 per cent of each ecological region in MPAs by 2012. Some authors caution applying blanket targets to conservation since some rare or vulnerable habitats may require more protection than others, and some abundant habitats, such as deep muddy bottoms, probably do not require as much area in a protected area as would be achieved with a blanket target (Agardy, Bridgewater et al. 2003, Carwardine, Klein et al. 2009).

The design of MPA networks involves decisions about the size, location, shape and overall proportion of reserves as well as considerations of the economic cost of displaced fishing activity. Reserve siting algorithms, designed to identify networks of reserves with specific proportions of habitats spread over geographic areas have, therefore, been developed (Sala, Aburto-Oropeza et al. 2002, Airamé, Dugan et al. 2003, Leslie, Ruckelshaus et al. 2003, Leslie 2005).

The RCAs designated in British Columbia by Fisheries and Oceans Canada between 2004 and 2006 as harvest refuges for inshore rockfish are not MPAs (Robb, Bodtker et al. 2011). Robb et al. (2010) argue that they are not MPAs since they were not designated though any MPA legislative tool such as Canada's Ocean Act, but rather through a fishery closure using the Fisheries Act and, therefore, do not meet the International Union for Conservation of Nature (IUCN) definition of an MPA since RCAs lack the permanency of an MPA. RCAs also have no legislative authority over non-fishing activities. An example of this was the RCA adjacent to Texada Island where a barge terminal was permitted (http://www.daviebay.com/). Others, however, consider RCAs to be "de facto" MPAs. RCAs are also not complete "no-take" reserves, but restrict fisheries that target or lead to substantial inshore rockfish bycatch (Yamanaka and Logan 2010). The RCAs objective of rebuilding rockfish populations in RCAs by limiting directed or undirected catch of rockfish is, however, consistent with the idea of rockfish harvest refugia (Carr and Reed 1993, Yoklavich 1998, Yamanaka and Logan 2010). Therefore, the principles of MPA design and evaluation can also be applied to RCAs. Evaluating how RCAs contribute to rebuilding rockfish populations is critical to rockfish management plans and recovery strategies and is necessary to adaptively manage these species. It is also important to understand their effectiveness in order to assess how they can contribute to a system of MPAs in B.C.

Rockfish biology

Rockfish of the genus *Sebastes* are a diverse group with at least 65 species in the northeast Pacific between Alaska and Baja California. Thirty to 36 species are found in British Columbia (Love, Yoklavich et al. 2002). Inshore rockfish populations in B.C. (for which RCAs were designed) are grouped together for management purposes and are defined as species which aggregate over rocky areas in nearshore waters between about zero to 200 metres depth and include quillback (*S. maliger*), yelloweye (*S. rubberimus*), copper (*S. caurinus*), tiger (*S. nigrocinctus*), China (*S. nebulosus*) and black (*S. melanops*) (Yamanaka and Logan 2010) (Figure 1). Other rockfish species often found with inshore species include two small species not targeted by fisheries, Puget Sound (*S. emphaeus*) and greenstriped (*S. elongatus*), and juveniles of yellowtail (*S. flavidus*), canary (*S. pinniger*), redstripe (*S. proriger*), bocaccio (*S. paucispinis*), silvergrey (*S. brevispinis*) and vermillion (*S. miniatus*) rockfish, with adult distribution in deeper waters. Blue (*S. mystinus*), dusky (*S. ciliatus*) and brown (*S. auriculatus*) rockfish are relatively uncommon in most nearshore waters in B.C.

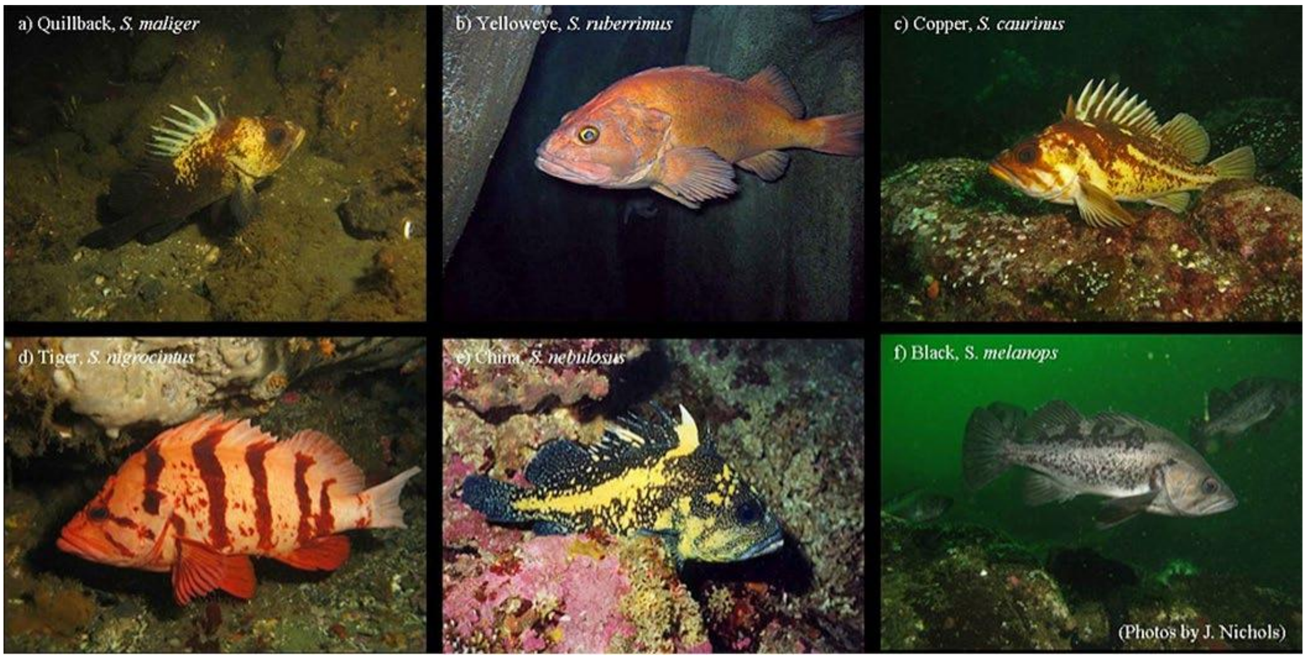

Figure 1 *Images of inshore rockfish species in British Columbia. All species are in the genus,* Sebastes *and are as follows: a) quillback, b) yelloweye, c) copper, d) tiger, e) China, and f) black rockfish. Some common names of rockfish include rock cod, red snapper and black bass. (Photos by Janna Nichols).*

Rockfish species possess life history characteristics that make them intrinsically vulnerable to effects of fishing (Leaman 1991, Parker, Berkeley et al. 2000, Love, Yoklavich et al. 2002). Rockfish have a closed (physoclistic) gas bladder and therefore suffer from barotrauma when they are brought to the surface from depth (Parker, McElderry et al. 2006). Therefore, discarded rockfish suffer high mortality rates (Hannah and Matteson 2007). This characteristic means that catch and release strategies are likely to be ineffective for preventing rockfish mortality as bycatch (Parker, Berkeley et al. 2000, Yamanaka and Logan 2010). Rockfish also display sedentary behaviours that may also contribute to their vulnerability to overfishing. As a result of low movement rates of many rockfish species, once a localized reef has been fished out, it may take many years for the local population to recover via new recruitment (Parker, Berkeley et al. 2000). In addition, fishers will move from one reef to another and serially deplete the reefs while maintaining high catch rates (hyperstability) making early detection of catch declines difficult (Yoklavich 1998, Kronlund and Yamanaka 2001).

Life history characteristics such as maximum age, large size, and late age at maturity also make rockfish vulnerable to overfishing (Table 1). Rockfish are long-lived and have delayed sexual maturity and slow asymptotic growth for up to 50 per cent of their lives (Leaman 1991). Age at maturity is variable but is typically between five and seven years and can be as old as 20 years or 50 centimetres long. Consequently, many species reach marketable size prior to becoming sexually mature (Parker, Berkeley et al. 2000). Delayed maturity and increased lifespan will be adaptive if mortality is primarily on pre-reproductive individuals or if the expectation of successful reproduction is low. As a result, rockfish have little buffering against the effects of reduced lifespan induced by exploitation (Leaman 1991). Although viviparous, rockfish can be extremely fecund, producing between 10,000 and up to nearly three million larvae, depending on the species and size/age of the female (Love, Yoklavich et al. 2002) (Table 1). However, high fecundity rates do not appear to mitigate risk of extinction or enable more rapid recovery from exploitation (Dulvy, Sadovy et al. 2003). Long-lived species including rockfish typically undergo numerous years of low recruitment interspersed with occasionally high or extremely good cohorts when oceanographic conditions are favourable. Since years of favourable conditions may be few and far between, longevity has been referred to as the "storage effect" (Dulvy, Sadovy et al. 2003). Truncating the age structure of long-lived fish through fishing therefore increases extinction risk and reduces the recovery potential (Dulvy, Sadovy et al. 2003).

Life-history traits of fish were used in an evaluation of intrinsic vulnerability to extinction. Maximum length, age at first maturity, longevity, von Bertalanffy growth parameter *K*, natural mortality rate, fecundity, strength of spatial behaviour and geographic range were used as input variables in a fuzzy logic expert system and rated on a scale of one to 100 with 100 being the most vulnerable (Cheung, Pitcher et al. 2005). Intrinsic vulnerability for rockfish species was calculated following this methodology and most inshore rockfish species have scores above 60 and as high as 78 for yelloweye rockfish (Magnuson-Ford, Ingram et al. 2009).

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed both inside and outside populations of yelloweye rockfish as special concern in 2008 and quillback as threatened in 2009 (COSEWIC 2008, COSEWIC 2009). Yelloweye have been added to schedule 1 of the Species at Risk Act (SARA), but quillback have not yet been added to a schedule. None of the other inshore species has been assessed yet and there are likely insufficient data to do so. Yelloweye rockfish in Puget Sound have been proposed for designation as "threatened" under American endangered species legislation (Williams, Levin et al. 2010).

COSEWIC designations were based on life history criteria of yelloweye and declining trends in abundance demonstrated through research survey data. Truncation of age/size structure of yelloweye rockfish has been observed in some locations (Kronlund and Yamanaka 2001) and local size/age structure change for quillback is also possible but has not been assessed.

The loss of older fish in a population has substantial demographic consequences as larger fish produce greater numbers and quality of larvae (Berkeley, Hixon et al. 2004). Berkeley et al. (2004b) showed that older female black rockfish not only produced more larvae than younger females, but that the larvae were larger and were provisioned with greater resources in the form of a larger oil globule which enabled larvae to grow faster and to withstand longer periods of starvation. Surviving longer starvation periods increases survival (Berkeley, Chapman et al. 2004). Age-related differences in timing and location of spawning may also help to stabilize recruitment (Berkeley, Hixon et al. 2004). A study in Oregon found that older black rockfish extruded young earlier in the year and produced a greater proportion of recruits (Bobko and Berkeley 2004). Older female blue, olive and yellowtail rockfish also produce higher quantity and quality larvae that are released earlier in the spawning season (Sogard, Berkeley et al. 2008). The failure to recover in favourable ocean conditions due to truncated age composition and the fact that younger fish are not as productive as older fish has been called "longevity overfishing" (Beamish, McFarlane et al. 2006).

Beamish et al. (2006) stress the importance of managing the age structure of long-lived fish such as rockfish through the use of interconnected networks of MPAs (Berkeley, Hixon et al. 2004). Life history characteristics and ecological traits of fish also influence the effectiveness of protection in an MPA. Traits include: species maximum body size as a surrogate for age at maturity, growth and reproductive output, habitat type, depth range, schooling behaviour, yearly displacement, home range size, territoriality and mobility (Jennings 2000, Jennings 2001, Claudet, Osenberg et al. 2010). Inshore rockfish species possess many of these characteristics and have long been thought to be ideal candidates for protection in MPAs (Carr and Reed 1993, Yoklavich 1998, Parker, Berkeley et al. 2000, Berkeley, Hixon et al. 2004).

Table 1 *Life-history traits of inshore and common shallow-shelf rockfish species found in rockfish conservation areas in B.C. (Richards 1986, Love, Yoklavich et al. 2002). B.C.-specific figures are given when possible. Groupings are: 1a=common B.C. inshore species; 1b=less common B.C. inshore species; 1c=inshore shallow-shelf; 2=shallow-shelf or slope species with shallower juvenile distributions (100 per cent maturity shown in absence of information on 50 per cent). Information specific to B.C. (indicated with*) is given when possible, since length and age at maturity have been found to increase with latitude (Haldorson and Love 1991, Love, Yoklavich et al. 2002).*

						50% maturity				
						Female		Male		
Group	Common name	Latin name	Total depth range (m)	Max size (cm)	Max age	size (cm)	age	size (cm)	age	Fecundity (larvae/yr)
1a	copper	*S. caurinus*	0-183	66	50	34	6	32	4	16,000-640,000
1a	Puget Sound	*S. emphaeus*	3-366	18	22	11	1-2			3,300-58,000
1a	quillback*	*S. maliger*	0-274	61	95	29	11	25	10	?
1a	black	*S. melanops*	0-366	69	50	41	6-7	36	6-7	125,000-1,200,000
1a	China	*S. nebulosus*	3-128	45	79	30*	6*	30*	6*	?
1a	tiger	*S. nigrocinctus*	18-98	61	116					?
1a	yelloweye	*S. ruberrimus*	15-49	91	118	46	19	54	22	1,200,000-2,700,000
1b	brown	*S. auriculatus*	0-135	56	34	24-31	4-5	24-31	4-5	55,000-339,000
1b	blue	*S. mystinus*	0-549		44					?
1c	greenstriped	*S. elongatus*	12-95	43	54	23	7	23	7	11,000-295,000
2	yellowtail	*S. flavidus*	0-549	66	64	36-45		32-44		56,900-1,993,000
2	vermillion	*S. miniatus*	6-436	76	60	37	5	35	5	63,000-2,600,000
2	canary	*S. pinniger*	0-838	76	84	35-45*	7-9*	41*	7-12*	260,000-1,900,000

Inshore rockfish fishery and management in B.C.

Inshore rockfish have been harvested on the coast of British Columbia for millennia by coastal First Nations peoples. A zooarchaelogical study on the west coast of Vancouver Island consistently found rockfish remains in middens that dated back as far as 1,500 years ago (McKechnie 2007). Aboriginal people in the Salish Sea also fished and consumed rockfish and it is thought that they were a staple food that could be harvested at any time of year when seasonally abundant species were not available (Williams, Levin et al. 2010). Commercial fishing for inshore rockfish in B.C. began in the mid-1800s as they were caught incidentally in the lingcod (*Ophiodon elongatus*) fishery. A directed hook-and-line fishery for inshore rockfish expanded in the 1970s in response to the development of a lucrative live-fish market in Vancouver. Quillback rockfish are the target of the live fishery although the less common copper, tiger, China and black rockfish are also landed. Yelloweye are targeted for a fresh rather than live market. The fishery was unrestricted in the early 1980s until a license (termed "ZN license") and logbook system, as well as annual assessment and hook-and-line surveys, were put in place in 1986. Throughout the 1990s, various management actions were taken, including the imposition of total allowable catch (TACs); however, rapid growth in this fishery outpaced measures to limit efforts. Other commercial groundfish fisheries such as trawl, halibut, lingcod and dogfish also catch inshore rockfish either as targeted catch or bycatch; therefore, measures to limit catch in the directed fishery alone are insufficient to conserve stocks without also reducing bycatch and incidental take in these other fisheries. In addition to incidental catch in other groundfish fisheries, rockfish are also targeted in recreational and aboriginal fisheries, and are bycatch in salmon trawl, shrimp trawl and invertebrate trap fisheries (Yamanaka and Logan 2010).

Rockfish catch in the "inside" or the protected waters of the Strait of Georgia, Johnston Strait and Queen Charlotte Strait, east of Vancouver Island, peaked in the late 1980s. Catch in the "outside" waters, those waters west of Vancouver Island and the central and north coasts of B.C., peaked in the early 1990s and then sharply declined (Yamanaka and Logan 2010). Although data were insufficient at the time for a comprehensive stock assessment, symptoms of overfishing such as declining catch rates, and anecdotal information about local depletion of stocks and considerable at-sea discarding practices raised concerns for sustainability of stocks (Yamanaka and Logan 2010). The more accessible inside and southern fishing grounds likely experienced serial depletion of local reef areas whereby high catches are maintained by continually moving to new reefs (Kronlund and Yamanaka 2001). Serial depletion can cause hyperstability of catch rates, masking declines in stock assessments (Hilborn and Walters 1992) as well as giving fishers a false impression of the population size (Kronlund and Yamanaka 2001). In the case of the ZN fishery, high participant turnover also eroded the historical frame of reference required for the appropriate impression of spatial trends in fishing success (Kronlund and Yamanaka 2001).

In 2001, non-governmental organizations (NGOs) lobbied for actions to protect inshore rockfish, and the American Fishery Society policy statement on the conservation and management of rockfish (Parker, Berkeley et al. 2000) helped to bring attention to rockfish conservation (Yamanaka and Logan 2010). In 2001, DFO science recommended four specific measures which became the basis of the Inshore Rockfish Conservation Strategy: 1) account for all catch; 2) decrease fishing mortality; 3) establish areas closed to all fishing; and 4) improve stock assessment and monitoring (Yamanaka and Lacko 2001). In November 2001, the minister of fisheries and oceans committed to "develop a plan to reverse the inshore rockfish decline and ensure stock rebuilding" (Yamanaka and Logan 2010).

Accounting and managing for total rockfish mortality in all groundfish fisheries henceforth became guiding principles in the integration of groundfish fisheries which brought about major changes to all groundfish fisheries, including a 100 per cent at-sea observer or electronic monitoring as well as dockside monitoring of these fisheries. Successful reform and integration of the fisheries has been attributed, in part, to the shared incentive for all fisheries to participate since all fisheries were united in their dependence on access to rockfish quota (Davis 2008). The integration scheme would also allow the transfer of fish quotas across these fisheries to cover the non-directed catch of rockfish, thereby eliminating discarding. Recreational fishing catch monitoring in the form of creel surveys and logbook reporting from guides and lodges was also expanded and enabled bimonthly catch estimates from the creel survey. Daily recreational bag limits for rockfish were decreased from 10 to five rockfish in the north and central coast, from five to three on the west coast of Vancouver Island, and from three to one on the inside waters. Inshore rockfish total allowable catch (TAC) was reduced up to 50 per cent in outside waters and 75 per cent in inside waters between 2002 and 2005 (Yamanaka and Logan 2010). The value of the inshore rockfish catch between 2002 and 2005 is estimated at $2.3 million annually (Davis 2008).

Rockfish conservation areas

A major component of the conservation strategy was the establishment of areas closed to fishing. A 2002 press release describing the strategy explained that "Extensive inshore rockfish habitat must be protected to provide a buffer against scientific uncertainty and contribute to the protection and rebuilding of rockfish stocks." Proposed targets for closure from all fishing were up to 50 per cent of rockfish habitat within the inside area and 20 per cent of the outside area (Yamanaka and Logan 2010). A team made up of DFO managers, scientists, enforcement and communications personnel as well as a member from the province of B.C., BC Parks, and Parks Canada Agency was established and stakeholder consultation was subsequently planned and carried out. Activities allowed in RCAs were reviewed by the team which decided that fishing activities that were likely to incidentally or directly catch inshore rockfish are prohibited while all other fisheries are still permitted (Table 2).

The RCA designation process followed three steps, with broad consultation at each step: 1) data gathering for closed-area proposals; 2) internal DFO review of proposals and verification with fishery catch data; and 3) DFO rockfish habitat analysis to meet the closed area targets, spread evenly across statistical areas. Thirty per cent of habitat in the waters between Vancouver Island and the mainland, termed "inside," and 20 per cent of the remaining "outside" area were targeted, although the original recommendation for "inside" waters was 50 per cent of rockfish habitat. Additional considerations in the placement, shape and boundaries of the RCAs included ease of description in fishery regulation, recognition by the public and ease of monitoring and enforcement (Yamanaka and Logan 2010).

Table 2 *Fisheries prohibited and permitted in RCAs by sector*

Sector	Prohibited fisheries	Permitted fisheries
First Nations		• fishing for food, social and ceremonial purposes
Commercial	• groundfish bottom trawl • groundfish hook and line for halibut, inside rockfish, outside rockfish, lingcod, dogfish • sablefish by trap • salmon trolling	• groundfish by mid-water trawl • invertebrates by hand-picking or dive • crab by trap • prawn by trap • scallop by trawl • salmon by seine or gillnet • herring by gillnet, seine and spawn-on-kelp • sardine by gillnet, seine, and trap • smelt by gillnet • euphausiid (krill) by mid-water trawl • opal squid by seine
Recreational	• groundfish by hook and line • salmon trolling, jigging or mooching • spearfishing	• invertebrates by hand-picking or dive • crab by trap • shrimp/prawn by trap • smelt by gillnet

Because the spatial distribution of rockfish habitats coastwide are unknown, rockfish habitat was modelled using a bathymetrically derived complexity model (Ardron 2002) and historical rockfish catches (commercial and recreational) (Yamanaka and Logan 2010). This model was used to determine if the conservation targets had been met as well as to try to evaluate candidate RCAs. Broad consultation occurred throughout the designation process that lasted three years. The suite of 164 RCAs was officially implemented in 2007 although they were phased-in between 2004 and 2006.

Twenty-eight per cent of modelled rockfish habitat was protected on the inside and 15 per cent on the outside (Yamanaka and Logan 2010). Yamanaka and Logan note that "other closed-area initiatives (e.g. national marine conservation areas)" were underway and were expected to result in further fishing closures in the outside area. Only the area of modelled rockfish habitat protected inside the RCAs was included in the final percentages although the total area shown in Table 2 is greater than the proportion of protected rockfish habitat that was used to calculate the targets. The mean RCA size is nearly 30 square kilometres, the smallest (Hardy Bay-Five Fathom Rock) is less than a hectare in size (.01 square kilometres) and the largest (West Aristazabal Island) is over 500 square kilometres (Table 3). The RCAs in northern and southern B.C. are shown in Figures 2 and 3, respectively, indicated in green.

Table 3 *Total area and proportion of modeled rockfish habitat protected by the RCAs (Yamanaka and Logan 2010)*

RCA statistics	**Total area** (km^2)	**Area of rockfish habitat** (km^2)
Number of RCAs	164	
Total area	4847.2	2060.3
Total inside	1518.5	897.4
Total outside	3328.7	1162.9
Mean/median size	29.6/10.8	
Standard deviation	61.2	
Minimum size	0.1	
Maximum size	509.1	

Photo credit: Rowan Trebilco

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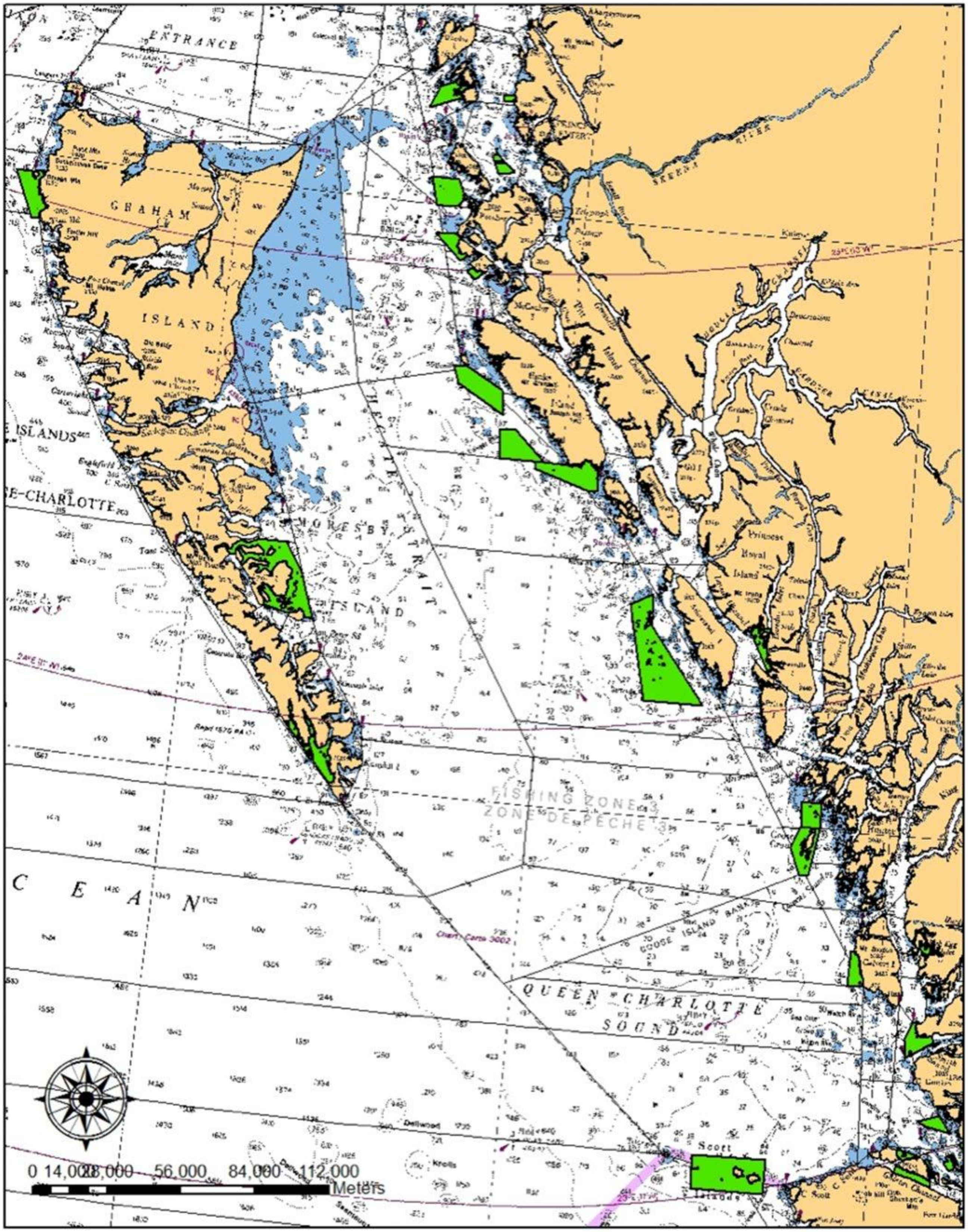

***Figure 2** RCAs in northern British Columbia are typically large.*

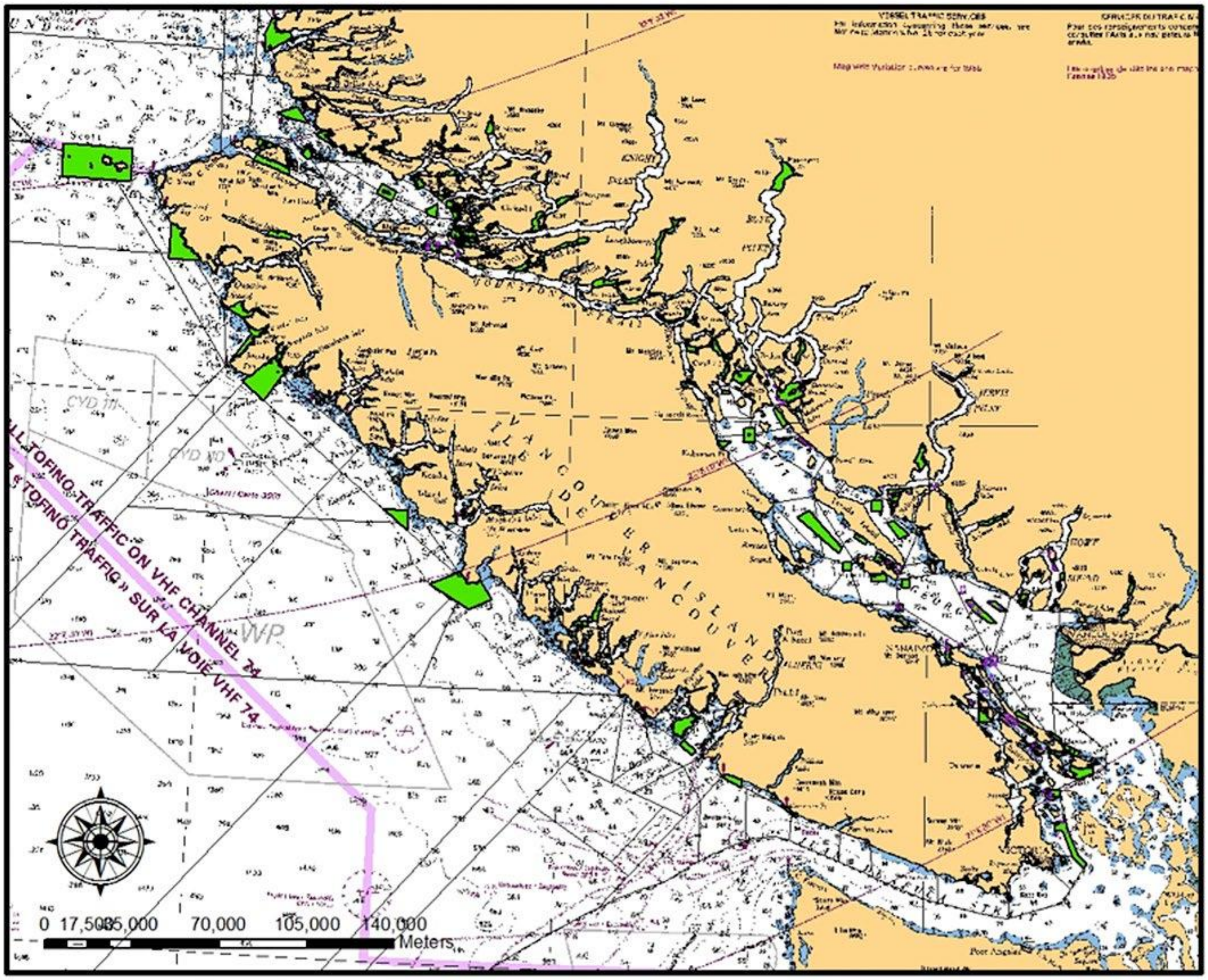

Figure 3 *One hundred twenty-five of 164 RCAs in southern B.C. are found in "inside" waters between Vancouver Island and the mainland and are typically smaller than RCAs in "outside" waters.*

Empirical research into the effectiveness of RCAs

Monitoring effectiveness is a critical step in the use of MPAs in fisheries management. Reserves that are not actually effective due to poor design or other factors can give resource managers a false sense of security (Allison, Lubchenco et al. 1998, NRC 2006, Gaines, Lester et al. 2010, Gaines, White et al. 2010, Hamilton, Caselle et al. 2010). Ecosystem-based management and adaptive management require an understanding of which MPAs in a network are outperforming others and which are underperforming (Hamilton, Caselle et al. 2010).

The design of MPA monitoring programs is an important consideration. Ideally, a before-after-control-impact (BACI) (Underwood 1992, Underwood 1994) sampling design to assess reserve effects should be used (Allison, Lubchenco et al. 1998, Russ, Stockwell et al. 2005, Pelletier, Claudet et al. 2008). However, observations from before MPAs are established are often not available (Russ, Stockwell et al. 2005, Hamilton, Caselle et al. 2010). An alternative to BACI design is the after-control-impact (ACI) design with temporal and spatial comparisons or CI with only spatial comparisons of control (non-RCA) and impact (RCA) in order to infer reserve effects (Glasby 1997, Pelletier, Claudet et al. 2008, Claudet and Guidetti 2010). Adding to the challenge is that some methods of sampling, such as extractive fishery surveys, may not be appropriate in an MPA (Field, Punt et al. 2006).

In B.C., work on evaluating the effectiveness of RCAs is just beginning. However, evidence from the U.S. suggests that MPAs are an effective tool for conserving rockfish populations. California has worked to establish a network of MPAs under the California Marine Life Protection Act. Prior to this act, only 2.7 per cent of California state waters were protected in small and mostly nearshore reserves. In 2003, a network of 13 reserves was designated in the Channel Islands. By 2013, 16 per cent of state waters will be protected in 124 reserves (Gleason, Fox et al. 2013). Much of the science of MPA theory and design has, therefore, originated in California. One of the earliest demonstrations showed that two older marine reserves in California had significantly larger rockfish and greater biomass (and therefore reproductive output) than non-reserve sites, while a one-year-old reserve showed no difference from open areas (Paddack and Estes 2000). No significant difference in density was found between reserve and open sites; the authors suggested this might be due to low power to detect change or factors such as small reserve sizes leading to increased amounts of spillover or behavioural traits such as territoriality that limits fish density but not size (Paddack and Estes 2000). Five years after the Channel Islands marine reserve network was established, positive reserve effects were found for targeted (fished) species while no differences existed for non-targeted species using scuba diving surveys (Hamilton, Caselle et al. 2010). Targeted species biomass was approximately two times higher inside reserves than outside and targeted species biomass trajectories increased with time. Many of the targeted species that showed significant reserve-to-non-reserve ratios after controlling for density differences associated with biogeography were rockfish species: blue, gopher, olive, vermillion and copper rockfish (Hamilton, Caselle et al. 2010). Remotely operated vehicle (ROV) surveys targeting deeper-dwelling species were also undertaken in the Channel Islands between 2005 and 2008 (Karpov, Bergen et al. 2012). They compared the density of fish on hard-bottom substrates between 20 and 100 metres in depth among three site pairs inside and outside of reserves (two other site pairs were dropped). Results were not consistent across sites; however, some species of rockfish showed significantly higher density in some reserves in some years. The authors expect that with additional time, "the full dimension of protection should become evident" (Karpov, Bergen et al. 2012).

To date, a number of different researchers including scientists from or working for governments (Fisheries and Oceans Canada, Parks Canada Agency and the Heiltsuk First Nation), academia (University of British Columbia, Simon Fraser University and Florida State University) and NGOs (Vancouver Aquarium, the Galiano Conservancy Association and the Reef Environmental Education Foundation) have collected monitoring data related to rockfish and RCAs in British

Columbia. ROVs, scuba surveys and hook-and-line surveys have been conducted in RCAs to assess, monitor and study the RCAs. Some genetic studies on rockfish have also recently been completed and can provide insight into rockfish conservation.

ROV surveys

The need for non-destructive monitoring tools to sample depressed populations in protected areas has led to an increase in the popularity of ROVs to assess marine resources (Stoner, Ryer et al. 2008). The size, operability and cost of ROVs have decreased in recent years making this technology more accessible. In addition to abundance and size data, visual surveys also have the ability to collect information on habitat use, behaviour and associations with other species (Yoklavich, Cailliet et al. 2002, Laidig, Watters et al. 2009, Love, Yoklavich et al. 2009, O'Farrell, Yoklavich et al. 2009). Stoner et al. (2008) contend that there is no better way to monitor fish in structurally complex habitats. The greatest concentrations of quillback and yelloweye rockfish distributions are deeper than safe scuba diving depths (Richards 1986), so for these inshore rockfish species, ROV surveys are preferable to scuba surveys.

Habitat is a crucial source of variability for fish communities so ignoring habitat quality when assessing MPA effects results in increased residual variability and can reduce the statistical power of comparisons. Habitat variables should be collected at the same time as fish counts and included in the model for identifying reserve effects (Pelletier, Claudet et al. 2008). ROVs collect data on fish and habitat simultaneously, so habitat can be controlled for in an evaluation of RCAs. Depth is also recorded continuously and can be used as a covariate since inshore rockfish distribution varies with depth (Richards 1986).

A Fisheries and Oceans Canada (DFO)-UBC project supported by DFO and a National Sciences and Engineering Research Council of Canada (NSERC) strategic grant to Drs. John Shurin and Eric Taylor of UBC, Dr. Isabelle Côté of SFU and Lynne Yamanaka of DFO, used remotely operated vehicles to survey RCAs and is part of the author's PhD dissertation (Haggarty in preparation).

Because there are no comparable ROV data from before RCAs were established, the study employs the CI design whereby data from inside RCAs are compared to nearby sites that are open to fishing (Underwood 1992). Paired transects 300 to 900 metres long were planned and plotted in GIS in appropriate rockfish habitat inside and outside of RCAs. Most transect lines were perpendicular to the shore and were travelled from deep to shallow, although transects in areas with very steep walls had to be run parallel to shore. A few small RCAs had only one transect inside and one outside, while larger RCAs had several transects inside the RCA and in control sites. RCAs that are adjacent or very close by were pooled for analysis. This resulted in 31 RCAs in this analysis.

The density of rockfish on transects inside and outside RCAs were compared using the average response ratio (ARR) as a measure (ARR = mean density in the reserve / mean density outside) (Hedges, Gurevitch et al. 1999, Russ, Stockwell et al. 2005, Hamilton, Caselle et al. 2010). Species with ARRs greater than one are more abundant inside reserves, whereas species with ARRs less than one are more abundant outside reserves (Figure 4). Response ratios of the density of these indicator species/groups were calculated: quillback, yelloweye, greenstriped and all inshore rockfish combined (quillback, yelloweye, copper, China, tiger and black rockfish) as well as kelp greenling, and lingcod (Figure 5).

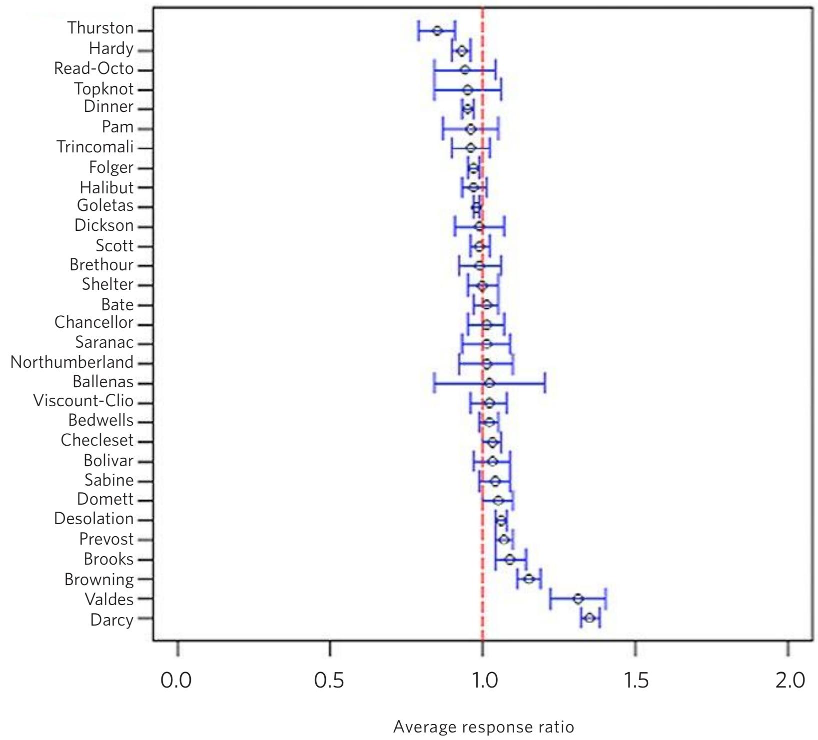

Figure 4 *Mean average response ratio (ARR) for combined indicator species (kelp greenling, lingcod, quillback, yelloweye, and greenstriped rockfish) by reserve. Error bars are standard errors. Values greater than one indicate higher densities found inside the RCA.*

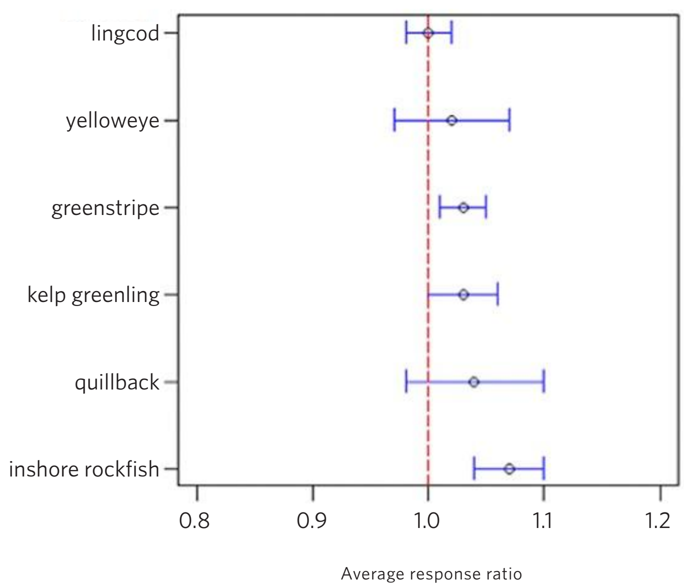

Figure 5 *Mean and standard error of ARRs from all RCAs by species.*

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Results and summary

Transects inside and outside 31 RCAs were sampled using ROVs. The density of lingcod, kelp greenling, inshore rockfish, quillback, yelloweye and greenstriped rockfish found inside and outside of RCAs was compared using the ARR. Few RCAs showed ARRs significantly greater than one, which would indicate that higher densities were found in the RCA (Figure 4). Although the mean inshore rockfish ARR was slightly above one, none of the species, fished or non-commercial, showed strong reserve responses (Figure 5). Although not shown in this report, commercial catch adjacent to the RCA, the relative habitat quality sampled and the age of the RCA were plotted with ARRs (Haggarty in preparation). Although habitat quality affected the ARR of a couple of RCAs, the average habitat score ratio inside to outside of the RCAs was close to one and therefore comparable for most RCAs. The age of the RCAs when sampled ranged from three to seven years; however, age doesn't appear to affect ARR. The commercial catch of the indicator species was zero or very low in the area sampled outside of most RCAs. This raises a question as to whether or not we should expect to see a significant difference in the RCA. Fish populations inside and outside of RCAs may both be increasing in response to other management measures implemented under the Rockfish Conservation Strategy at the same time as the RCAs, such as reduced catch quotas, fishery integration and 100 per cent monitoring. Since comparable data from before RCAs were established do not exist, it is not possible to assess the trajectory of populations inside and outside of RCAs over time. These ROV data are a valuable data set that can be compared to in the future. A long-term monitoring program using ROVs should be implemented to continue to track the performance of RCAs.

Scuba surveys

Several groups have undertaken scuba surveys to assess rockfish population abundance in 24 RCAs in B.C. between 2009 and 2012 (Table 4). Scuba surveys are a common way to monitor nearshore reef fish populations and they are thought to be effective for monitoring species of rockfish that have a shallow depth distribution such as copper, black, China, and Puget Sound rockfish as well as kelp greenling and perhaps lingcod (Haggarty and King 2006). Quillback and yelloweye rockfish abundance increases below 25 metres (Richards 1986); therefore, scuba surveys, constrained to depths above 20 to 30 metres, will not adequately assess their populations. Surveys are commonly performed using belt transects between 25 and 30 metres long and between 1.5 and four metres wide, although a roving diver technique can also be used. Fish within the area surveyed are identified to species and counted as the diver swims the transect length. The length of the fish can also be visually estimated. The resulting metrics are fish density or biomass, or count per unit of effort (CPUE) for roving diver counts. Between two to eight transects are usually completed per site and sites within the RCA are paired with sites of comparable habitat outside the RCA. Little scuba data from before RCAs were put into place is available to track the performance of the RCA with time.

Table 4 RCAs surveyed by scuba diving in B.C., 2005 to 2012

Author	Publication date	RCA surveyed	Region	Years surveyed
Jeff Marliave and Wendell Challenger, Vancouver Aquarium	2009	West Bay Lion's Bay Bowyer I.	Howe Sound	2006
Michelle Paddack, Jeff Marliave, Alejandro Frid, Vancouver Aquarium	2011 and in prep	Bowyer I. Pam Rock West Vancouver	Howe Sound	2010, 2011
Ryan Cloutier, Isabelle Côté, SFU	2011	Bedwell Harbour Portland I. Brethour I. Patey Rocks Prevost I. Bowyer I. Lion's Bay Pam Rock West Vancouver Upper Centre Bay Lasqueti I. S. Thormanby McNaughton Pt. Davie Bay Sabine Channel	Gulf Islands Howe Sound Central Strait of Georgia	2009 2009 2010 2010 2010 2009 2009 2009 2010 2010 2009 2009 2009 2010 2010
Anne Salomon et al., SFU	2010 and in prep	Lyell I.	Haida Gwaii	2009-2013
BCCES: Russ Markel and Rebecca Martone, UBC	In prep	Checleset Bay S. Moresby	Vancouver I. West Haida Gwaii	2010
Dana Haggarty, UBC	In prep	Broken Group	Barkley Sound	2010, 2011
Pacific Rim NPR	2013	Broken Group	Barkley Sound	2008-2012
Pacific Rim NPR	In prep	Broken Group Pachena	Barkley Sound Barkley Sound	2009-2011 2009
Galiano Conservancy Association, Lia Chalifour	2012	Trincomali Ch. Gossip Shoals	Gulf Islands	2012
Reef Environment Education Foundation (REEF) volunteers	2013	West Vancouver (Whytecliff Park)	Howe Sound	1998-2013

Vancouver Aquarium

The first study published on RCAs was by Marliave and Challenger (2009). They sampled three sites in Howe Sound in 2006 using the roving diver technique and a catch-per-unit-effort (CPUE) measure in combination with a model of "occupancy" which accounts for fish that are present, but not observed (Marliave and Challenger 2009). They found that both copper and quillback rockfish are highly associated with piled boulder habitats that can be mapped with technology such as side-scan sonar, but this habitat type is often not identified with broad-scale bathymetry that was used in the habitat model to identify rockfish habitat for designation. In comparing CPUE from RCAs and non-RCA sites, they did not detect any evidence of a "reserve effect"; however, they acknowledge that a difference was not expected since RCAs had just been established. They state that all RCAs studied "encompass rockfish populations that may prosper under protection from fishing pressure." Theirs are also important baseline data that can be monitored over time.

Paddock et al. (2011, in preparation) followed up on Marliave and Challenger's (2009) work in Howe Sound by conducting dive surveys using 30-by-two metre belt transects at ten sites inside and outside of RCAs (Table 4). They compared the density of copper and quillback rockfish and greenling (kelp greenling and lingcod) inside and outside of RCAs as well as by depth and habitat type using generalized linear mixed effect models. Although there was no overall evidence for an effect of the management designation, there was some support for higher abundance of rockfish in RCAs in the deeper depth stratum (20 to 25 metres). However, there was a general trend for increased density of rockfish with depth, and the two sites with the deepest transects and greatest densities were also RCAs. The best model describing rockfish density and biomass indicated a positive effect of depth, food resources (shrimp counts), biotic structure (invertebrate and algae counts), rugosity index (habitat complexity) and an interaction term of depth and RCA. Non-RCA sites had low fish densities overall and the authors suggest that fishing pressure is still quite high in Howe Sound. They also speculate that since uniform RCA effects were not apparent in the RCAs studied, fishing effort in RCAs may still be occurring. They support this argument with their observation that uncharted deep reefs that had been mapped prior to this project had the highest densities and biomass of fish in them. Some of these uncharted reefs are found in RCAs and will likely aid in the recovery of rockfish populations in those RCAs and in Howe Sound. The importance of protecting high-quality rockfish habitat is also highlighted by this research (Paddack, Marliave et al. 2011).

Simon Fraser University

Ryan Cloutier completed his M.Sc. at SFU with Dr. Isabelle Côté on the direct and indirect effects of marine protection in the RCAs (Cloutier 2011). He completed dive surveys at 15 sites in three regions: Howe Sound, the southern Gulf Islands and the central Strait of Georgia (Table 4). He evaluated RCA performance using two response variables: rockfish presence and rockfish abundance (density). He used a model to identify important factors in determining rockfish presence and abundance including region, RCA protection, protection duration (age of the RCA at sampling) and habitat variables such as depth, rugosity and kelp and boulder cover. This study was the first to document the effectiveness of RCAs in rebuilding rockfish populations. Ryan found there was a significant effect of protection in RCAs on rockfish density. RCAs had, on average, 1.6 times (95 per cent confidence interval 1.0 to 2.6) the rockfish density (all rockfish species pooled) than non-RCA sites while accounting for differences in habitat quality. There was no association between density and the age of the RCA, but there was a significant difference in rockfish abundance among regions. The central Strait of Georgia had the highest rockfish densities, followed by the southern Strait of Georgia. Howe Sound had by far the lowest rockfish density of the three areas. Rockfish density was also predicted by rugosity, which highlights the importance of protecting suitable rockfish habitat (Cloutier 2011).

Dr. Anne Salomon's lab at SFU has also conducted research into the effectiveness of RCAs. She and her graduate students have completed dive surveys for fish and invertebrates using belt transects at three sites within the Lyell Island RCA in Haida Gwaii as well as at three sites at each of two other areas outside of the RCA. They have surveyed the sites annually since 2009 and have compared biomass estimates among sites and regions using a generalized linear mixed effects model. In 2009 all rockfish biomass estimates varied more among sites than they did among the three areas; therefore, no effect of the RCA was apparent (Salomon, Lee et al. 2010). They found similar results in 2010 (unpublished report). They do intend to do a complete analysis of five years of data in the fall of 2013 (personal communication, Anne Salomon).

University of British Columbia

As part of the B.C. Coastal Ecosystem Services (BCCES) study researching the ecosystem-level effects of sea otters on kelp forests, Drs. Russ Markel and Rebecca Martone and their colleagues performed fish density surveys in kelp forests in B.C. Some surveys were done inside and outside of the Checleset Bay RCA, in Kyuquot Sound on the west coast of Vancouver Island and the South Moresby RCA in Haida Gwaii in 2010. They collected data on fish density and biomass in kelp forests using transects perpendicular to shore from the shallow low intertidal to the outer edge of the kelp forest.

Some study sites were located in RCAs and some outside, so these data can also be used to compare fish biomass inside and outside of RCAs. In the Kyuquot area, only one site was located in the Checleset Bay RCA so data were not analyzed. In the Gwaii Haanas National Park Reserve, three of their study sites were found in the South Moresby RCA and three were found outside the RCA (but within the park). The biomass (grams of fish per square metre) of the dominant species: black rockfish, copper rockfish and kelp greenling as well as the sum of these three species plus lingcod, was compared between sites inside versus outside the RCA using a non-parametric t-test (Mann-Whitney test). No significant difference between treatments was found for rockfish or total fish biomass, while significantly greater biomass of kelp greenling was found outside of the RCA (Figure 6). Habitat variables such as substrate, complexity and amount of kelp were not included in this analysis.

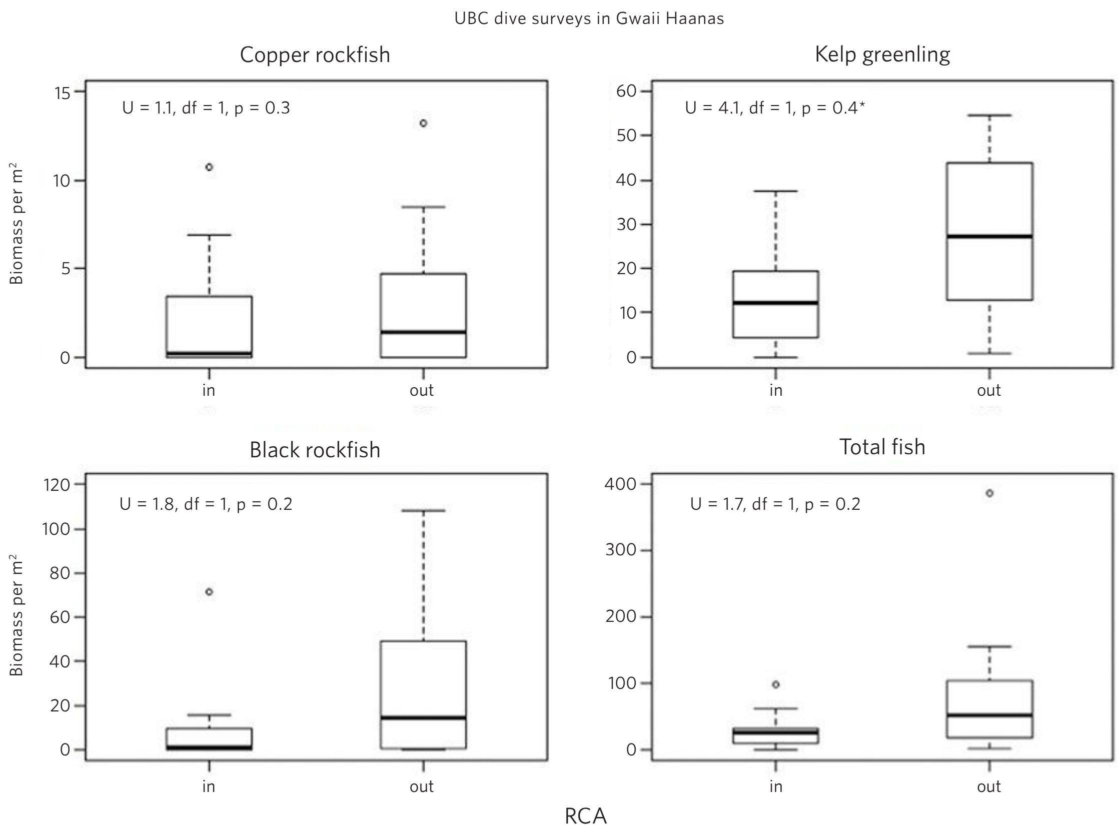

Figure 6 *Copper rockfish, black rockfish, kelp greenling and total fish biomass at sites inside and outside the Lyell Island RCA in Gwaii Haanas National Park Reserve (data courtesy of Rebecca Martone and Russell Markel, UBC).*

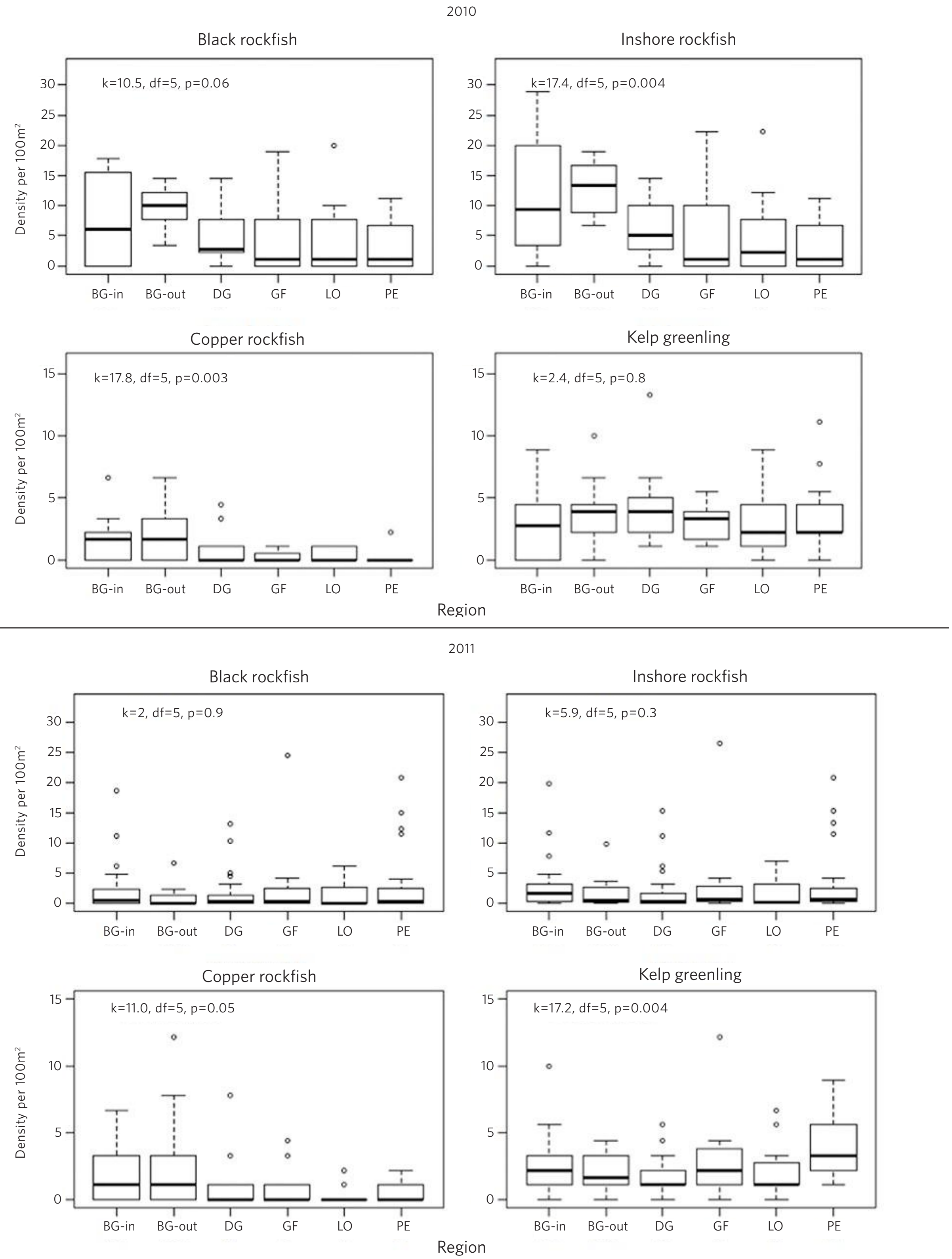

***Figure 7** Boxplot of the density of black rockfish, copper rockfish, inshore rockfish (black, copper, quillback, China and tiger) and kelp greenling at sites in six regions in Barkley Sound sampled in 2010 and 2011. Regions codes: BG-in=broken group in (in RCA), BG-out=broken group out, DG=deer group, GF=George Fraser I., LO=Loudoun Channel, and PE=prasex (Prasiola Point to Execution Rock on Vancouver Island).*

In 2010 and 2011, scuba surveys were conducted to explore the influence of recruitment strength on adult rockfish abundance in Barkley Sound (Haggarty in preparation).To do so, fish surveys were completed using scuba and 30-by-three-metre belt transects. Divers counted and estimated the length of rockfish and greenlings in 2010 and 2011 at 30 sites in six regions of Barkley Sound, including sites within the Broken Group Islands (BGI) RCA (BG-in) and in the BGI section of the Pacific Rim National Park Reserve (BG-out), but adjacent to the RCA. The density of black and copper rockfish greater than 10 centimetres, as well as combined inshore rockfish (black, copper, quillback, China, tiger; no yelloweye were observed) and kelp greenling were compared among regions using the non-parametric Kruskal-Wallis test for each year. Other fish species were not abundant enough to perform statistical comparisons. In 2010, the density of copper rockfish was significantly higher in the BGI (inside and outside the RCA) than it was closer to Bamfield (PE) (Figure 7). The inshore rockfish combined density was also significantly higher in the BGI (BG-out) than at the site with the lowest density (PE). Kelp greenling density did not vary by region. In 2011, black rockfish density and inshore rockfish density were higher and more variable than in 2010 in all regions. This might be the result of a strong black rockfish recruitment event in 2006 (Markel, Robinson et al. in preparation). There was no significant difference among regions. Although not significant, there is a trend for greater density of copper rockfish in the BGI RCA as well as adjacent to the RCA (BG-out) than Loudoun Channel (LO) (Figure 7).

Pacific Rim National Park Reserve

Parks Canada also monitors fish populations within Barkley Sound. Five RCAs overlap with the boundaries of the Pacific Rim National Park Reserve (NPR). The BGI RCA is completely within the BGI Unit of Pacific Rim NPR, and a small section of the Folger Passage RCA is within the BGI. The Pachena Point, Dare Point and Carmanah RCAs overlap the West Coast Trail unit of the park. Parks Canada monitors kelp forest fish in the BGI using scuba diving and 25-by-four-metre belt transects as part of their ecological integrity monitoring program. The dive survey in the BGI has been completed annually from 2008 to 2012 and is projected to continue. Three of the four sub-tidal sites monitored are within the RCA. A recent review of data showed that the density of black rockfish, as well as the combined rockfish category, was in decline. Copper rockfish, on the other hand, showed no trend (Yakimishyn and Zharikov 2013).

Since 2004, Parks Canada also annually monitors the ecological integrity of fish populations in eelgrass beds using beach seines. Five of 10 eelgrass meadows sampled are within the BGI RCA. Beach seining in eelgrass is a good way to monitor rockfish recruitment. Rockfish recruitment is highly variable year-to-year, and no trend for black rockfish or all rockfish was apparent. However, a moderate increase in copper rockfish (22 per cent, plus or minus nine) between 2004 and 2012 was observed (Yakimishyn and Zharikov 2013).

Parks Canada also undertook a dive survey to study RCAs. Using the same methods as their kelp forest fish survey, they counted and estimated the length of reef fish at sites inside and outside of the BGI RCA in 2009, 2010 and 2011. They also surveyed the Pachena RCA in 2009, but did not survey a comparable site outside of the RCA. They did, however, observe black and copper rockfish in the Pachena RCA. The density of black, copper, inshore rockfish (black, copper, quillback, tiger, China) and kelp greenling from the sites inside and outside of the BGI RCA is shown in Figure 8. Conclusions on the comparisons over time are, however, difficult to draw since different sites were sampled in the RCA in different years and habitat data are not available to assess if the habitat at the various sites is comparable (Table 5). There is no significant difference in any fish species density inside to outside of the RCA in any year (Parks Canada, unpublished data).

Table 5 *Sampling locations for RCA study by Pacific Rim NPR, 2009 to 2011*

Location		RCA status	2009	2010	2011
Cooper	Broken Group Islands	inside	x		
Onion	Broken Group Islands	inside	x	x	
Thiepval	Broken Group Islands	inside	x	x	
Pachena RCA*	Vancouver Island	inside	x		
Dicebox	Broken Group Islands	inside		x	x
Dempster	Broken Group Islands	inside			x
Rainbow	Broken Group Islands	inside			x
Gibraltar	Broken Group Islands	outside	x	x	x
Kyen	Broken Group Islands	outside	x	x	x
Ohiaht	Deer Group Islands	outside	x	x	x
Brabant*	Broken Group Islands	outside			x

**omitted from Figure 8*

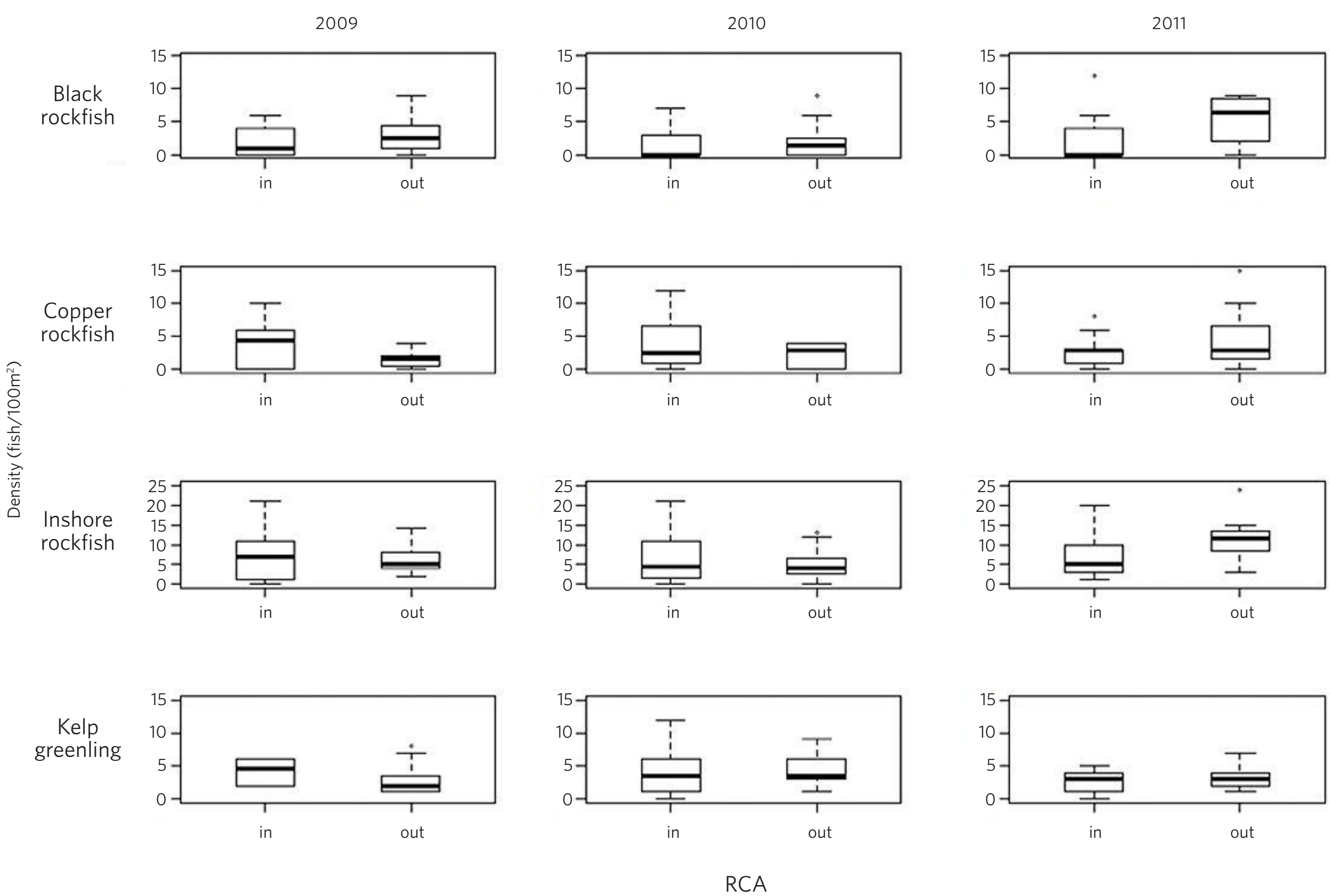

Figure 8 *Fish density at sites inside and outside the Broken Group Islands RCA in 2009, 2010 and 2011. Data from the Pachena RCA and Brabant Island are not shown.*

Galiano Conservancy Association

In 2012, the Galiano Conservancy Association secured some funding through the Mountain Equipment Co-op community grants program to survey rockfish populations around Galiano Island in the southern Gulf Islands. There are five RCAs within close proximity to Galiano and scuba surveys were completed in two of them (Table 4) as well as in two areas outside of the RCAs. Two, 30-by-two-by one-metre belt transects were surveyed per site. They observed rockfish at all four sites. Five species of rockfish were observed, but copper and quillback rockfish were the predominant rockfish species observed. The Spanish Hills site outside of the RCA had very high densities of rockfish. They acknowledge that more sites should be sampled to get a better understanding of the RCAs. They also observed that a large portion of the south end of the Trincomali Channel RCA contained little suitable rockfish habitat and that if boundaries of this RCA could be changed, it should be shifted to the north to encompass the Spanish Hills site. The Galiano Conservancy Association is planning to use this information in an outreach campaign on the island and among recreational fishers to help support the RCAs and educate the public about rockfish (Chalifour 2012).

Reef Environmental Education Foundation (REEF)

REEF is a non-profit organization founded in 1990 out of a concern for ocean health. Their mission is "to conserve marine ecosystems for their recreational, commercial, and intrinsic value by educating, enlisting and enabling divers and other marine enthusiasts to become active stewards and citizen scientists. REEF links the diving community with scientists, resource managers and conservationists through marine-life data collection and related activities" (REEF). REEF teaches divers to identify fish and invertebrates and how to complete surveys using the roving diver technique while they scuba dive or snorkel (Pattengill-Semmens , Pattengill-Semmens and Semmens 2003). Data collected by REEF citizen scientists using the roving diver technique has been found to be scientifically (Schmitt, Sluka et al. 2002, Holt, Rioja-Nieto et al. 2013) valid and have been used in numerous scientific papers (see http://www.reef.org/db/publications). In 1998, the Living Oceans Society teamed up with REEF to expand the REEF protocol into British Columbia and the U.S. Pacific Northwest. There are currently 3,723 surveys from British Columbia in the REEF database; 486 surveys are from Whytecliff Park in West Vancouver, which was made the West Vancouver RCA in 2006.

The REEF database is open-source and REEF encourages scientists to use their data in analyses. REEF compared data collected inside one park, Whytecliffe Park, between 1998 and 2013 (REEF 2013). Whytecliff Park was the only dive site with enough data over the years. It was designated as an RCA in 2006. Reef data uses two metrics: the per cent sighting frequency (%SF) and the density score (D); %SF for each species is the percentage of all dives in which the species was recorded; D for each species is a weighted average index based on the frequency of observations in different abundance categories. Density score is calculated as: $D=\{(nSx1)+(nFx2)+(nMx3)+(nAx4)\} / (nS + nF + nM + nA)$, where nS, nF, nM, and nA represent the number of times each abundance category (single, few, many, abundant) was assigned for a given species. Values range from one to four.

Figure 9 shows REEF data for inshore rockfish and greenling from Whytecliff Park between 1998 and 2013. Effort, calculated as the total number of hours surveyed, varies by year, and no surveys were completed in 2001. Kelp greenling is the most frequently sighted fish species at Whytecliff Park and their D is quite stable. The lingcod D may be declining. D for copper and quillback rockfish are also quite stable over time, whereas the sighting frequency is quite variable and may be related to the amount of effort. Other rockfish species are sighted less frequently. Increased sighting frequency of yelloweye rockfish in the mid-2000s may be indicative of a good yelloweye recruitment event since the yelloweye most commonly observed by divers are usually juveniles. Black rockfish are uncommon in the Strait of Georgia and the observations in 1998 may be misidentifications associated with the infancy of the project. The observations of black rockfish in 2006 to 2010 may be as a result of a black rockfish release in Howe Sound by the Vancouver Aquarium.

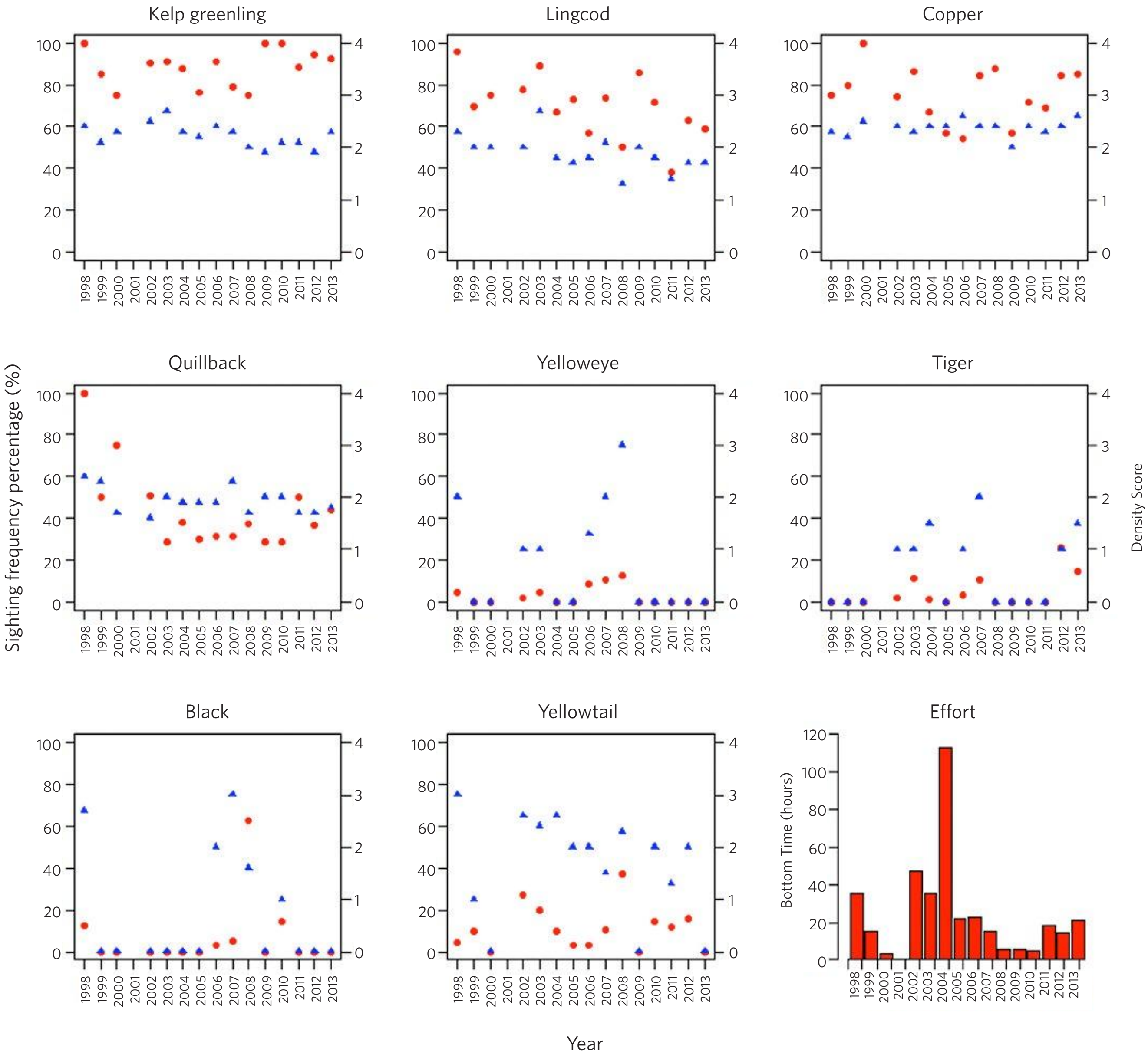

Figure 9 *REEF data for main rocky reef species from Whytecliffe Park/West Vancouver RCA, 1998 to 2013. The two metrics given are the per cent sighting frequency (red circles) and the density score (blue triangles). Effort at this dive site is the total number of hours spent surveying per year. No surveys were completed in 2001.*

Hook-and-line surveys

Hook-and-line surveys have been used by Fisheries and Oceans Canada to assess rockfish and lingcod populations since the 1980s (Richards and Cass 1985). Hook-and-line surveys use standardized fishing gear and methods. Fishers jig for bottom fish for a prescribed amount of bottom time (the time fishing gear is actively fishing) in different depth strata. The resulting relative abundance metric is a research catch per unit of effort (CPUE) that can be compared among depths, sites and years when sampling sites are re-surveyed. Research CPUE has been found to be proportional to the density of lingcod and copper rockfish observed by scuba survey (Haggarty and King 2006). CPUE of quillback and yelloweye rockfish in deeper depth strata is also likely to be indicative of their relative abundance, but these species are not adequately sampled using scuba surveys. Hook-and-line surveys are relatively inexpensive to perform and have the added benefit of collecting biological data such as sex, maturity, length, weight, age and stomach contents. Because sampling is lethal, hook-and-line surveys are often not used to monitor RCAs; however, recently developed devices that return rockfish to the depth they were caught at and, therefore, reverse the effects of barotrauma (Ingfei 2012), may make this type of survey more appropriate for RCAs. DFO has not done any hook-and-line surveys to assess the RCAs, although historical data from the 1980s, 1990 and 2003 to 2005 exist for many sites within and near RCAs in the Strait of Georgia and Johnstone Strait. Fisheries and Oceans Canada conducts surveys for rockfish using longlines; however, these surveys do not take place in RCAs.

Heiltsuk First Nation

In 2006 and 2007, the Heiltsuk First Nation conducted a hook-and line-survey to collect baseline information on the newly implemented Goose Island and MacMillan Group RCAs (although technically two RCAs, they are adjacent). Five sites inside of the RCA and five sites outside were fished in September 2006 and an additional 12 sites were sampled in May 2007. Three depth zones were sampled: zero to 25 metres, 26 to 50 metres and 51 to 75 metres. Catch rates for copper rockfish were highest in the shallow depth zone and greater in the two deeper zones for quillback rockfish. This result is expected and follows known depth preferences of these species (Richards 1986) and has been found in other surveys (Haggarty and King 2006). Catch rates for most species were greater in September than in May in the shallow and middle depth strata, potentially indicating seasonal differences in abundance related to a depth migration. No significant difference in catch rates between sites inside and outside of the RCAs was found. This result was not unexpected since the RCAs had just been put in place in 2004 (Haggarty, Norgard et al. 2007). These data are useful baseline information that could be compared to in any future work by the Heiltsuk or groups partnering with them.

University of British Columbia

Hook-and-line surveys were also performed in 2009 and 2010 by UBC researchers (Dick, Markel, and Martone, in preparation) as part of the BCCES study. This component of the BCCES study aimed to assess fish biomass and relative abundance in regions of B.C. with and without sea otters and with varying levels of fishing pressure. CPUE data for rockfish and greenling were collected using standardized research hook-and-line-fishing protocols similar to the methods presented in Haggarty and King (2006). They also collected biological data including stomach content data and sampled fish tissues for a trophic analysis using stable isotopes. Study sites included areas inside and outside of the Checleset Bay RCA in Kyuquot Sound. Sites were fished for a total of 30 minutes of bottom time. CPUE (fish per hour) from within the Checleset Bay RCA can be compared to CPUE from outside of the RCA, as well as to other sites outside of the RCA that are within Kyuquot Sound, but are closer to Kyuquot. Fishing pressure is thought to be greater closer to the village of Kyuquot. Using the Kruskal-Wallis test, the catch rates for the main species were compared: black rockfish, copper rockfish, kelp greenling and lingcod, as well as a total rockfish category that included all rockfish species that were caught (black, copper, blue, canary, China, quillback, vermillion, yelloweye and yellowtail). Catch rates for black rockfish were significantly higher in the RCA than just outside of it, but not different from Kyuquot. Copper rockfish catches, as well as the total rockfish CPUE, were significantly higher inside and outside of Checleset Bay than they were near Kyuquot. No significant difference in catch rates were found for kelp greenling and lingcod among regions (Figure 10). Differences in copper and total rockfish catch rates among regions might reflect increased fishing rates close to Kyuquot and relatively low fishing pressure in Checleset Bay (inside and outside the RCA).

Simon Fraser University

In addition to doing dive surveys in the Lyell Island RCA on Haida Gwaii, Salomon et al. (2010) also collected some fish using hook and line to collect samples for a trophic analysis. While fishing for samples, they used standardized methods to collect CPUE data. Data have not yet been analyzed.

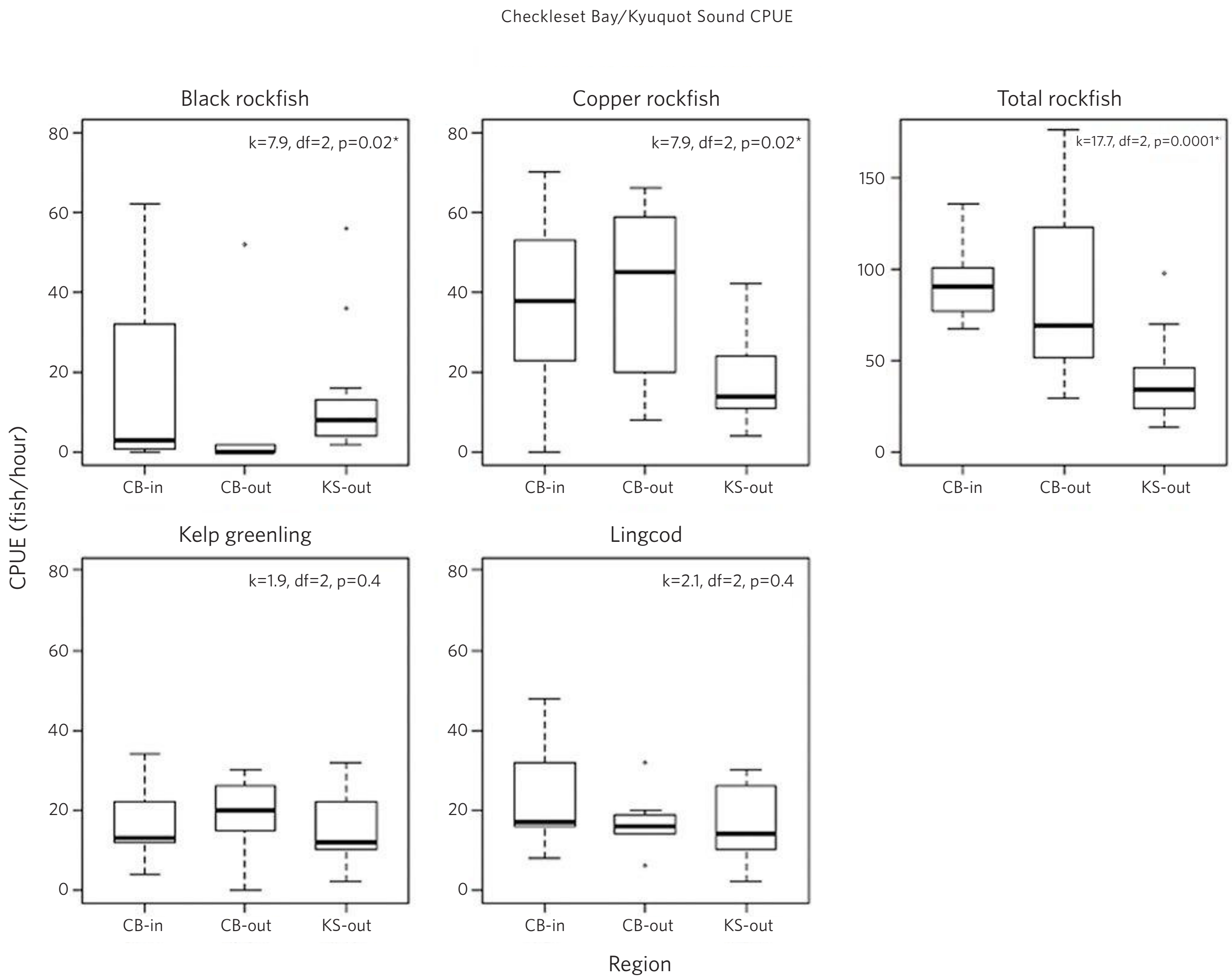

Figure 10 *Catch per unit of effort (CPUE) of inshore rockfish and greenling species caught inside and outside the Checleset Bay RCA (CB-In, CB-Out) as well as fish caught outside of the RCA but within closer proximity to the village of Kyuquot (KS-Out); (data courtesy of Rebecca Martone, Russell Markel and Stefan Dick, UBC).*

Genetic studies

Three recent genetics studies on rockfish have been undertaken in B.C. Matt Siegel and Stefan Dick did their M.Sc. theses on rockfish genetics with Drs. Eric Taylor and Jon Shurin at UBC, and Dr. Katie Lotterhos completed her PhD at Florida State University with Dr. Don Levitan. Although the genetics work doesn't directly involve monitoring RCAs, the scientific research into rockfish genetics has important implications for the connectivity of rockfish populations in B.C. and among RCAs.

Matt Siegel studied the population structure of yelloweye rockfish using samples from 672 individuals from Sitka, Alaska to Oregon; most samples were from B.C. Genetic structure analysis revealed population subdivisions that correspond with major oceanographic systems such as the Strait of Georgia and the outer coast and possibly between the outer coast and Bowie Seamount (Siegel 2011).

Stefan Dick studied copper rockfish gene flow in B.C.'s fjords. He hypothesized that, due to restricted water movement, fjords were a barrier to dispersal and, therefore, gene flow. He compared 17 microsatellite loci from individuals from five fjords to open coast systems on Vancouver Island (Quatsino Sound and Holberg Inlet; Kyuquot Sound and Kyuquot Inlet; Nootka Sound and Muchalat Inlet; Clayoquot Sound and Tofino Inlet; Barkley Sound and Alberni Inlet). Results from the genetic analysis showed that dispersal of copper rockfish larvae between coastal waters and the fjord heads is severely limited and fjord populations are largely isolated. Populations at the mouths of the fjords, however, show greater genetic similarity to coastal populations. He also studied the growth and age of the different populations and found that individuals in the inlet populations grow and mature more slowly than on the outer coast (Dick, M.Sc. thesis in preparation). This study has implications for connectivity of the RCAs since RCAs in inlets may not be connected to other RCAs, despite potentially short geographic distances.

Lotterhos, Dick et al. (in press) studied the estimated dispersal distance of black rockfish in B.C. and the U.S. Genetic analysis was done on samples from Alaska, the outer coast of B.C., Washington and Oregon. Using the isolation by distance theory and estimated black rockfish density from dive surveys, they used a model to estimate the dispersal distance. They found the mean dispersal distance to be six to 184 kilometres per generation. They compared this distance to the spacing among RCAs and found that most RCAs are connected to at least one other RCA by less than the estimated dispersal distance (Lotterhos, Dick et al. in press). The average distance among RCAs is less than 40 kilometres and most are within 100 kilometres of another RCA (Figure 11). From these results, rockfish in the Frederick Island RCA, at the northwest tip of Haida Gwaii, are likely to be isolated from rockfish in other RCAs as it is 165 and 217 kilometres away from the next closest RCAs. The other two RCAs on Haida Gwaii, Lyell Island and South Moresby, may also be somewhat isolated from other RCAs (although areas within the Gwaii Haanas National Marine Conservation Area (NMCA) may help to connect them). Although Holberg Inlet RCA on northern Vancouver Island is only 53 kilometres from its neighbouring RCA (Topknot), information presented in Dick (in preparation) indicates that it may be isolated from Topknot due to a lack of water flow between the coast and inlet. Likewise, Bedwell Sound RCA may also be more isolated than distance would suggest. This study only considered RCAs on B.C.'s outer coast; however, connectivity results may be similar for inside populations. Since there are more RCAs in inside waters, they are typically closer together (mean distance is 8.5 kilometres, maximum is 77 kilometres) and are likely to be well-connected. Some RCAs located on the mainland inlets such as Bute Inlet North and Loughborough may, however, be isolated from other RCAs. Connectivity for other inshore rockfish species with similar larval pelagic durations and similar densities are expected to show similar results; however, the average dispersal distance for species with shorter pelagic duration is likely shorter.

RCAs in inside waters are considerably closer together than they are on the outside (Figure 12). The mean distance among inside RCAs is 8.5 kilometres (standard deviation is 9.2). Therefore, it is expected that the inside RCAs will be well connected through larval dispersal for most rockfish species. The exception may be RCAs at the heads of inlets such as Bute Inlet North.

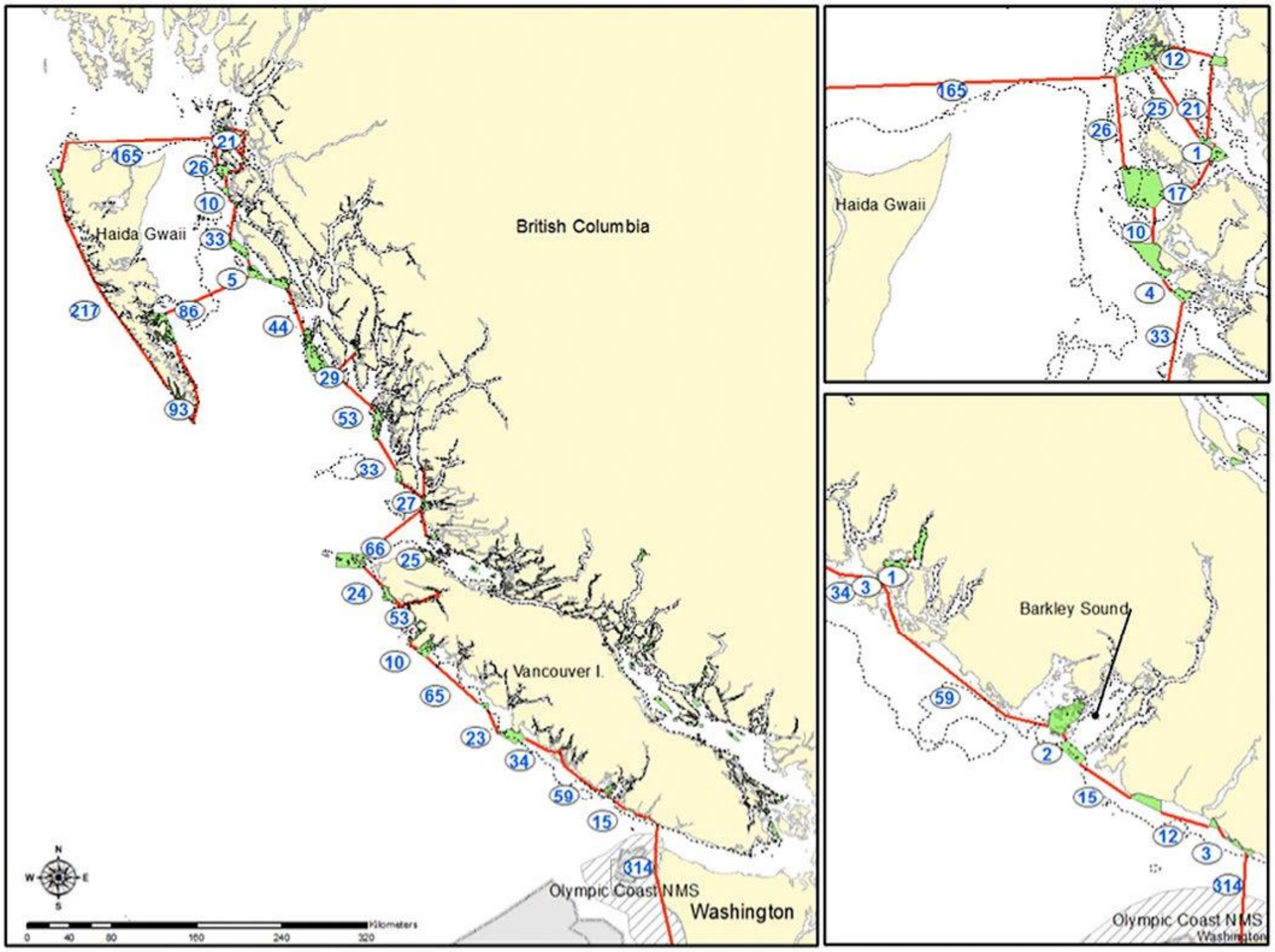

Figure 11 *Distances (in kilometres) between outer coast RCAs in B.C. are shown in blue.*

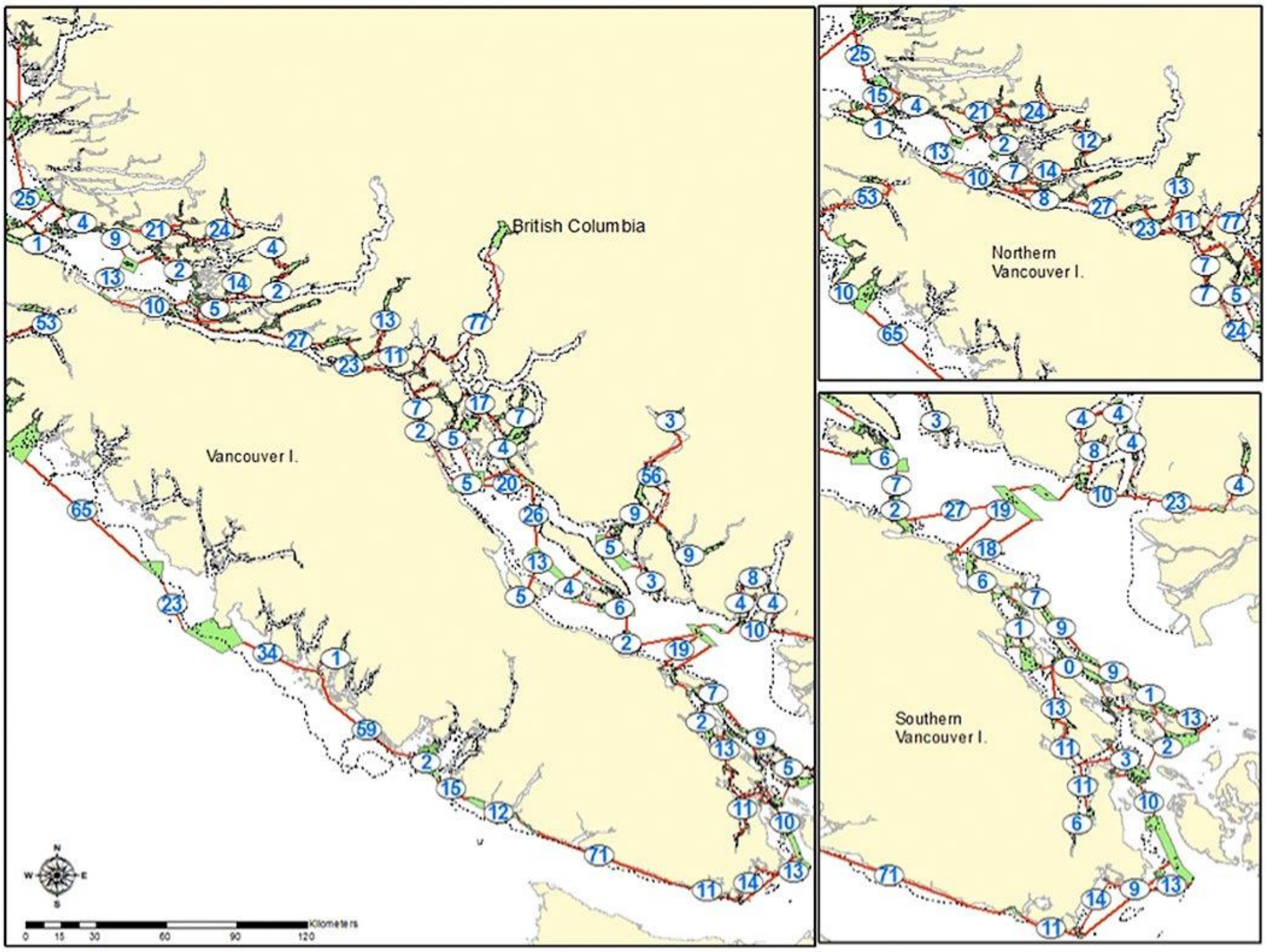

Figure 12 *Distances (in kilometres) between RCAs in Vancouver Island inside waters are shown in blue.*

Compliance monitoring in RCAs

The effectiveness of marine reserves and RCAs requires the support and acceptance of the fishing community. This is not only evident from theory, since for a marine reserve to have the desired effect on fish populations fishing pressure must be eliminated or at least reduced (Gaines, White et al. 2010), but has also been demonstrated empirically. Reserves with high rates of non-compliance show limited recovery of fish communities (Kritzer 2004, McClanahan, Graham et al. 2009, Ainsworth, Morzaria-Luna et al. 2012, Campbell, Hoey et al. 2012).

Another topic in the author's PhD dissertation (Haggarty in prepartion) looks at compliance with recreational fishing regulations in the RCAs. The dissertation examined two questions: Has recreational fishing effort changed in RCAs since they were established? And what factors affect compliance in RCAs? The full methods and analysis are available from the author, but not presented in this report. However, the results and conclusions are summarized below.

Fishing effort is often not monitored in reserves. Although compliance with RCA regulations by the commercial fishery is known to be quite high due to the use of electronic monitoring with global positioning systems (GPS), recreational compliance had not previously been addressed. Poaching and a lack of recreational compliance has been addressed as a concern with RCAs as a result of anecdotal information (Marliave and Challenger 2009). This study is the first assessment of recreational compliance in RCAs and uses the position of recreational fishing boats engaged in fishing observed in DFO's aerial surveys that are part of the creel survey that monitors the sport fishery (see Zetterberg, Watson et al. 2012). Raw data from aerial surveys of the Strait of Georgia in 2003 (pre-RCA), 2007 (just after establishment) and 2011 were geo-referenced and digitized using GIS.

It was found that recreational compliance in RCAs is low and, although effort declined with time in RCAs, effort adjacent to RCAs also declined. The effort in RCAs, as compared to a one-kilometre-wide buffer was, however, lower in all three time periods (Figure 13). Some RCAs had no recorded effort in any time period, but many have effort in all three years (Figure 14). Effort in a few RCAs even increased after their implementation. Overall effort in the sport fishery in general may have also decreased and might be related to the economy and higher gas prices.

Factors affecting compliance are likely to be complex, but the current evidence indicates that the greatest factor that influences fishing in the RCA is the amount of fishing adjacent to the RCA and the second most important factor is the size of the RCA, with larger RCAs having greater effort density than smaller RCAs (Haggarty, in preparation). RCAs with a longer perimeter to their areas also seem to be more at risk to fishing than more compact RCAs. RCAs that are closer to fishing lodges (within 15 to 20 kilometres) also have greater effort. These results seem to indicate that most fishers are not likely to be actively targeting RCAs, but if there is greater effort in the region, and if RCAs are a large "target", then people are more likely to be fishing in them. Most fishing patterns in B.C. are not driven by rockfish catch since the primary target of most recreational fishers in B.C. is not rockfish, but salmon and the most sought-after groundfish are halibut and then lingcod (Fisheries and Oceans Canada 2012). Fishers may not, as a result, be aware of the regulations or locations of RCAs. However, rockfish are caught incidentally in these fisheries and they are prohibited from taking place in RCAs.

There may also simply be a lack of awareness about RCAs. After an initial outreach campaign associated with the Rockfish Conservation Strategy that is no longer funded, DFO has not done much to promote RCAs aside from references in their sport fishing guide and signs at some boat ramps. A booklet published about RCAs has been out of print since at least 2009 and fishers must now go to the internet to download an electronic copy of the booklet (Fisheries and Oceans Canada 2008). The location of RCAs are not publicly available in any electronic form or on mapping software used by sport fishers and it is, therefore, very difficult to determine where they are and, more importantly, where a fisher is in relation to them. This is particularly a problem in inside waters where there are numerous RCAs. The printed regulations are also confusing, since the fisheries that are permitted in RCAs are listed and the information says that "fishing activity <u>not</u> listed above is restricted"; however, the information on RCAs does not specify that salmon and halibut fishing are prohibited in RCAs. Information provided on RCAs at boat ramps does, however, clearly state that all fishing for all fin fish is prohibited.

The number of patrol hours by region was also significant in the model, although the patterns were difficult to interpret. Nonetheless, many RCAs in areas that are heavily patrolled, such as near Victoria, have relatively good compliance. Conversely, the most heavily fished RCA, Topknot, on the northwest coast of Vancouver Island, is in a remote area within close proximity to fishing lodges in Quatsino Sound, but which is also rarely patrolled as a result of the area's remoteness. Additional enforcement activity would also likely increase compliance in RCAs.

Other factors that were not included in the model may also affect compliance in some RCAs. Local stewardship activities by residents or groups might also influence compliance. For example, Lion's Bay, a community in Howe Sound, has printed information about the Lion's Bay RCA and local residents with waterfront properties bordering the RCA actively promote it. The Lion's Bay RCA is the only RCA in Howe Sound that had less effort in 2011 than in 2003. There might be other cases similar to this one. Park type did not, however, affect compliance. There was no difference in fishing effort among RCAs that were not parks and those that are also national parks, provincial parks or provincial ecological reserves.

Not all effort that appears to be recreational fishing is necessarily non-compliance. There was no way to tell from the creel survey data if boats were First Nation fishers pursuing their constitutional right to harvest fish for food, social and ceremonial use in RCAs. Effort in RCAs did not, however, seem to increase close to First Nation communities and this is not thought to be a major source of bias.

Despite the lack of compliance in many RCAs, the proportional effort in RCAs in most management areas is quite low. The exception is the Topknot RCA that experiences 10 per cent of the effort of Pacific Fishery Management Areas (PFMA) 27 to 127. RCAs near Nanaimo (PFMA 17) and in the Southern Gulf Islands (PFMA 18) experience eight per cent and six per cent of the effort, respectively, although this effort is spread across many RCAs. This may have an effect on the performance of some RCAs.

Compliance with recreational regulations needs to be improved through outreach, education and enforcement. The accessibility of smart phone technology might be used to develop tools (apps) that help fishers locate RCAs using GPS and cellular technology, educate people about rockfish and inform them of regulations. RCA performance will likely be improved with greater recreational compliance.

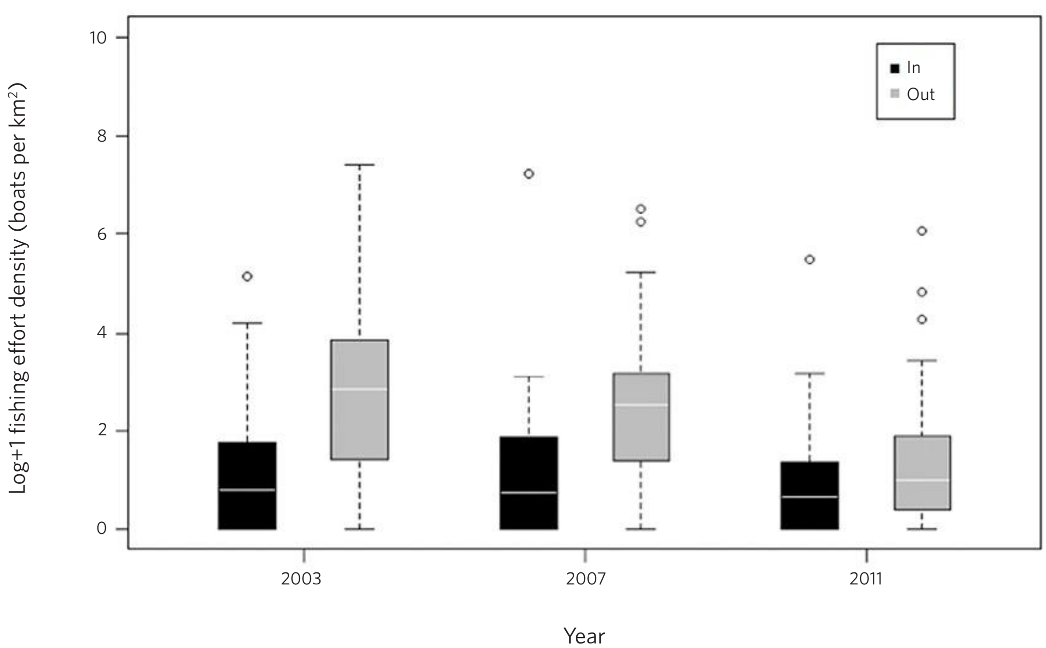

Figure 13 *Boxplot of standardized log +1 fishing effort density (boats per square kilometre), in and outside of RCAs in 2003, 2007 and 2011. Outliers are not shown.*

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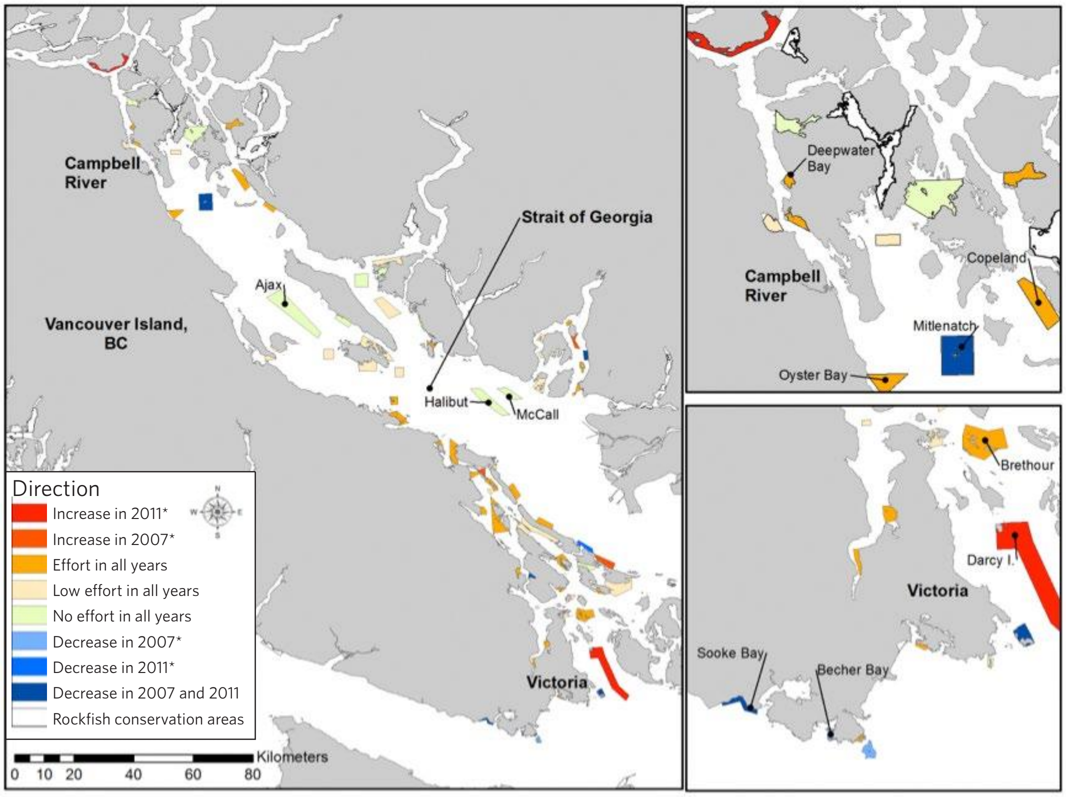

Figure 14 *Changes in recreational effort with time by RCA. Increases and decreases of effort are RCAs with significant effort while other RCAs showed no significant difference in effort with time.*

Synthesis

The effectiveness of MPAs is likely to vary spatially and among species with different ecologies and life histories and with time since protection (Molloy, McLean et al. 2009). The life-history characteristics that make rockfish susceptible to overfishing also indicate their recovery will be slow. Slow growth, large size and older ages at maturity are all correlated with slow recovery potential (Hutchings 2001, Dulvy, Sadovy et al. 2003, Dulvy, Ellis et al. 2004, Hutchings and Reynolds 2004). Given these characteristics, the recovery of rockfish will require the coincidence of good recruitment and reduction in fishing mortality (Murawski 2010). Late age at maturity is an indicator of slow recovery. Because rockfish are so long-lived, the earliest we are likely to be able to detect any reserve effects for rockfish is predicted to be between five to 10 years (Yoklavich 1998). In a meta-analysis of reserves, Babcock et al. (2010) determined time to first detection of a reserve effect on target species was 5.13 plus or minus 1.9 years. Although the analysis included global locations and a wide range of target species, the authors were surprised that time lag was not longer since most target species shared life-history characteristics of longevity and slow growth (Babcock, Shears et al. 2010). Higher biomass (1.8 times) and density (1.5 times) of targeted species, including five species of rockfish, was found in reserves in the Channel Islands in California after only five years (Hamilton, Caselle et al. 2010). Nonetheless, it is likely that rockfish in British Columbia may take longer than three to seven years of protection to start to respond to protection in RCAs. Although some of the studies reviewed in this section show that some RCAs are starting to have an effect, most have not shown statistical differences among RCAs and non-RCA sites. One reason for this might be that RCAs are still considered to be “new” or “young” at the time they were sampled.

The amount of fishing occurring outside of an MPA may also determine the strength of a reserve effect (Mosqueira, Cote et al. 2000, Claudet and Guidetti 2010). If fishing has also been curtailed adjacent to an RCA, then a reserve effect may not be apparent due to a decreased effect size. In addition to establishing RCAs, Fisheries and Oceans Canada also decreased the fishing mortality in commercial and recreational fisheries. Fishing mortality was not, however, decreased equally everywhere on the coast. Fishing mortality in waters inside of Vancouver Island, where rockfish populations were considered to be in greater jeopardy, was reduced by 75 per cent from 2001, while mortality in outside waters was decreased by 50 per cent from 1997 to 1998 (Yamanaka and Logan 2010). As a result of the decrease in fishing quotas, open areas around many RCAs, particularly in the Strait of Georgia, have very low commercial effort and, therefore, show no or very little difference in the amount of fishing inside of RCAs. This low-treatment-effect size greatly reduces the statistical ability to detect change. It also means that much larger areas are acting as de facto RCAs, from a commercial fishery perspective.

The design of monitoring is another important consideration. Ideally, employing a BACI (Underwood 1992, Underwood 1994) sampling design to assess reserve effects should be used (Allison, Lubchenco et al. 1998, Russ, Stockwell et al. 2005, Pelletier, Claudet et al. 2008). However, "before" observations are often not available (Russ, Stockwell et al. 2005, Hamilton, Caselle et al. 2010). An alternative to the BACI design is the after-control-impact (ACI) design with temporal and spatial comparisons (CI) with only spatial comparisons of control (non-RCA) and impact (RCA) in order to infer reserve effects (Glasby 1997, Pelletier, Claudet et al. 2008, Claudet and Guidetti 2010). All the studies described here to evaluate RCAs used the CI design by using spatial comparisons of RCAs and non-RCAs, although some are moving towards the ACI design. All are limited by not have any "before" data for comparison. This makes it impossible to track if there are more fish in any RCA since the closure. Collecting future data that can be compared to any of these studies will be valuable to assess RCAs over time.

Several authors whose work is described in this section observed that habitat inside some RCAs is not as good as habitat found outside of RCAs. Habitat is a crucial source of variability for fish communities, so ignoring habitat quality when assessing MPA effects results in increased residual variability and can reduce the statistical power of comparisons. Therefore, habitat variables should be collected at the same time as fish counts and included in the model for identifying reserve effects (Pelletier, Claudet et al. 2008). This is particularly true for the inshore rockfish which are closely associated with rocky habitats (Love, Yoklavich et al. 2002). Habitat quality in RCAs is likely to be one of the most important features determining their effectiveness. Rockfish habitat quality varied greatly in RCAs that were surveyed using ROVs. Although the mean habitat score for each ROV transects inside RCAs was 607.1, the standard deviation was 185.2 and scores ranged from 303.3 (quite poor) to 1,224.5 (excellent). The habitat model that DFO used to designate RCAs used coarse bathymetry and commercial catch data to identify rockfish habitat. In ground truthing this habitat model, Cloutier and Côté (personal communication, Isabelle Côté) found the model was accurate at identifying unsuitable rockfish habitat but no better than random when predicting the location of "suitable" rockfish habitat. Better habitat models can be made with finer scale bathymetry data such as multi-beam and side scan sonar data and with fisher-independent data such as ROV observations that are now available. Lynne Yamanaka and colleagues have been working to develop more detailed rockfish habitat models (Yamanaka, Picard et al. 2012). Also, a new rockfish model to assess the habitat available in RCAs is being developed (Haggarty in prepartion). Both models should be used to evaluate RCAs and to suggest refinements in the RCA network.

Genetic studies that have recently been completed have important ramifications for RCAs. The isolation of inlet populations of copper rockfish cautions that these populations may require special attention and protection since they are isolated from populations on the open coast. This also means that populations in RCAs in the inlets may not contribute larvae to populations outside of the inlets (i.e., be connected to other RCAs). However, they may be very important for the population in the inlet. Due to the number and placement of RCAs on the coast, most RCAs are predicted to be well-connected in a network of RCAs. This is important since benefits from multiple reserves that are well-designed may be synergistic (Murray, Ambrose et al. 1999, NRC 2000, Botsford, Hastings et al. 2001, Botsford, Micheli et al. 2003, Palumbi 2003, Roberts, Branch et al. 2003, Gaines, White et al. 2010).

Recreational compliance in RCAs has been shown to be low. Continued recreational fishing effort might also be affecting the performance of some RCAs. Education, outreach and enforcement of RCAs should be ameliorated.

Photo credit: Rowan Trebilco

Acceptance of RCAs by the fisheries sectors

In order to gauge the acceptance of RCAs by the commercial, recreational and First Nation fisheries sectors, representatives of these groups who are directly impacted by the fisheries closures were asked questions over email or phone. As a result of a short timeline to complete this work, particular individuals had to be targeted rather than soliciting information broadly from these sectors. The timing of the survey (May to June, 2013), however, was unfortunate as people engaged in fishing are preparing for their fishing season or actively fishing. Response to our survey was, therefore, low.

Commercial sector

The three major commercial fisheries in the groundfish sector are the trawl, sablefish trap and halibut long-line fisheries. Hook-and-line fisheries for lingcod, dogfish and rockfish have traditionally been smaller scale. Although disparate in fishing method and size, these fisheries often target the same species either directly or as bycatch. All directed groundfish fisheries are prohibited in RCAs as well as salmon trolling (see Table 2). Hook-and-line groundfish fisheries are the primary commercial fisheries impacted by RCAs.

The 2002 Rockfish Conservation Strategy brought about many changes to the groundfish fishery and RCAs clearly forced changes to the spatial fishing effort of the hook-and-line component of the groundfish fleet. However, beginning in 2006, the Pacific commercial groundfish sector also underwent a major reform through the commercial groundfish initiative (Davis 2008).

A guiding principle of the initiative was an objective to account and manage for total rockfish mortality in all groundfish fisheries, which resulted in the integration of all groundfish fisheries. Changes in management include a 100 per cent at-sea observer or electronic monitoring, dockside monitoring and individual transferable quotas for all fisheries. Furthermore, in advance of the integration process, the total allowable catch (TAC) for inshore rockfish was reduced up to 75 per cent between 2002 and 2005.

The combination of RCAs, individual quotas, reduced catch and comprehensive catch monitoring has resulted in a significant change in how the fleet removes their allowable catch. In particular, limited quotas for inshore rockfish, combined with the need to account for these species in all groundfish gear types, resulted in inshore rockfish becoming primarily a bycatch species of the larger fisheries.

It is within this reformed management context that representatives from the commercial industry caucus (CIC), the BC Seafood Alliance, T-Buck Suzuki and the halibut industry (B.C. Pacific Halibut Management Association) were asked the following questions about RCAs:

As you know, Canada has committed to developing a system of marine protected areas on the Pacific coast and some of these areas will be identified in the various planning initiatives that are ongoing. RCAs, while not widely considered MPAs, in reality, are some of the best spatial protection we currently have along the B.C. coast and will likely be considered part of the MPA network.

What we would like to learn from the commercial halibut and rockfish fleets are:

1. Does the halibut/rockfish commercial fishing industry continue to see the importance of RCAs as part of the management strategy of rockfish?

2. Does the halibut/rockfish commercial fishing industry feel that RCAs are "working" to either recover rockfish or in their role as an insurance policy?

3. What is the halibut/rockfish commercial fishing industry sense about the health of inshore rockfish populations in general?

4. Is there a need to expand RCAs into other depth strata or habitat of additional rockfish species (i.e., rougheye, shortraker)?

5. Does the halibut/rockfish commercial fishing industry have any comments with respect to the current management of RCAs (e.g., enforcement, monitoring, etc.)?

Commercial responses:

We corresponded with representatives from the Pacific Halibut Management Association, the CIC and T Buck Suzuki. All had very interesting insights to share with us. Respondents were actively involved in fishing and were representatives of the fishing industry.

1. Does the halibut/rockfish commercial fishing industry continue to see the importance of RCAs as part of the management strategy of rockfish?

    a. "Not a bad idea but probably wouldn't have pushed for them at the same time as integration."

    b. They are not as important as integration but are extra insurance.

    c. "I support them; it can't hurt. It's a proactive approach to management."

    d. Yes, they are important. Proper monitoring and assessment are also needed to feed into larger stock assessment and the fisheries management work.

    e. It is difficult to assess RCAs as just one component of the conservation strategy that also included reductions in allowable harvest limits and increased monitoring levels in the commercial groundfish fisheries. However, commercial harvesters see the importance of continuing with the current management measures, particularly since they are relatively young with respect to long-lived species. Commercial fishers also see the importance of collecting the data necessary to assess the effectiveness of the measures and the health of inshore rockfish.

    f. "It (the conservation strategy) was a tough pill to swallow, but we did it and it's paid off."

2. Does the halibut/rockfish commercial fishing industry feel that RCAs are "working" to either recover rockfish or in their role as an insurance policy?

    a. Anecdotal information says yes they are working in most areas, yet full scientific monitoring and assessments is needed.

    b. "All aspects of the conservation strategy are working together. Integration solved a lot of problems. It wiped out cheaters in one year and got rid of dumping. By the third year of integration, people liked it and the smart guys made it work for them. Now they fish only about one-third of what they used to fish above 80 fathoms (146 metres) due to bycatch. They have to fish deeper. If we knew what we know today, we would have put RCAs in the best areas since we can't fish them anyways due to bycatch."

   c. "I don't know if they are working. We don't think they are effective since people (sport and native) are still fishing in them. We account for every rockfish, but the 'sporties' don't care. Their discards aren't accounted for."

   d. "I think they will work, but will need 10 years. It's a no-brainer. There should be more, not less."

   e. "It's too early to tell. Some species in certain areas are doing well. There is no way to tell since we can't fish in them."

   f. There is anecdotal information that inshore rockfish are recovering and that RCAs may be working in some areas of the coast. It is difficult to say whether signs of recovery are attributable solely to RCAs or one of the other measures introduced as part of the 2002 Rockfish Conservation Strategy or the combined effect of all the measures introduced.

   g. Rather than expressing opinion or assertion, the commercial industry would prefer to be able to base its response on peer-reviewed science, particularly given the costs RCAs imposed on the fleet in general. Unfortunately, the existing network of MPAs was implemented without a program to properly answer such questions over time. While work has been done to try to address this deficiency, it needs to be fully addressed as soon as possible.

3. What is the halibut/rockfish commercial fishing industry sense about the health of inshore rockfish populations in general?

   a. Doing better in most areas.

   b. Extremely good in some areas such as northwest of Vancouver Island and the west coast of Haida Gwaii. A little depleted around Port Hardy and Cook Bank, area 5A.

   c. Fish stocks are climbing. Recent stock assessment for quillback was good and the DFO stock assessment scientists are very conservative.

   d. "Fish are coming back in a big way."

   e. Although the industry would prefer to be able to base its response on peer-reviewed science, there is anecdotal information that inshore rockfish are recovering and commercial harvesters report seeing more fish on the grounds, particularly in certain areas of the coast. Further, some commercial fisherman report that they can no longer set their gear in some areas of the coast previously fished for fear of catching too many rockfish and hitting their limits before they can catch their halibut quota. In other words, integrated fishing has created "new" rockfish conservation areas.

4. Is there a need to expand RCAs into other depth strata or habitat of additional rockfish species (i.e., rougheye, shortraker)?

a. Need to use full adaptive management approach, monitor, evaluate and reassess objectives and update RCA strategy, including siting.

b. I don't see going deeper necessary. Inside 100 fathoms (182 metres) will protect most inshore rockfish and catch very few below 108 fathoms (198 metres).

c. It would be nice to know the utility of the existing RCAs first.

d. We still need areas to fish.

e. To the best of our knowledge, the DFO CSAS (Canadian Science Advisory Secretariat) peer-reviewed science process has not identified a need to expand RCAs into other depth strata along the B.C. Coast.

f. Integration has helped other species like rougheye.

5. Does the halibut/rockfish commercial fishing industry have any comments with respect to the current management of RCAs (e.g., enforcement, monitoring, etc.)?

    a. "The commercial sector has been very supportive of RCAs, and is generally in compliance. If RCAs are to be effective, other sectors need to be equally onside. Some education/enforcement may help and a monitoring plan would be helpful here as well."

    b. "As RCAs are generally not monitored and factored into stock assessment models, any resulting spillover is not factored into fisheries quota. As all groundfish in B.C. are managed under one IFMP (Integrated Fisheries Management Plan) in which fishermen are fully accountable for their catch (e-monitoring, logbook, on-board observers, DS monitoring), they tend to be pushed further away from RCA boundaries to avoid species with limited quota that are benefiting from the RCA protection (i.e., spillover creates a de facto larger closed area as fishermen try to avoid species)."

    c. "As you are aware, the commercial halibut fleet has 100 per cent at-sea monitoring in place using video-based electronic monitoring systems with vessel tracking using global positioning satellite systems. This independent monitoring ensures compliance with RCA boundaries within the commercial halibut fishery. If RCAs are to meet their intent as a sanctuary or insurance policy, there needs to be proper monitoring of and compliance by the other fishing sectors restricted from the areas."

    d. A comprehensive assessment program needs to be developed and implemented to be able to determine if RCAs are meeting the stated objectives.

    e. "Sports and native fishermen are still fishing in them. This defeats the purpose of the RCAs."

    f. "FSC fishing is still allowed in RCAs and the department (DFO) can't do anything about it. This creates an exclusive zone they can fish in. If there is a conservation concern, everyone should have to comply."

    g. The usefulness of RCAs needs to be tracked so that we know what to expect in the future.

    h. "Unfortunately the existing network of RCAs was implemented without 1) a program to collect baseline data that would be needed to assess if the closures were meeting the stated objectives; 2) a plan to assess the impacts over time; and 3) an overall strategy to enforce compliance with the closures by all fishing sectors."

i. I worry that areas that are open will become overfished as the fishing pressure is focussed outside of the RCAs, especially in areas of high effort such as around Port Hardy. Quota for 5A needs to come out of a greater area of 5A and not as focussed around Port Hardy. As quota increases, this may become more of an issue.

Commercial Summary

Commercial industry representatives are supportive of RCAs as a conservation and management measure and feel they provide added insurance for rockfish populations. Many feel effects will not be apparent for at least 10 years. All feel it is important that RCAs be monitored and assessed using peer-reviewed scientific processes so that they can confirm if sacrifices the commercial industry has made have been worthwhile. They also feel that assessing the effectiveness of RCAs is complicated by the other management changes of decreased quotas, fishery integration and 100 per cent monitoring that were put into place at the same time as RCAs. Some feel that integration has probably had a greater effect on rockfish populations than RCAs. Fishery integration and the need to avoid rockfish bycatch have led to areas of the coast not being fished. In addition, if RCAs begin to have spillover of rockfish, harvesters may need to avoid the boundaries of RCAs in order to not exceed bycatch quotas. As a result, RCAs may become larger and additional "de facto" RCAs may exist. Most feel that rockfish populations are increasing in many parts of the coast. All have concerns with continued fishing from the recreational and First Nation sectors in RCAs. They see a need for education and enforcement of RCAs. Other issues of concern include how to incorporate RCAs into stock assessments. They also feel strongly that a comprehensive assessment program needs to be developed and implemented to be able to determine if RCAs are meeting the stated objectives.

Recreational sector

Recreational fishing is a major pastime in Canada. Tidal recreational fishing in B.C. is very important to the British Columbian economy. In 2010, $368 million was spent on "direct fishing expenditures" (package fishing deals, food and lodging, transportation, fishing services, fishing supplies, other) and $520 million on "major purchases related wholly or partly to recreational fishing" (fishing equipment, boating equipment—i.e., boats and motors, camping equipment, special vehicles and real estate) (Fisheries and Oceans Canada 2012). According to the 2010 survey of recreational fishing in Canada, 245,572 residents, non-residents and foreign visitors held adult tidal recreational fishing licenses in B.C. Of these, 93 per cent were considered to "active" fishers. The total number of days fished in B.C. tidal waters was estimated to be over two million or an average of nine days per fisher. Eighty per cent of the anglers are males with an average age of 53 years (50 years for females). The top three species caught in B.C. tidal waters are chinook, coho and sockeye salmon (Fisheries and Oceans Canada 2012).

Inshore rockfish are taken in the tidal recreational fishing sector, managed by Fisheries and Oceans Canada. Rockfish are targeted as well as caught as bycatch while angling for other bottom fish such as halibut and lingcod, and while trolling or mooching for salmon. They are also caught as bycatch while fishing prawn (commercially and recreationally) (Favaro, Rutherford et al. 2010). Despite a commonly held belief that recreational fishing has little or no impact on marine populations, recreational fisheries have been found to have an impact on marine populations (Coleman, Figueira et al. 2004, Lewin, Arlinghaus et al. 2006) and in many areas, recreational fisheries are the main fisheries that target rockfish populations (Schroeder and Love 2002). This is the case in the Strait of Georgia (Figure 15), where the commercial rockfish catch has recently greatly declined. The recreational catch of inshore rockfish in regions of southern B.C. (the west coast of Vancouver Island and Johnstone/Queen Charlotte Strait) makes up a smaller proportion of the catch. Although data for northern B.C. is not available, it is thought that the proportion of recreational catch is similarly low as it is in Johnstone/Queen Charlotte Strait.

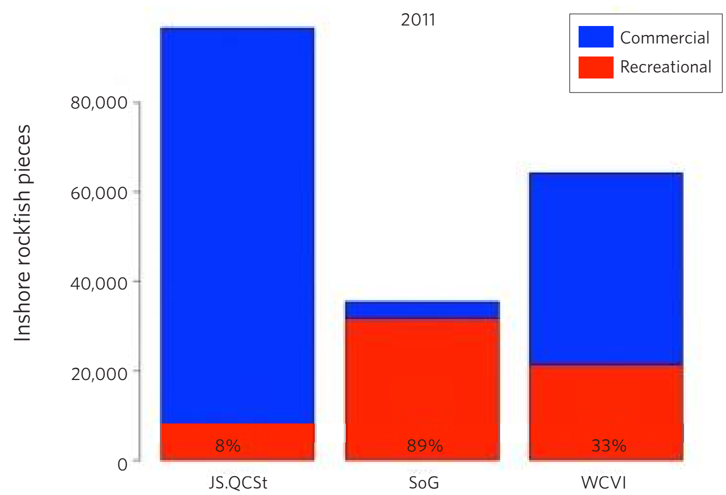

Figure 15 *Per cent of recreational catch and total number of pieces of inshore rockfish caught in the recreational fishery and all commercial fisheries combined in 2011 (data from Fisheries and Oceans Canada).*

In order to gauge the acceptance of RCAs among the recreational community, representatives from the Sport Fishing Advisory Board (SFAB) were asked the same questions as the commercial industry representatives (above) to get the perspective of the general recreational fishing community.

Sport Fishing Advisory Board (SFAB) responses:

We were only in communication with two SFAB representatives and both were from southern B.C. We did not have success reaching a northern representative.

1. Does the recreational fishing sector continue to see the importance of RCAs as part of the management strategy of rockfish?

    a. The SFAB was an active participant in the process that led to identification of the current RCAs. The board thought that protection of rockfish was overdue and agreed both to the creation of RCAs and to reduce retention limits for anglers.

    b. We were supporters of creating RCAs to protect the inshore species and although the department has yet to show evidence they are working, we agreed this program will require many years before a determination can be made as to its success, and currently support the program.

2. Does the recreational fishing sector feel that RCAs are "working" to either recover rockfish or in their role as an insurance policy?

    a. I am not aware of any empirical data which would allow me to answer this question. However, the SFAB made a genuine effort to identify areas of suitable habitat and can only assume that the lack of recreational and commercial harvest in those areas has contributed to an increase in abundance, assuming that this growth is not being undermined by the potential for First Nations harvest.

3. What is the recreational fishing sector's sense about the health of inshore rockfish populations in general?

    a. Again, I lament the lack of empirical data that would allow an answer to this question.

4. Is there a need to expand RCAs into other depth strata or habitat of additional rockfish species (i.e., rougheye, shortraker)?

    a. Before answering this question I would need to know whether the current program is delivering the anticipated results. We also would need to have detailed data with respect to proposed candidate areas so that a judgement could be made about the potential impact on recreational fishing for other species.

    b. Additions would take considerable discussions.

    c. Any increase of these RCAs into other depth strata could be an issue, but would be location-dependent. Recreational fishing depths are generally limited by our equipment being used but rougheye could be incidentally caught in very small numbers while targeting other species such as halibut to 55 fathoms (100 metres) or moderately deeper. Shortraker is a different issue, as basically it was not encountered until one fish at 50 fathoms (90 metres) or more.

5. Does the recreational fishing sector have any comments with respect to the current management of RCAs (e.g., enforcement, monitoring, boundaries, locations, etc.)?

    a. Given current budget restrictions, it is unlikely that adequate resources are being devoted to these management issues.

    b. We have suggested a boundary change in one area on the west coast of Vancouver Island where an increased closed area was offered in exchange for access to a small, sheltered area that would facilitate salmon fishing in bad weather. The department rejected the request saying that it was not prepared to contemplate any changes at present.

In order to get the perspective of the "professional" recreational fishery sector, owners and operators of fishing lodges and guiding businesses, a Google Earth search was conducted looking for tidal fishing lodges and guides that advertise their services on the internet. Forty-four businesses were contacted and asked to fill in the following questionnaire (see Appendix 1 for information provided with this questionnaire).

Name (optional):____

Business: ____

Position (i.e., guide, manager, owner, etc.):________________________

1. Are there any RCAs close to your lodge or in the area fished by your guests?

2. Which RCAs are in close proximity to your lodge or fishing area? Refer to the maps below (list or circle).

3. Do you/your guides inform your guests about the location and regulations in RCAs?

4. Have you seen or documented increased catches of rockfish that would indicate the RCAs are "working" to recover rockfish? If not, do you feel that RCAs are an insurance policy for the future recovery of rockfish?

5. Do you think RCAs are an important part of the current management strategy of rockfish?

6. In your opinion, has fishing effort (commercial, recreational, aboriginal) decreased in RCAs with which you are familiar?

7. What is the health of inshore rockfish populations in your area?

8. Do you have any comments with respect to the current management of RCAs (e.g., enforcement, monitoring, etc.)?

Commercial recreational responses:

The response rate to the survey from fishing lodges and guides was low. Only four lodges/guides responded from a total of 44 contracted. Two respondents ran sport fishing lodges, one was a guide and one runs an eco-tourism B&B.

All four respondents knew the location of the RCAs close to their businesses and said that they provided guests with information about RCA locations and regulations. Although most respondents have not noticed an improvement in catches with respect to RCAs, they felt RCAs "no doubt have a positive impact" or "can't hurt". The health of rockfish varies by region from "very good" to "In historic terms, poor. In the shorter term, i.e., the last seven years that we have been in business, holding its own" to "in Nootka and Esperanza inshore rockfish populations are much lower than they were 10 years ago." Two respondents thought RCAs needed improvement:

> "Some of the RCAs should be reviewed and perhaps be re-considered with more emphasis on traditionally productive areas. In view of DFO staff shortages and remoteness location of many RCAs, I question their conservation value."

> "RCAs could represent a much better insurance policy if they were significantly upgraded. I think that they are part of the current management strategy of rockfish but are flawed and need to be improved."

One respondent felt that limiting rockfish catch from eight to one fish per day had a greater impact on rockfish conservation and on sport effort. The reduced catch limit also affected their business by eliminating most of the "oriental" business. He feels that catch limits are more enforceable and effective than RCAs. The ecotourism lodge owner felt that "RCAs could be a more useful tool if they were designated completely no take. Not only would this eliminate bycatch but simplify enforcement and monitoring."

Recreational summary

Recreational fishing respondents were generally supportive of RCAs as a management strategy for inshore rockfish. They are not yet aware of evidence showing that they are working, but acknowledge that this will take many years. Like the commercial sector, they would like to see monitoring and an evaluation of RCAs. The perception of the health of rockfish populations varies by region. They wanted to see changes made to some RCAs or even many RCAs in hopes of providing access to some fishing grounds or improving the network of RCAs. They acknowledged that enforcement and monitoring are issues, particularly given Fisheries and Oceans' current budget restrictions.

First Nations

Aboriginal harvesting is a constitutional right that is not infringed upon in RCAs. As such, First Nation harvesters are permitted to target rockfish or take them as bycatch in RCAs. Some First Nations may, however, voluntarily choose to restrict their harvest in RCAs. Ayers et al. (2012) found that First Nation' perspectives on no-take zones (NTZ) in MPAs were divergent and complex. Although there was low support for permanent NTZs, respondents showed greater support for seasonal and temporary closures as these concepts more closely align with traditional First Nation management regimes. Support for closed areas was, however, seen more positively if the First Nation was to have greater involvement in their establishment and management. Another important point raised by Ayers et al. (2012) was that despite the historic importance of marine resources to all B.C. Coastal First Nations, today they have varying degrees of connections to marine resources, although all maintain marine harvesting is a part of their aboriginal right. The aboriginal relationship to marine resources has been eroded to varying degrees and for reasons including the development of commercial and recreational fisheries, policy and political decisions (Ayers, Dearden et al. 2012). It is, therefore, expected that First Nations' views on RCAs will be complex and divergent.

First Nation representatives who were identified to the author as having some knowledge of fisheries and fisheries resources were contacted by email or phone and asked the following questions (see Appendix 1 for information provided with this questionnaire).

1. Was your First Nation consulted on the establishment of RCAs in its traditional territory?
2. Are RCAs seen as an important part of the current management strategy of rockfish?
3. Which RCAs are found in your First Nation's traditional territory? Refer to the maps below.
4. Have you seen or documented increased catches of rockfish that would indicate the RCAs are "working" to recover rockfish? If not, do you feel that RCAs are an insurance policy for the future recovery of rockfish?
5. Has fishing effort (commercial, recreational, aboriginal) decreased in RCAs in your traditional territory as a result of RCAs?
6. What is the health of inshore rockfish populations in your traditional territory?
7. Do you have any comments with respect to the current management of RCAs (e.g., enforcement, monitoring, etc.)?

First Nations responses:

Response from First Nation representatives was also low. Only three people provided answers to the questions, a couple of others referred me to other people and a couple responded that there were no RCAs in their traditional territories. Two of the people who provided feedback worked as fisheries manager or officer, the other was a chief and fisher. One respondent felt the survey was an inadequate way to involve First Nations in a review of RCAs in their territory. The low response rate proves this to be true. A better approach is to address this topic at existing planning processes such as through MaPP (Marine Planning Partnership for the North Pacific Coast). It would also be useful to complete a more in-depth study on the topic of First Nations' perspectives on RCAs that could involve greater representation from the communities. The involvement of local field assistance would also likely increase response rates as was found in the study by Ayers et al. (2012). A personal connection does seem to help since the author has worked in the past with the two First Nations that responded to the survey: the Heiltsuk and the Stz'uminus (formerly Chemainus).

Despite the low response rate, some interesting information was shared. The First Nations in question were either—to their knowledge—not consulted or not adequately consulted on the creation of RCAs in their territories. The respondent from the Heiltsuk was very familiar with the two RCAs in Heiltsuk territory, while the respondents from Stz'uminus were not familiar with the location of all 10 RCAs in their territory.

The Heiltsuk fishery manager does see RCAs as an important insurance policy but is not sure if they are working yet as they have not done any research on this topic. He believes that fishing effort has decreased in the RCAs. The health of rockfish populations is thought to still be "very low in all areas with the increased sport volume." The Heiltsuk have developed a marine-use plan which they will be sharing with the province and the DFO which may add to rockfish management.

In Stz'uminus, one respondent does not support RCAs, while the other supports the notion of them but commented that they would only be an important management action if the Stz'uminus were involved with DFO in their management. Neither had any information to support if RCAs were working on the health of rockfish populations. One felt that sport effort had not decreased in RCAs and that sport fishermen were still fishing lingcod in them. Some Stz'uminus members choose to not fish in RCAs due to pressure from other, non-First Nations. The Stz'uminus chief told me that when he fishes in the Active Pass RCA, a local resident regularly uses a blow horn to inform him that his fishing activity is being reported to DFO. He felt that the public needs to be educated that fishing in RCAs is an aboriginal right and that they shouldn't be harassed for it. He felt that Stz'uminus members also need to be educated about their right to fish in RCAs as well as the overall conservation issues associated with rockfish so that they could decide to fish or not fish in RCAs. Both respondents wanted information on the performance and monitoring of RCAs. "The closures were made only based on catch statistics, but no formal study of populations has been undertaken. This leads to uncertain acceptance of the closures. (There has been) no follow up from DFO on how stocks are doing or further investigation of closure areas."

Synthesis

Most respondents from all sectors support RCAs and felt they are at least a good form of insurance for rockfish management. Most respondents felt there isn't any evidence that RCAs have started working yet, although many acknowledge that it will take time for RCAs to start working given the long lifespan of RCAs. Some felt there was anecdotal evidence that some RCAs were working but that it was hard to separate the effects of RCAs without considering the effects of other management changes to commercial and recreational fisheries brought in along with RCAs under the Rockfish Conservation Strategy. Depending on the geographic region the respondents where familiar with, the perception of the health of rockfish populations was thought to be improving, steady, poor or unknown.

All sectors wanted additional information about the effectiveness of RCAs and felt RCAs must be monitored and evaluated. Most respondents from all sectors also felt that additional education about RCAs and much greater enforcement is required. Commercial and First Nations respondents remarked that sport fishers are still fishing in RCAs. Recreational and commercial fishers felt that First Nation FSC (food, societal and ceremonial) fisheries in RCAs may undermine their conservation efforts. First Nation fishers felt the public requires greater education that it is an aboriginal right to fish in RCAs and that First Nation members require more education about rockfish conservation concerns and conservation. Respondents from all sectors felt the need to use a full, adaptive management approach and to monitor, evaluate, reassess objectives and update the RCA strategy including evaluating the siting of RCAs.

Photo credit: Rowan Trebilco

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Conclusion: The value of RCAs in a network of MPAs in B.C.

Due to many of their life-history characteristics such as extreme longevity, sporadic recruitment success, small home range size and poor survival after being discarded, inshore rockfish are inherently vulnerable to being overfished (Parker, Berkeley et al. 2000). In British Columbia, overharvesting has resulted in COSEWIC designations of special concern and threatened for yelloweye rockfish and quillback, respectively. The life-history characteristics that make them vulnerable to overfishing also make them good candidates for protection in MPAs (Yoklavich 1998). Rockfish have, therefore, been key species for protection in networks of MPAs that have been developed in California (Gleason, Fox et al. 2013) and Oregon (personal communication, D. Fox, Oregon Department of Fish and Game).

Including RCAs in a network of MPAs will offer additional protection to rockfish and other species sharing the same habitat since they will be designated under the legislative framework of the Oceans Act. Oceans Act MPAs offer greater permanency than RCAs currently regulated through fishery closures under the Fisheries Act. MPAs may also require stronger monitoring programs to assess whether objectives are being met. No long-term monitoring plan currently exists for RCAs. Additional fishery closures and added enforcement may also benefit rockfish in RCAs that are "upgraded" to MPAs.

Although DFO largely reached their target of protecting 30 per cent of rockfish habitat in inside waters, they only achieved around 15 per cent protection in outside waters, five per cent short of their goal of 20 per cent of rockfish habitat (Yamanaka and Logan 2010). Yamanaka and Logan (2010) anticipated that other MPA initiatives would achieve additional fishery closures in outside waters. To date, little additional rockfish habitat has been set aside through other initiatives.

In addition to RCAs being logical candidates for inclusion in an MPA network, there may also be a need to protect additional rockfish habitat to meet the program's objective.

A challenge of any MPA designation is buy in from user groups and getting areas initially established. In this regard, RCAs are logical candidates for inclusion in an MPA network as they have been designated and protected to most fishing activity from between six and nine years.

Of all fish species associated with nearshore rocky reef ecosystems, rockfish are the most inherently vulnerable to fishing mortality. As such, rockfish can also be considered "flagship species" whose protection will confer protection on other species and habitat that are associated with them. In other words, if rockfish populations are given adequate protection in these areas, many other species may benefit.

Other ecological values in RCAs

Many RCAs are found along shorelines and, therefore, also protect important intertidal and nearshore sub-tidal habitat. In addition to rocky-reef habitat, kelp forests and eelgrass beds are important rockfish habitat. Kelp forests and eelgrass beds are important juvenile habitat for rockfish (Markel 2011). Kelp forests and eelgrass beds also support numerous other species and ecosystem values in B.C. (Robinson, Yakimishyn et al. 2011,Watson and Estes 2011, Robinson and Yakimishyn 2013). Many nearshore RCAs have kelp forests and eelgrass beds within them. Sub-tidal kelp forests are poorly mapped in B.C. and, therefore, their distribution relative to RCAs is likely underestimated. Using data from the BC Marine Conservation Analysis (BCMCA) Atlas (BCMCA 2011) and the location of RCAs, it was found that 23 RCAs, or 14 per cent, contain eelgrass beds and 79 RCAs, or 48 per cent, contain kelp forests (Table 6). For example, the BGI RCA within Pacific Rim NPR contains many eelgrass beds (Figure 16). Kelp forests are also present in the BGI (Yakimishyn and Zharikov 2013) but are not mapped with this data set.

Table 6 Area of eelgrass beds and kelp forests in RCAs and the number and per cent of RCAs with these habitat (data from BCMCA)

Feature	Total	Number of RCAs with feature	Per cent of RCAs with feature
Eelgrass beds Area (km^2) and % of total RCA Area with eelgrass	19 (0.4%)	23	14.0
Kelp forest Area (km^2) and % of total RCA Area with kelp	100 (2.1%)	79	48.2
RCA total area (km^2)	4831		

Other RCAs, such as Folger Passage, are not near shore and protect deeper rocky reefs, depicted in this example with a model of rockfish habitat created by Parks Canada Agency (McBlane, unpublished data) and the soft habitat that surround them (Figure 16). Many species are found in this soft substrate habitat surrounding the rockfish habitat. Soft substrates are a common habitat feature in RCAs and, therefore, understanding these habitat are an important aspect when considering the role of RCAs in a broader MPA network.

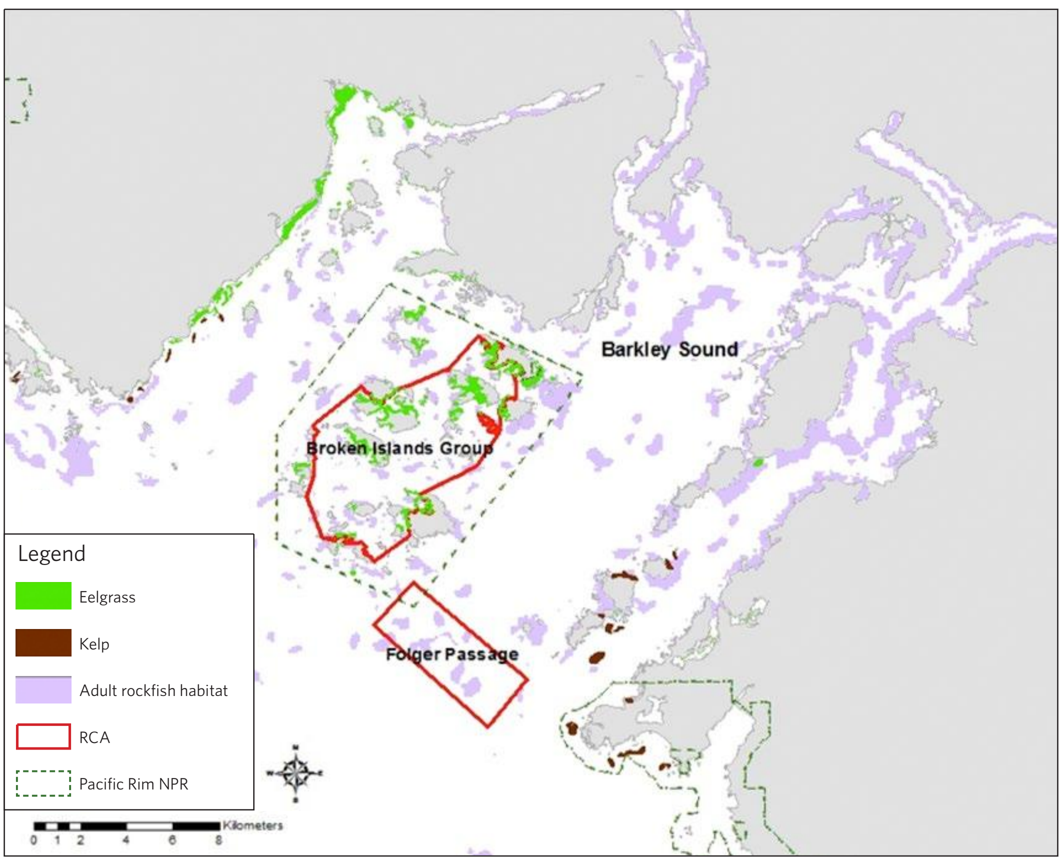

Figure 16 *Eelgrass beds and kelp forests in RCAs in Barkley Sound (data courtesy of BCMCA and Parks Canada Agency).*

Protection for other species in RCAs

Many species other than rockfish are also protected in RCAs both in the rockfish habitat as well as adjacent habitat. Appendix 2 lists 90 taxa of fish that were identified and counted on ROV transects in RCAs (Haggarty, in preparation). Other rocky-reef dwelling fish likely to benefit from RCAs include often caught species such as lingcod, kelp greenling and cabezon.

Movement patterns of a species are as important to consider as habitat in deciding if a species is likely to be protected in a reserve. Species such as lingcod are known to exhibit extreme site fidelity to rocky reefs (Starr, O'Connell et al. 2004, King and Withler 2005); however, they will also make long forays off reefs and outside of protected area boundaries. Although this "spillover" may slow the increase of biomass within reserves, in the long run, it may help to support fisheries outside of RCAs (Starr, O'Connell et al. 2004). Kelp greenling and cabezon have small home ranges, averaging 1,000 square metres, and are resident on rocky reefs and surrounding habitat (Lea, McAllister et al. 1999, Love 2011). They are, therefore, likely to be adequately protected in RCAs.

Other fish species that are found in RCAs are less obvious. Some species, such as shiner surfperch, are not commercially or recreationally important, but may be very significant ecologically as they are preyed upon by numerous species. Many species observed in RCAs live on non-rocky reef habitat surrounding rocky reefs. These non-reef habitat often form the majority of the habitat features in an RCA and include sand, mud, gravel and mixed substrates. Species very common to these habitat are juvenile and adult flatfish, spotted ratfish, Pacific cod, hake and walleye pollock, numerous species of sculpin, skate and other odd bottom-dwelling creatures like blackbelly eelpout (Appendix 2). All of these species may benefit from reduced fishing mortality and habitat destruction as a result of RCA regulations.

RCAs were designated in waters shallower than 200 metres. Many commercially caught flatfish and cod species found in waters deeper than 200 metres utilize shallower habitat as juveniles. Likewise, juveniles of rockfish species that are found in deeper waters such as canary, yellowtail, widow, boccacio and sharpchin rockfish are also found in RCAs and have been observed during the ROV surveys (Appendix 2). RCAs may, therefore, play a role in protecting critical juvenile habitat for commercially important groundfish species other than inshore rockfish.

Pelagic species such as Pacific herring and Pacific sardine may also use RCAs, particularly for spawning and rearing. Pelagic species are not well-represented in the ROV data since surveys were focused on benthic habitat and did not record many pelagic species. However, an overlay of RCAs and data on the herring spawn habitat index (HSI) collected by DFO and presented in the BCMCA atlas (BCMCA 2011) shows that 70 RCAs (43 per cent) contain herring spawning habitat (Table 7). Where herring spawn is present in an RCA the average HSI class ranges from 1.0 (lowest) to 6.0 (vital) (Appendix 3).

In addition to quantifying the fish that were observed on ROV transects, common, abundant and habitat-forming invertebrates were also recorded during video review. Appendix 2 lists 75 invertebrate taxa that were observed in RCAs. Note that this is not a comprehensive list of the invertebrates present or their abundance along the transects, since not all invertebrates that were recorded were counted and many others were not visible. Nonetheless, this list provides a sense of the diversity of species found in RCAs. Many of these species form important habitat for fish and other invertebrates and are, therefore, key to supporting biodiversity. Important habitat-forming species observed during the ROV surveys include gorgonian corals, glass and boot sponges, sea pens and whips, and anemones. Habitat-forming invertebrates are often at risk from bottom contact fishing methods such as bottom trawl, traps and longlines and, therefore, may benefit from protection in RCAs. Most habitat-forming invertebrates are also important habitat features for rockfish (Marliave, Conway et al. 2009).

Other invertebrate species that were observed in RCAs are commercially fished species such as giant red sea cucumbers, prawn, crab and Pacific octopus. Although they are still permitted to be fished in RCAs, they may also benefit from some level of habitat protection. Northern abalone, an endangered invertebrate species found on shallow rocky reefs and in kelp forests, were not observed on our ROV surveys due to abalone's shallow distribution and cryptic behaviour. The author has observed northern abalone in RCAs during scuba surveys. Abalone fisheries in B.C. are closed for conservation purposes but abalone are still know to be poached (Lessard, Campbell et al. 2007). They may, therefore, benefit from any increased enforcement or stewardship of RCAs. If any RCAs were upgraded to MPAs that prohibited additional fisheries, these invertebrate species would also benefit.

Table 7 *Other ecological and management features mapped in RCAs using BCMCA Atlas data*

Feature	Total	Number of RCAs with feature	Per cent of RCAs with feature
Average herring spawn habitat index (HSI) class	1.1	70	42.7
# Harbour seal haul-outs	179	64	39
# Sea lion colonies and rookeries	12	9	5.5
# Seabird colonies	80	65	39.6
RCAs that are also protected areas		34	20.7
RCA total area (km^2)	4831		

Other ecological values can also be mapped in RCAs using data from the BCMCA atlas. The number of RCAs that have harbour seal haul-outs, stellar sea lion colonies and rookeries, California sea lion colonies and seabird colonies (ancient murrelet, Cassin's auklet, double-crested cormorant, pelagic cormorant, pigeon guillemot, rhinoceros auklet) is given in Table 7. These species prey on rockfish and other fish species, so they may also benefit from the RCAs. Thirty-four RCAs (21 per cent) also overlap with protected areas (national park reserves and national marine conservation area reserves; provincial parks, protected areas or ecological reserves; or other types of protected areas) (Table 7 and Appendix 4). Protection of the ecological, social and recreational values in these areas may therefore be enhanced by RCAs.

Trophic cascades

Prawn and other shrimp abundance may eventually be driven down in RCAs since they are important prey species of rockfish. As rockfish biomass increases in RCAs, they will consume more prey, thereby reducing the population of their prey species. This is termed a "trophic cascade". Trophic cascades have been observed in marine reserves in New Zealand (Shears, Kushner et al. 2012) and California (Hamilton, Caselle et al. 2011) where fish predators of urchins control urchin populations and therefore shift community dynamics of kelp and invertebrates. Although B.C. does not have any major fish predators of sea urchins, trophic cascades might be expected to occur for shrimp and prawn species through increased predation from both rockfish and lingcod (Frid and Marliave 2010). Cloutier (2011) looked for evidence of trophic cascades in RCAs and, although he did not find any differences in community structure between RCAs and open sites, he did find that RCAs had fewer crab and spot prawn in them, as compared to open sites. Another trophic cascade that is possible in RCAs is that greater lingcod abundance in RCAs may exert increased predation pressure on rockfish populations. Although this is theoretically possible, neither increased lingcod abundance nor increased predation risk to rockfish in RCAs has yet to be been demonstrated.

Lessons learned from RCAs

British Columbia now has almost a decade of experience with spatial protection in the network of RCAs. Several lessons from this experience should be applied to the developing MPA network:

1. All empirical studies of RCAs reviewed in this report are limited by their lack of data from before the reserves were established. If proper foresight and resources are applied, this problem can be avoided and data can be collected prior to MPA establishment. For example, the system of marine reserves in Oregon is being phased in to allow for data to be collected prior to establishment (personal communication, D. Fox, Oregon Department of Fish and Wildlife). This greatly improves ability to assess performance of reserves and apply adaptive management.

2. Long-term monitoring of reserves is necessary to determine their effectiveness. Assessments of which reserves are performing well and which reserves are underperforming are necessary ingredients for adaptive management (Hamilton, Caselle et al. 2010, White, Botsford et al. 2011). Monitoring data and reserve assessments are also necessary to gain and retain buy in from fishing communities. All fishing sectors interviewed for this report felt strongly that they wanted to see long-term monitoring put into place in RCAs and were anxious to know how RCAs were performing. However, it is difficult to get support for long-term monitoring. The need for monitoring should, therefore, be specified and planned for in the establishment of MPAs.

3. Outreach, education and enforcement plans must also be developed and maintained for networks of MPAs. Commercial compliance with RCAs is very high since electronic fishery monitoring was put in place shortly after they were established. Recreational compliance, on the other hand, was found to be quite low. Recreational effort in 44 of 77 RCAs in the Strait of Georgia has not significantly dropped as a result of RCA establishment and compliance in many other RCAs around Vancouver Island in 2011 was also quite low. Greater education and outreach regarding RCA boundaries and regulations as well as why they are important is desperately needed. NGOs that have the ability to reach a broad spectrum of society such as the David Suzuki Foundation and the Vancouver Aquarium could play important roles in this regard. Modern tools such as smart-phone applications that employ GPS technology should be explored. These tools could both educate people about conservation initiatives as well as help people navigate in our increasingly complex world of spatially explicit management regulations. Compliance monitoring should also be built into monitoring plans to assess if regulations are having their desired effects. Enforcement must also be made a priority and supported with funding.

4. Although many RCAs protect good rockfish habitat and contain good rockfish populations, not all RCAs are likely to be effective. Some RCAs were simply not well-located. A review of RCAs needs to be undertaken to identify which are likely to be successful and which are sub-optimal. White, Botsford et al. (2011) very elegantly put it: "Now that networks of reserves have been implemented worldwide, the time is ripe for the implementation of adaptive management. … Questions need to evolve from "Do reserves work?" to "When and why do marine reserves work, how long does it take, and what should we be measuring?"

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Appendix 1 First Nation and recreational lodge/charter surveys

First Nation fisheries' perspectives on rockfish conservation areas

Dana Haggarty, M.Sc., PhD candidate
On behalf of the David Suzuki Foundation

Background:

Rockfish Conservation Areas (RCAs) were put into place from 2004 to 2006 as part of DFO's Rockfish Conservation Strategy. This was meant to help stop the decline in the number of inshore rockfish and help to increase and rebuild rockfish numbers (Yamanaka and Logan, 2010). "Inshore rockfish" include copper, quillback, yelloweye, tiger, China and black rockfish (See Figure A1 in main document for images of these species). As part of this strategy, 164 RCAs were designated all along the coast (See Figures A2 to A5). Although RCAs are not full no-take zones, they prohibit commercial and recreational fishing activity that directly or indirectly catch inshore rockfish. Aboriginal harvesting is a constitutional right that is not infringed upon in RCAs. As such, First Nation harvesters are permitted to target rockfish or take them as bycatch in RCAs. Some First Nations may, however, voluntarily choose to restrict their harvest in RCAs. However, in the commercial and recreational fishery, rockfish catch by hook-and-line and trawl, salmon troll and shrimp trawl fisheries are not permitted. Roe herring and invertebrate hand-pick or trap fisheries are permitted in RCAs (Yamanaka and Logan 2010).

Ayers et al. (2012) found that First Nations' perspectives on no-take zones (NTZ) in Marine Protected Areas (MPAs) were divergent and complex. Although there was low support for permanent NTZs, respondents showed greater support for seasonal and temporary closures, as these concepts more closely align with traditional First Nation management regimes. Support for closed areas was, however, seen more positively if the First Nation was to have greater involvement in their establishment and management. Another important point raised by Ayers et al. (2012) was that despite the historic importance of marine resources to all B.C. Coastal First Nations, today they have varying degrees of connections to marine resources, although all maintain marine harvesting is a part of their aboriginal right. The aboriginal relationship to marine resources has been eroded for reasons that include the development of commercial and recreational fisheries, policy and political decisions (Ayers, Dearden et al. 2012). Consequently, we expect First Nations' views on RCAs to be complex and divergent.

We are conducting research into the effectiveness of RCAs. One area of research concerns the degree to which RCAs have been accepted by the commercial, recreational and aboriginal fisheries. We are interested in perceptions on how RCAs are functioning and if rockfish populations are seen to be improving as a result of RCAs.

Questions:

Name: _____________________________

First Nation: _________________________

Position (i.e. fisheries or resource manager, councillor, fisher, etc.):

____

1. Was your First Nation consulted on the establishment of RCAs in its traditional territory?

2. Are RCAs seen as an important part of the current management strategy of rockfish?

3. Do you know where RCAs are in your traditional territory?

4. Which RCAs are found in your First Nation's traditional territory? Refer to the maps below (list or circle).

5. Have you seen or documented increased catches of rockfish that would indicate RCAs are "working" to recover rockfish? If not, do you feel RCAs are an insurance policy for the future recovery of rockfish?

6. Has fishing effort (commercial, recreational, aboriginal) decreased in RCAs in your traditional territory as a result of RCAs?

7. What is the health of inshore rockfish populations in your traditional territory?

8. Do you have any comments with respect to the current management of RCAs (e.g., enforcement, monitoring, etc.)?

Figure A1 *Images of the inshore rockfish species in British Columbia. All species are in the genus,* Sebastes *and are: (a) quillback, (b) yelloweye, (c) copper, (d) tiger, (e) China, and (f) black rockfish. Some common names of rockfish include rock cod, red snapper and black bass.*

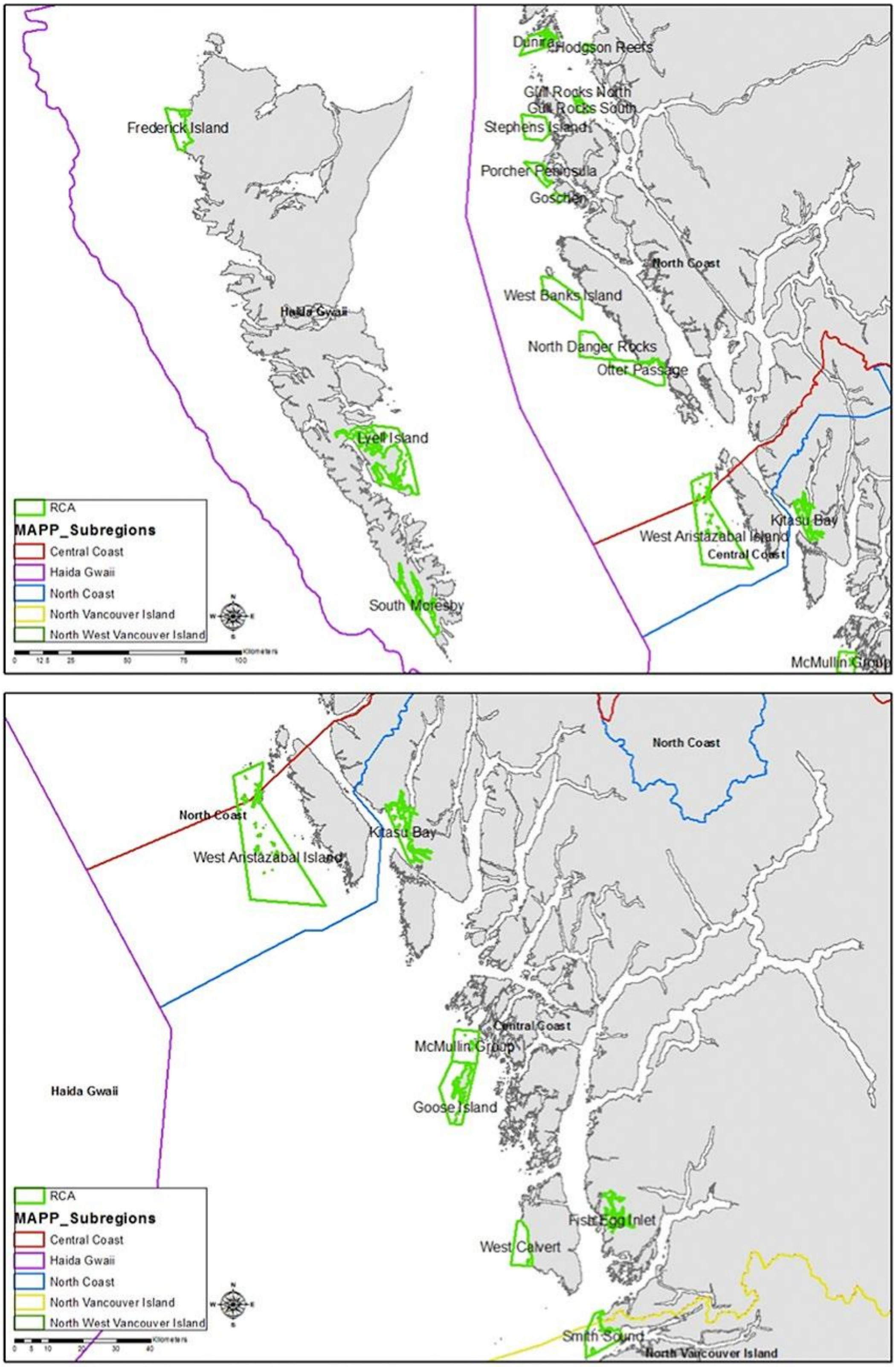

Figure A2 *Rockfish conservation areas in (a) Haida Gwaii and the north and (b) central coast of B.C.*

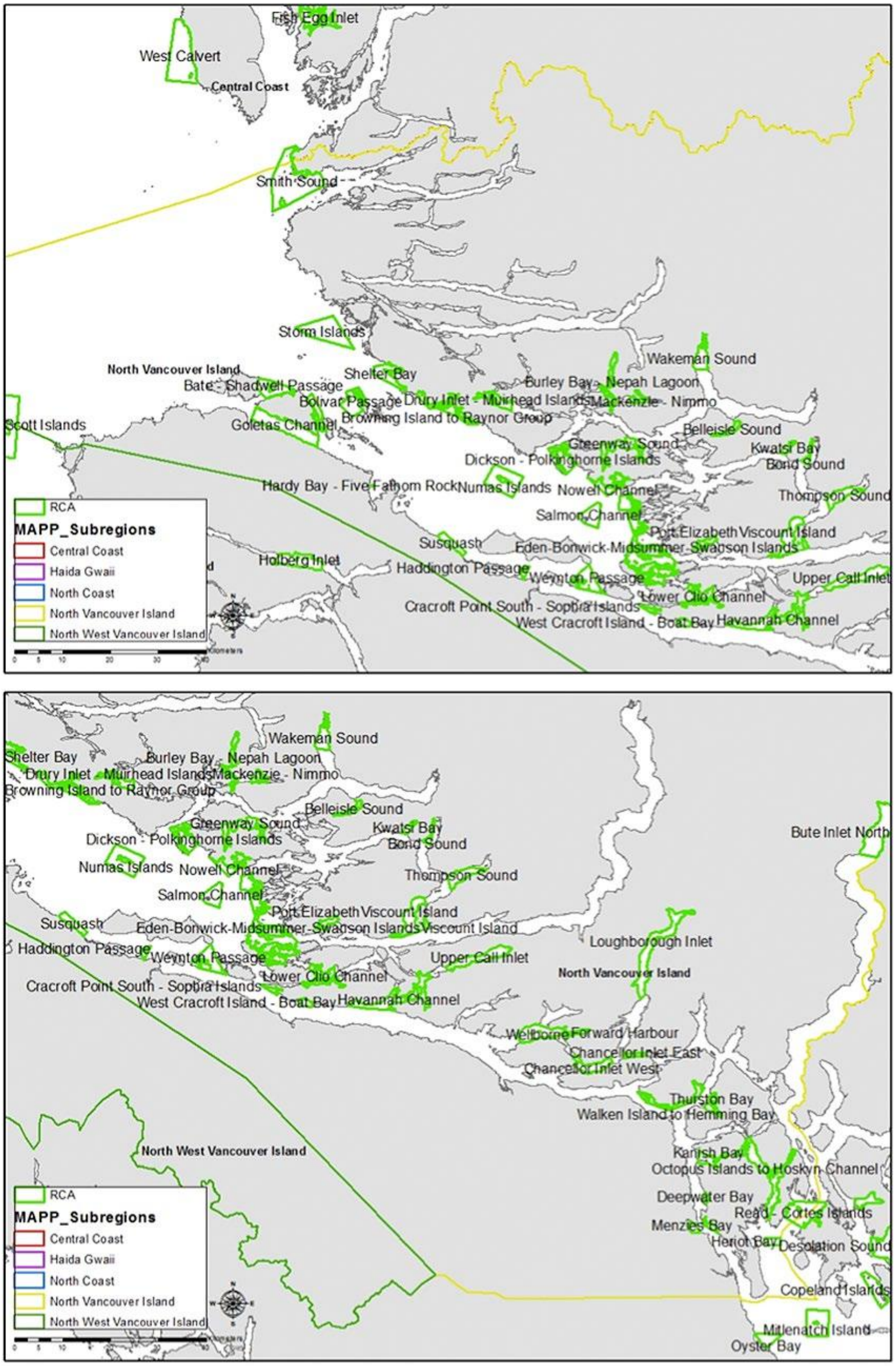

Figure A3 *Rockfish conservation areas in the North Vancouver Island planning area of B.C. (a) Queen Charlotte Strait, (b) Johnston Strait.*

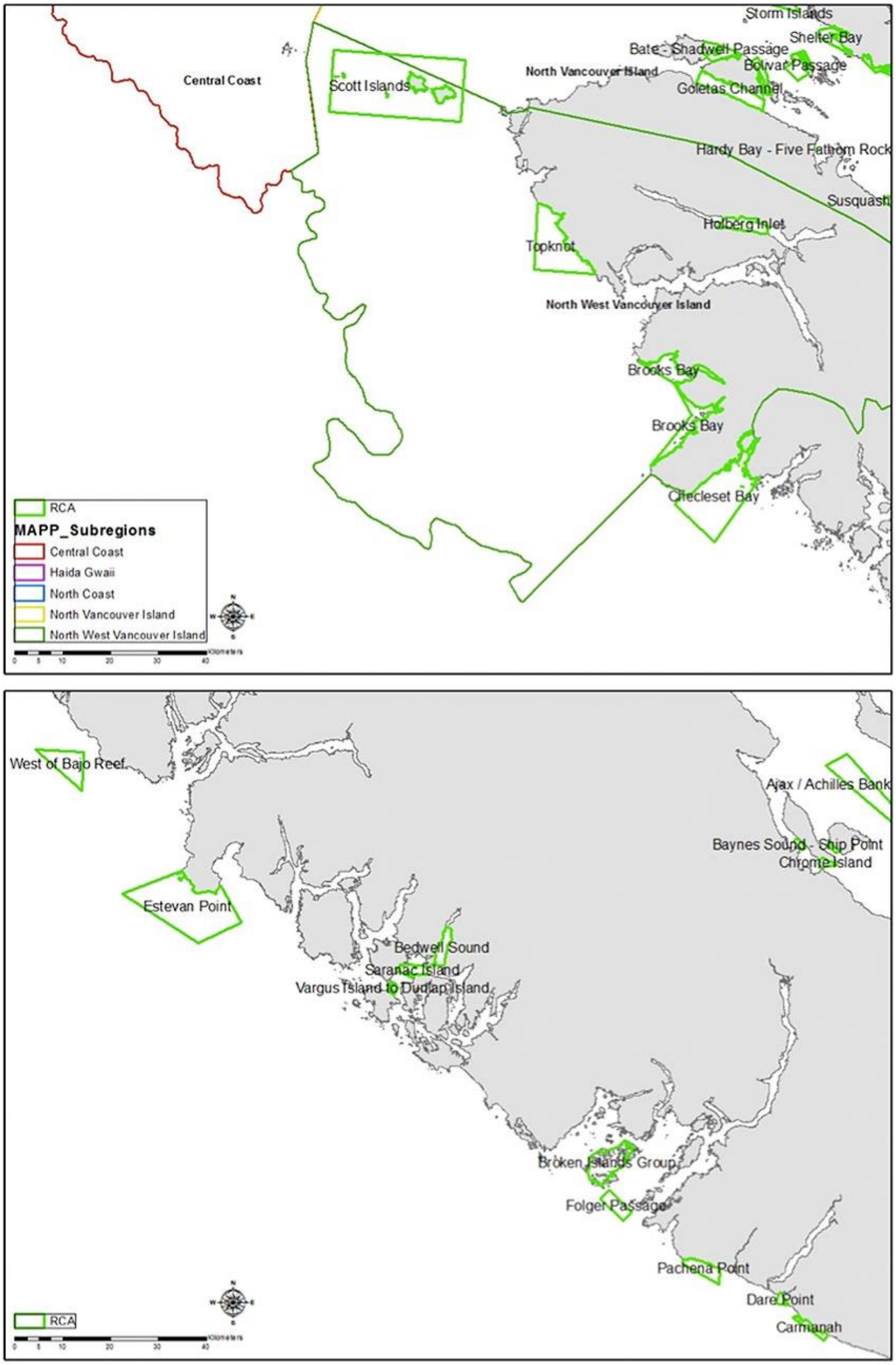

Figure A4 *Rockfish conservation areas on the west coast of Vancouver Island, B.C., (a) north, (b) south.*

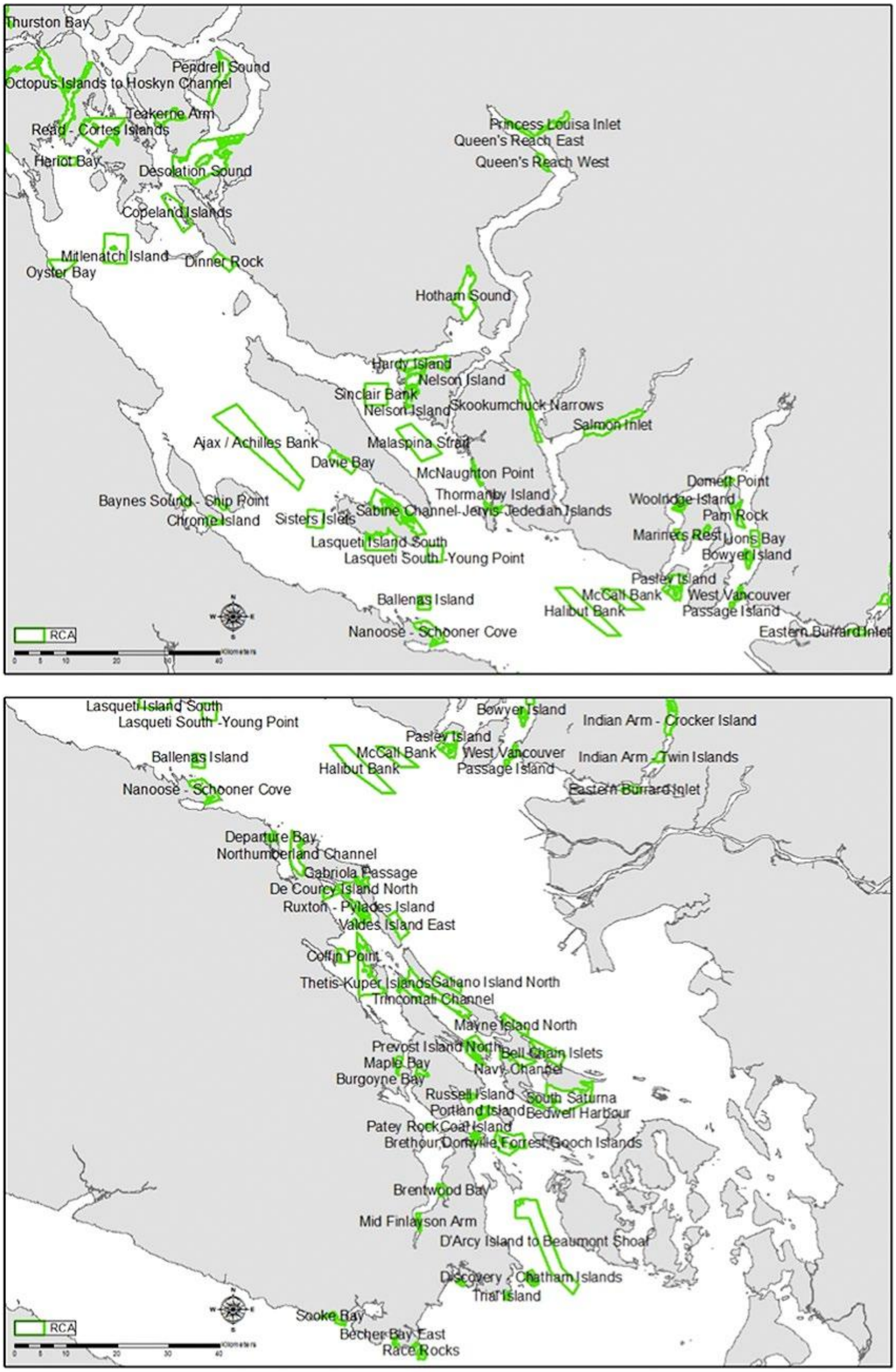

Figure A5 *Rockfish conservation areas in the Salish Sea, B.C, (a) north, (b) south*

Recreational lodge/charter perspectives on rockfish conservation areas

May 10, 2013

Dana Haggarty, M.Sc., PhD candidate

On behalf of the David Suzuki Foundation

Background:

Rockfish conservation areas (RCAs) were put into place from 2004 to 2006 as part of DFO's Rockfish Conservation Strategy. This was meant to help stop the decline in the number of inshore rockfish and help increase and rebuild rockfish numbers (Yamanaka and Logan, 2010). "Inshore rockfish" include copper, quillback, yelloweye, tiger, China and black rockfish (see Figure 1 for images of these species). As part of this strategy, 164 RCAs were designated all along the coast (See figures 2 to 5).

Although RCAs are not full no-take zones, they prohibit commercial and recreational fishing activities that directly or indirectly catch inshore rockfish. Aboriginal harvesting is a constitutional right that is not infringed upon in RCAs. As such, First Nation harvesters are permitted to target rockfish or take them as bycatch in RCAs. Some First Nations may, however, voluntarily choose to restrict their harvest in RCAs. However, in the commercial and recreational fishery, rockfish catch by hook-and-line and trawl, salmon troll and shrimp trawl fisheries are not permitted. Roe herring and invertebrate hand-pick or trap fisheries are permitted in RCAs (Yamanaka and Logan 2010).

We are conducting research into the effectiveness of RCAs. One area of research concerns the degree to which RCAs have been accepted by the commercial, recreational and aboriginal fisheries. We are interested in perceptions on how RCAs are functioning and if rockfish populations are seen to be improving as a result of RCAs. We greatly appreciate you taking a moment to fill in this questionnaire, particularly in this busy season!

(Figures 1 to 5 from above followed.)

Appendix 2 Species quantified on ROV surveys in RCAs

Scientific name	Common name	Number
Fishes		
Sebastinae	rockfish	7334
Hydrolagus colliei	spotted ratfish	1563
Cymatogaster aggregata	shiner perch	1366
Sebastes maliger	quillback rockfish	1344
Sebastes emphaeus	Puget Sound rockfish	1250
Gadidae	codfish	1227
Theragra chalcogramma	walleye pollock	1143
Pleuronectiformes	flatfish	973
Zoarcidae	eelpout	852
unknown fish	unknown fish	747
Hexagrammos decagrammus	kelp greenling	562
Sebastes pipnniger	canary rockfish	558
Sebastes flavidus	yellowtail rockfish	527
Sebastes ruberrimus	yelloweye rockfish	378
Sebastes elongatus	greenstriped rockfish	367
Ophiodon elongatus	lingcod	346
Sebastes nebulosus	China rockfish	262
Agonidae	poacher	245
Sebastes entomelas	widow rockfish	201
Sebastes caurinus	copper rockfish	193
Cottidae	sculpin	155
Sebastes helvomaculatus	rosethorn rockfish	143
Lipariscus nanus	pygmy snailfish	136
Sebastes zacentrus	sharpchin rockfish	108
Lepidopsetta bilineata	southern rock sole	99
Sebastes nigrocinctus	tiger rockfish	80
Microstomus pacificus	dover sole	78
Merluccius productus	Pacific hake	73
Sebastes miniatus	vermilion rockfish	71
Lumpenus sagitta	snake prickleback	70
Sebastes mystinus	blue rockfish	59
Stichaeidae	prickleback	59
Rhacochilus vacca	pile perch	49
Gadus macrocephalus	pacific cod	44
Myoxocephalus polyacanthocephalus	great sculpin	43
Bathymasteridae	ronquil	30
Parophrys vetulus	English sole	30
Clupea pallasii	Pacific herring	27

Scientific name	Common name	Number
Embiotocidae	surfperch	24
Sebastes brevispinis	silvergray rockfish	18
Glyptocephalus zachirus	rex sole	17
Chirolophis decoratus	decorated warbonnet	15
Ronquilus Jordani	northern ronquil	14
Hippoglossus stenolepis	Pacific halibut	13
Sebastes melanops	black rockfish	10
Hemilepidotus hemilepidotus	red Irish lord	9
Sebastes wilsoni	pygmy rockfish	9
Podothecus accipenserinus	sturgeon poacher	7
Raja rhina	longnose skate	7
Percidae	perch	6
Scorpaenichthys marmoratus	cabezon	6
Lycodes pacificus	blackbelly eelpout	5
Microgadus proximus	Pacific tomcod	5
Osmeridae	smelt	5
Sebastes diploproa	splitnose rockfish	5
Squalus suckleyi	north Pacific spiny dogfish	5
Anarrhichthys ocellatus	wolf eel	4
Enophrys bison	buffalo sculpin	4
Liparidae	snailfish	4
Lyopsetta exilis	slender sole	4
Rajidae	skate	4
Salmonidae	salmonid	4
Clupeidae	herring	3
Porichthys notatus	plainfin midshipman	3
Raja binoculata	big skate	3
Ruscarius meanyi	Puget Sound sculpin	3
Ammodytidae	sand lance	2
Gobiidae	goby	2
Hexagrammos stelleri	whitespotted greenling	2
Hyperprosopon argenteum	walleye surfperch	2
Malacocottus kincaidi	blackfin sculpin	2
Nautichthys oculofasciatus	sailfin sculpin	2
Platichthys stellatus	starry flounder	2
Sebastes crameri	darkblotched rockfish	2
Sebastes paucispinis	bocaccio	2
Sebastes proriger	redstripe rockfish	2
Sebastes variegatus	harlequin rockfish	2
Brosmophycis marginata	red brotula	1
Citharichthys stigmaeus	speckled sanddab	1

Scientific name	Common name	Number
Dasycottus setiger	spinyhead sculpin	1
Hemilepidotus spinosus	brown Irish lord	1
Hexagrammidae	greenling	1
Icelinus borealis	northern sculpin	1
Icelinus filamentosus	threadfin sculpin	1
Isopsetta isolepis	butter sole	1
Jordania zonope	longfin sculpin	1
Leptocottus armatus	Pacific staghorn sculpin	1
Limanda aspera	yellowfin sole	1
Odontopyxis trispinosa	pygmy poacher	1
Reinhardtius stomias	arrowtooth flounder	1
Invertebrates		
Asteroidea	starfish	3165
Parastichopus californicus	giant red sea cucumber	2864
Metridium	plumose anemone	1262
Crinoidea	sea lily and feather star	809
Hexactinellida	glass sponge	652
Munida quadrispina	squat lobster	606
Pennatulacea	sea pen	335
Pycnopodia helianthoides	sunflower starfish	297
Pandalus platyceros	prawn	255
Pachycerianthus fimbriatus	tube anemone	249
Strongylocentrotus purpuratus	purple sea urchin	193
Anthopleura	giant green anemone	188
Chlamys hastata	spiny scallop	156
Balticina septentrionalis	sea whip	150
Pisaster brevispinus	pink short-spined star	65
Nudibranchia	seaslug	55
Dendrobranchiata	shrimp	52
Euryalina	basket star	44
Actiniaria	anemone	42
Ptilosarcus gurneyi	sea pen	40
Hydrozoa	hydroid	29
Demospongiae	bath sponge	27
Chionoecetes	tanner crab	26
Mediaster Aequalis	vermillion starfish	23
Strongylocentrotus franciscanus	red urchin	22
Virgularia	sea pen	22
Ceramaster patagonicus	cookie star	19
Strongylocentrotus droebachiensis	green urchin	19

Scientific name	Common name	Number
Sedentaria	tube worm	18
Echinacea	sea urchin	14
Enteroctopus dofleini	giant Pacific octopus	14
Gorgonacea	gorgonian coral	14
Pectinidae	scallop	14
Bivalvia	bivalve mollusc	13
Cancer magister	dungeness crab	13
Octopoda	octopus	12
Palaeotaxodonta	protobranchia	11
Cancer productus	red rock crab	10
Lopholithodes	box crab	9
Paragorgia pacifica	pink gorgonian coral	9
Solaster stimpsoni	striped sun starfish	9
Aeolidiidae	aeolid nudibranch	8
Brachiopoda	lampshell	8
Cirripedia	barnacle	8
Paguridae	right-handed hermit	8
Phrynophiurida	euryaline brittle star	8
Henricia leviuscula annectens	blood star	7
Luidia foliolata	sand star	6
Ctenodiscus crispatus	mud star	5
Porifera	sponge	5
Rossia pacifica	Pacific bobtail squid	5
Calcarea	calcareous sponge	3
Teuthida	squid	3
Balanophyllia	balanophyllia	2
Cancridae	cancer crab	2
Cephalopoda	cephalopod	2
Dermasterias imbricata	leather star	2
Lithodinae	*Lithodinae*	2
Pandalidae	pandalid shrimp	2
Aoridae	*Aoridae*	1
Ascidiacea	ascidian and tunicate	1
Balanophyllia elegans	orange cup coral	1
Brachyura	true crab	1
Crossaster papposus	rose starfish	1
Dorididae	sea lemon	1
Euphausiacea	euphausiids	1
Euspira lewisii	Lewis moonsnail	1
Evasterias troschelii	mottled star	1
Fusitriton oregonensis	Oregon triton	1

Scientific name	Common name	Number
Lithodes	king crab	1
Oregonia gracilis	graceful decorator crab	1
Orthasterias koehleri	long-armed sea star	1
Oxyrhyncha	spider crab	1
Pteraster tesselatus	cushion star	1
Solasteridae	Sun star	1

Appendix 3 Other ecological values mapped in RCAs (data from BCMCA)

RCA name	RCA area km²	Eel-grass area km²	Kelp area km²	Eel-grass %	Kelp %	Avg. SHI class	Seal haul-outs	Sea lion	Bird colony
Ajax / Achilles Bank	73.9	0.0	0.0	0.0	0.0	0.0	0		
Ballenas Island	5.8	0.0	0.0	0.0	0.0	0.0	1		PC,PG
Bate - Shadwell Passage	17.8	0.0	0.5	0.0	3.0	0.0	1		
Baynes Sound - Ship Point	2.5	0.0	0.0	0.0	0.0	4.7	0		
Becher Bay East	1.0	0.0	0.0	0.0	0.0	1.0	0		
Bedwell Harbour	2.5	0.0	0.0	0.0	0.0	1.0	1		PC,PG
Bedwell Sound	15.4	0.0	0.0	0.0	0.0	3.0	0		
Bell Chain Islets	13.0	0.1	3.8	0.4	29.0	2.3	2		PG
Belle Isle Sound	5.1	0.0	0.0	0.0	0.0	0.0	0		
Bentinck Island	0.5	0.0	0.0	0.0	7.6	0.0	1		PC,PG, BC
Bolivar Passage	16.7	0.0	0.0	0.0	0.0	0.0	3		CA
Bond Sound	3.8	0.0	0.0	0.0	0.0	1.0	0		
Bowyer Island	3.1	0.0	0.0	0.0	0.0	0.0	1		PG
Brentwood Bay	3.4	0.0	0.0	0.1	0.0	3.0	0		
Brethour, Domville, Forrest, Gooch Islands	18.8	0.0	1.8	0.0	9.4	0.0	11		PG
Broken Islands Group	46.3	4.2	0.0	9.0	0.0	2.5	3		PC
Brooks Bay	73.7	1.2	0.1	1.7	0.1	3.2	2		PG
Browning Island to Raynor Group	17.4	0.0	3.7	0.0	21.1	0.0	0		
Browning Passage - Hunt Rock	10.0	0.0	0.2	0.0	2.2	0.0	1		CA
Burgoyne Bay	2.6	0.0	0.0	0.0	0.0	0.0	1		
Burley Bay - Nepah Lagoon	10.7	0.0	0.0	0.0	0.0	2.8	0		
Bute Inlet North	46.2	0.0	0.0	0.0	0.0	2.8	0		
Carmanah	8.2	0.0	1.9	0.0	23.3	0.0	1	S-h	
Chancellor Inlet East	3.5	0.0	0.0	0.0	0.0	0.0	0		
Chancellor Inlet West	13.9	0.0	0.5	0.0	3.7	0.0	0		
Checleset Bay	149.4	0.4	1.4	0.3	0.9	1.5	1	S-h	PG
Chrome Island	3.9	0.9	0.0	24.3	0.0	5.8	1		PC,PG
Coal Island	3.1	0.0	0.5	0.0	15.5	1.0	4		PG
Coffin Point	4.3	0.8	0.0	18.2	0.0	5.5	0		
Copeland Islands	16.9	0.0	0.0	0.0	0.0	2.0	4		PG
Cracroft Point South - Sophia Islands	2.7	0.0	0.5	0.0	19.6	0.0	0		
Danger Reefs	1.5	0.0	0.0	0.0	0.0	0.0	1		PG
D'Arcy Island to Beaumont Shoal	53.9	0.0	3.8	0.0	7.0	0.0	3		
Dare Point	3.5	0.0	0.9	0.0	27.1	0.0	1		PC
Davie Bay	10.2	0.0	0.0	0.0	0.0	0.0	1		

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RCA name	RCA area km²	Eel-grass area km²	Kelp area km²	Eel-grass %	Kelp %	Avg. SHI class	Seal haul-outs	Sea lion	Bird colony
De Courcy Island North	4.0	0.0	0.2	0.9	4.3	4.6	3		PG
Deepwater Bay	1.8	0.2	0.0	8.9	0.0	2.3	0		PG
Departure Bay	2.7	0.0	0.0	0.3	0.0	4.3	2		PG
Desolation Sound	60.0	0.0	0.2	0.0	0.4	0.0	0		
Dickson - Polkinghorne Islands	15.9	0.0	0.0	0.0	0.2	0.0	0		
Dinner Rock	6.7	0.1	0.0	1.5	0.0	5.0	0		
Discovery - Chatham Islands	3.8	0.0	1.2	0.0	32.2	0.0	1		PC
Domett Point	2.1	0.0	0.0	0.0	0.0	0.0	0		
Drury Inlet - Muirhead Islands	11.7	0.0	0.0	0.0	0.0	0.0	0		
Dunira Island	79.0	0.0	1.7	0.0	2.1	2.0	0		RA
Duntze Head (Royal Roads)	0.9	0.0	0.5	0.0	56.6	2.0	1		PC
Eastern Burrard Inlet	2.7	0.0	0.0	0.0	0.0	0.0	0		PC
Eden-Bonwick-Midsummer-Swanson Islands	68.7	0.0	1.4	0.0	2.0	3.0	12		PG
Estevan Point	186.3	0.2	5.2	0.1	2.8	3.5	0	S-h, S-r	
Fish Egg Inlet	28.2	0.0	0.3	0.0	1.2	2.3	0		
Folger Passage	17.0	0.0	0.0	0.0	0.0	0.0	0		PC
Forward Harbour	3.3	0.0	0.0	0.0	1.4	0.0	0		
Frederick Island	113.9	0.0	1.3	0.0	1.2	0.0	0	S-h	CA
Gabriola Passage	2.7	0.0	1.3	0.0	48.6	5.0	3		PC,PG
Galiano Island North	9.8	0.0	0.0	0.0	0.0	0.0	2		DC,PC, PG
Goletas Channel	36.7	0.0	1.2	0.0	3.4	0.0	1		
Goose Island	105.5	0.0	5.9	0.0	5.6	0.0	0	S-h	PG
Goschen	14.5	0.0	0.1	0.0	0.8	1.5	0		
Greenway Sound	17.9	0.0	0.0	0.0	0.2	1.0	0		
Gull Rocks North	5.9	0.0	0.0	0.0	0.0	0.0	0		RA
Gull Rocks South	20.9	0.0	0.2	0.0	1.0	0.0	0		PG
Haddington Passage	2.5	0.0	0.1	0.0	2.5	0.0	0		
Halibut Bank	33.0	0.0	0.0	0.0	0.0	0.0	0		
Hardy Bay - Five Fathom Rock	0.1	0.0	0.0	0.0	0.0	1.0	0		PG
Hardy Island	16.0	0.2	0.0	1.1	0.0	1.0	0		
Havannah Channel	32.1	0.0	0.6	0.0	1.9	2.7	0		
Heriot Bay	5.1	0.0	0.0	0.0	0.0	2.0	0		
Hodgson Reefs	11.5	0.2	0.1	1.6	1.1	6.0	0		
Holberg Inlet	22.5	2.2	0.2	9.7	0.7	1.7	1		
Hotham Sound	22.4	0.0	0.0	0.0	0.0	0.0	0		
Indian Arm - Crocker Island	9.0	0.0	0.0	0.0	0.0	0.0	0		
Indian Arm - Twin Islands	2.9	0.0	0.0	0.0	0.0	0.0	0		
Kanish Bay	8.3	0.0	0.0	0.0	0.0	2.6	1		
Kitasu Bay	64.8	0.8	0.1	1.2	0.1	3.6	0		

RCA name	RCA area km²	Eel-grass area km²	Kelp area km²	Eel-grass %	Kelp %	Avg. SHI class	Seal haul-outs	Sea lion	Bird colony
Kwatsi Bay	3.4	0.0	0.0	0.0	0.0	0.0	0		
Lasqueti Island South	18.5	0.0	0.0	0.0	0.0	0.0	4		PG
Lasqueti South -Young Point	9.3	0.0	0.0	0.0	0.0	0.0	0		
Lions Bay	4.8	0.0	0.0	0.0	0.0	0.0	0		
Loughborough Inlet	37.1	0.0	0.0	0.0	0.0	1.7	0		
Lower Clio Channel	13.9	0.0	1.0	0.0	7.0	2.4	0		
Lyell Island	331.8	0.5	14.4	0.2	4.3	1.9	11		AM
Mackenzie - Nimmo	4.0	0.0	0.0	0.0	0.0	0.0	0		
Malaspina Strait	28.3	0.0	0.0	0.0	0.0	0.0	0		
Maple Bay	3.2	0.1	0.0	2.4	0.0	1.0	0		
Mariners Rest	1.9	0.0	0.0	0.0	0.0	0.0	0		
Maud Island	3.1	0.0	0.2	0.0	5.7	1.0	0		
Mayne Island North	7.1	0.0	0.9	0.0	13.4	2.0	3		
McCall Bank	13.4	0.0	0.0	0.0	0.0	0.0	0		
McMullin Group	68.8	0.0	1.2	0.0	1.8	3.0	0		PG
McNaughton Point	2.2	0.0	0.0	0.2	0.0	0.0	0		
Menzies Bay	3.9	0.1	0.2	2.5	5.7	0.0	0		
Mid Finlayson Arm	1.9	0.0	0.0	0.0	0.0	0.0	0		
Mitlenatch Island	24.9	0.0	0.0	0.0	0.0	0.0	0		DC, PC,PG
Nanoose - Schooner Cove	12.0	0.1	0.3	0.5	2.4	5.2	6		
Navy Channel	8.3	0.0	0.7	0.0	7.9	0.0	2		
Nelson Island	8.9	0.7	0.0	8.1	0.0	2.0	1		
North Danger Rocks	128.8	0.0	0.0	0.0	0.0	0.0	0		
Northumberland Channel	14.8	0.0	0.0	0.0	0.0	3.7	2		PC,PG
Nowell Channel	12.4	0.0	0.0	0.0	0.3	0.0	0		
Numas Islands	28.9	0.0	0.3	0.0	1.0	0.0	1		RA
Octopus Islands to Hoskyn Channel	35.9	1.8	1.2	5.0	3.5	0.0	2		
Otter Passage	162.5	0.0	0.5	0.0	0.3	0.0	0		PG
Oyster Bay	9.1	0.0	0.0	0.5	0.0	2.0	0		
Pachena Point	19.3	0.0	0.0	0.0	0.0	0.0	1		
Pam Rock	5.7	0.0	0.0	0.0	0.0	0.0	3		DC,PC
Pasley Island	12.0	0.0	0.0	0.0	0.0	2.5	6		PG
Passage Island	0.8	0.0	0.0	0.0	0.0	0.0	0		PC,PG
Patey Rock	0.9	0.0	0.0	0.0	0.0	0.0	1		PG
Pendrell Sound	15.3	0.0	0.0	0.0	0.0	0.0	0		
Porcher Peninsula	50.1	0.0	1.6	0.0	3.2	2.0	0		
Port Elizabeth	6.0	0.0	0.1	0.0	2.3	0.0	0		
Portland Island	3.0	0.0	1.4	0.0	46.9	0.0	3		PG
Prevost Island North	9.1	0.5	0.4	5.9	4.3	3.1	5		DC

RCA name	RCA area km²	Eel-grass area km²	Kelp area km²	Eel-grass %	Kelp %	Avg. SHI class	Seal haul-outs	Sea lion	Bird colony
Princess Louisa Inlet	6.3	0.0	0.0	0.0	0.0	0.0	0		
Queen's Reach East	4.5	0.0	0.0	0.0	0.0	0.0	0		
Queen's Reach West	3.5	0.0	0.0	0.0	0.0	0.0	0		
Race Rocks	2.7	0.0	1.2	0.0	45.2	0.0	0	S-h, S-r, C-h	PC,PG, BC
Read - Cortes Islands	30.3	0.4	0.0	1.2	0.0	1.2	0		
Reynolds Point - Link Island	4.3	0.2	0.3	3.8	7.0	5.0	2		PG
Russell Island	2.4	0.0	0.5	0.6	21.9	2.0	0		
Ruxton - Pylades Island	6.8	0.1	0.2	2.0	2.3	4.3	0		PC,PG
Sabine Channel - Jervis -Jedediah Islands	22.4	0.0	0.0	0.0	0.0	0.0	12		PC
Salmon Channel	14.5	0.0	0.0	0.0	0.0	0.0	2		PG
Salmon Inlet	17.5	0.0	0.0	0.1	0.0	0.0	0		
Saltspring Island North	8.5	0.0	0.0	0.0	0.0	4.0	5		PG
Saranac Island	10.9	0.1	0.0	1.0	0.1	3.3	0		
Savoie Rocks - Maude Reef	1.7	0.6	0.0	31.9	0.0	6.0	1		
Scott Islands	339.2	0.0	0.0	0.0	0.0	0.0	5		CA
Shelter Bay	15.5	0.0	0.2	0.0	1.6	1.0	0		
Sinclair Bank	19.2	0.0	0.0	0.0	0.0	0.0	0		
Sisters Islets	10.7	0.0	0.0	0.0	0.0	0.0	1		PC
Skookumchuck Narrows	13.2	0.0	0.1	0.0	0.5	1.0	0		
Smith Sound	70.8	0.0	1.6	0.0	2.2	0.0	0		PG
Sooke Bay	3.4	0.0	0.4	0.0	13.0	0.0	0		
South Moresby	132.9	0.8	11.4	0.6	8.6	2.8	3	S-h	AM
South Saturna	30.9	0.0	0.3	0.0	1.0	0.0	6		PG
Stephens Island	112.0	0.0	1.1	0.0	1.0	0.0	0	S-h	
Storm Islands	37.3	0.0	0.8	0.0	2.1	0.0	3		CA
Susquash	8.1	0.0	1.3	0.0	15.6	2.0	1		
Teakerne Arm	8.4	0.0	0.0	0.0	0.0	0.0	0		
Thetis-Kuper Islands	25.7	0.8	0.0	3.1	0.0	4.4	5		PG
Thompson Sound	13.9	0.0	0.0	0.0	0.0	1.3	0		
Thormanby Island	3.2	0.0	0.1	0.9	4.3	1.0	2		
Thurston Bay	6.6	0.0	0.0	0.0	0.0	1.0	0		
Topknot	96.1	0.0	2.4	0.0	2.5	0.0	1		
Trial Island	0.8	0.0	0.7	0.0	80.8	0.0	0		PC
Trincomali Channel	21.7	0.0	0.6	0.0	2.5	0.0	4		PG
Upper Call Inlet	21.0	0.0	0.0	0.0	0.0	0.0	0		
Upper Centre Bay	1.1	0.0	0.0	0.0	0.0	1.0	0		
Valdes Island East	10.1	0.0	1.1	0.0	10.7	3.5	1		DC
Vargus Island to Dunlap Island	2.8	0.4	0.0	14.2	1.6	4.3	0		
Viscount Island	22.0	0.0	0.0	0.0	0.0	0.0	0		
Wakeman Sound	12.5	0.0	0.0	0.0	0.0	4.0	0		

RCA name	RCA area km²	Eel-grass area km²	Kelp area km²	Eel-grass %	Kelp %	Avg. SHI class	Seal haul-outs	Sea lion	Bird colony
Walken Island to Hemming Bay	13.6	0.0	0.2	0.0	1.6	0.0	0		
Wellborne	23.0	0.2	1.3	0.8	5.8	0.0	0		
West Aristazabal Island	493.1	0.0	5.2	0.0	1.0	0.0	0	S-h	RA
West Banks Island	154.5	0.0	2.5	0.0	1.6	0.0	0		
West Bay	1.1	0.0	0.0	0.0	0.0	0.0	0		
West Calvert	57.1	0.0	0.0	0.0	0.0	0.0	0		
West Cracroft Island - Boat Bay	3.6	0.0	0.0	0.0	0.0	0.0	0		
West of Bajo Reef	41.8	0.0	0.0	0.0	0.0	0.0	0		
West Vancouver	2.8	0.0	0.0	0.0	0.0	1.0	1		PG
Weynton Passage	17.6	0.0	0.4	0.0	2.2	0.0	1		PG
Woolridge Island	3.8	0.0	0.0	0.0	0.0	0.0	0		
Total	**4831**	**19**	**100**	**0.4**	**2.1**		**179**	**12**	**80**
Present in RCA		23	79			70	64	9	65
Percent of RCAs		14.0	48.2			42.7	39.0	5.5	39.6

Codes: SHI=herring spawn habitat index class: 0=absent, 1=lowest, 2=low, 3=medium, 4=high, 5=major, 6=vital; sea lions: S-h=Stellar sea lion haul-out, S-r=Stellar sea lion rookery, C-h=California sea lion haul-out; bird colonies: AM=ancient murrelet, CA=Cassin's auklet, DC=double-crested cormorant, PC=pelagic cormorant, PG=pigeon guillemot, RA=rhinoceros auklet

Appendix 4 RCAs that are also protected areas (PAs)

RCA name	PA type	Park name
Bedwell Harbour	NPR	Gulf Islands NPR of Canada
Bell Chain Islets	NPR	Gulf Islands NPR of Canada
Broken Islands Group	NPR	Pacific Rim NPR of Canada
Brooks Bay	PP	Brooks Peninsula PP
Carmanah	NPR	Pacific Rim NPR of Canada
Checleset Bay	PP	Brooks Peninsula PP
D'Arcy Island to Beaumont Shoal	NPR	Gulf Islands NPR of Canada
Dare Point	NPR	Pacific Rim NPR of Canada
Desolation Sound	PP	Desolation Sound/Copeland Islands Marine PPs/ Tux'wnech Okeover Arm
Eden - Bonwick - Midsummer -Swanson Islands	PP	Broughton Archipelago Marine PP
Estevan Point	PP	Hesquiat Peninsula PP
Folger Passage	NPR	Pacific Rim NPR of Canada
Goose Island	PPA	Hakai Protected Area
Goschen	Other	Gitxaala Nii Luutiksm/Kitkatla Conservancy
Indian Arm - Crocker Island	PP	Indian Arm PP
Kitasu Bay	Other	Kitasoo Spirit Bear Conservancy
Lyell Island	NPR, NMCA	Gwaii Haanas NPR, NMCA and Haida Heritage Site
McMullin Group	PPA	Hakai Protected Area
Mid Finlayson Arm	PP	Gowlland Tod PP
Octopus Islands to Hoskyn Channel	PP	Main Lakes PP
Pachena Point	NPR	Pacific Rim NPR of Canada
Pendrell Sound	PER	East Redonda Island ER
Porcher Peninsula	Other	Gitxaala Nii Luutiksm/Kitkatla Conservancy
Portland Island	NPR	Gulf Islands NPR of Canada
Prevost Island North	NPR	Gulf Islands NPR of Canada
Read - Cortes Islands	PP	Ha'thayim Marine PP
Savoie Rocks - Maude Reef	PP	Helliwell PP
Scott Islands	PP	Lanz and Cox Islands PP
South Moresby	NPR, NMCA	Gwaii Haanas NPR, NMCA and Haida Heritage Site
South Saturna	NPR	Gulf Islands NPR of Canada
West Aristazabal Island	PER	Byers/Conroy/Harvey/Sinnett Islands ER
West Banks Island	Other	Lax Kul Nii Luutiksm/Bonilla Conservancy
West Calvert	PPA	Hakai Protected Area
West Vancouver	Other	Whytecliff Park
Number of RCA	34	
Percent of RCAs	20.7	

Codes: NPR=national park reserve, NMCA=national marine conservation area, PP=provincial park, PPA=provincial protected area, PER=provincial ecological reserve