

Conservation and compliance: A quantitative assessment of recreational fisher  
compliance in Rockfish Conservation Areas

by

Darienne Lancaster  
BAH, Queen's University, 2013

A Thesis Submitted in Partial Fulfillment  
of the Requirements for the Degree of

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in the School of Environmental Studies

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## **Supervisory Committee**

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### **Supervisory Committee**

Dr. Natalie Ban, School of Environmental Studies  
**Supervisor**

Dr. Philip Dearden, Department of Geography  
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## Abstract

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Concerns about declines in marine biodiversity led to the creation of marine protected areas and spatial fishery closures as tools for recovery. Yet many marine conservation areas suffer low levels of compliance from diverse fishing populations, including recreational fishers. Little research quantifies levels of recreational fisher compliance and its drivers, especially in temperate marine environments, despite the prevalence of this kind of fishing in some regions. This thesis addresses this knowledge gap through a study of recreational fisher compliance in Rockfish Conservation Areas (RCAs) in British Columbia, Canada. One hundred and sixty four RCAs were implemented between 2003 and 2007 and now cover 4847.2 km<sup>2</sup>. These conservation areas were created in response to widespread concern from fishers and non-governmental organizations about inshore rockfish population declines. However, recent research suggested that recreational fisher compliance might be low.

This thesis had two goals: 1) contribute to knowledge about, and develop methods of assessing, non-compliance within marine conservation areas, and 2) address the immediate problem of suspected recreational non-compliance in RCAs. I had the following objectives: 1) Assess ecological and social RCA effectiveness to date, using a framework for improving governance from the literature on common pool resources; 2) Assess recreational fisher knowledge and perceptions of RCAs, and 3) Quantify non-compliance and social and ecological compliance drivers in RCAs. Methods included a literature review, structured surveys with 325 recreational fishers at 16 locations in the Salish Sea (Southern Gulf Islands and Victoria area), and trail camera monitoring in 42 coastal locations (both RCAs and unprotected sites).

Results show that recreational fisher knowledge and compliance to RCA regulations is low. The assessment of social and ecological effectiveness shows much room for management improvement for recreational fisheries. This finding is supported by my survey and trail camera data. I found that 25.5% of recreational fishers had never

heard of RCAs and ~60% were unsure of RCA locations. The total non-compliance rate was 23% in RCAs. Seventy nine percent of trail camera monitored RCA sites showed confirmed or probable fishing activity, with no significant difference between fishing effort inside and outside RCAs. However, 77% of fishers surveyed believed that rockfish conservation is necessary with advertising, fisher education, and increased monitoring offered as solutions to non-compliance.

I recommend managers implement a public outreach and education campaign to address low levels of compliance. This study suggests that positive perceptions of marine conservation areas and conservation initiatives are not enough to create high compliance. Educating stakeholders and creating high levels of awareness should be an essential first step when creating marine conservation areas.

My research offers important insights into the study of non-compliance, and the immediate problem of recreational non-compliance in BC's RCAs. My successful use of a simple and cost/time efficient multiple methods approach to assessing compliance provides robust tools for future compliance analyses, and hence provides a valuable contribution to the compliance literature. The study also suggests that trail camera monitoring could be a promising new method for monitoring coastal conservation areas.

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## **Dedication**

This thesis is dedicated to the waters of the Salish Sea and to all the creatures that live there. Thank you to everyone who helped me to learn about and explore these waters on land, by boat, or through diving. Above all, thank you to all the great, old rockfish who inspired my research and who will surely outlive us all if they are given the chance.

# **Chapter 1: Introduction and Thesis Goals**

## **1.1 Introduction**

This study addresses the issue of recreational fisher non-compliance in marine conservation areas. Here compliance is defined as adherence to the rules (e.g. boundaries, gear restrictions) governing marine conservation areas. My research contributes new knowledge and explores a new method of assessing non-compliance through an in-depth study of recreational fisher non-compliance in Rockfish Conservation Areas (RCAs) in British Columbia (BC), Canada. This information is critical, not only in BC, but internationally where marine spatial conservation has become a popular conservation tool. Knowledge of non-compliance and its motivators, especially from seldom studied recreational fisher populations, is crucial to creating marine conservation areas that meet conservation targets. This introductory chapter gives a brief history of the topics and issues discussed in this thesis. Chapter 2, a literature review and assessment of RCA effectiveness, offers additional detail and background on the research topic. This introductory chapter also outlines the thesis goals and objectives, the thesis structure, and the rationale for adopting a mixed methods approach to assessing compliance.

## **1.2 Marine Spatial Conservation**

Overfishing and human caused marine degradation have seriously impacted the health of the oceans (Pauly et al 2002, Molfese et al. 2014). Many fisheries are currently collapsed, overexploited, or depleted, often leading to serious repercussions at an ecosystem level (Pauly et al. 2008, Dayton et al. 2000). The perception of the ocean as an inexhaustible resource for most of human history has led to mismanagement (Russ and Zeller 2003, Worm et al. 2006), and has made the collapse of many of the world's fisheries an iconic example of the tragedy of the commons in action. The tragedy of the commons, famously described by Hardin (1968), explains how shared, finite resources (e.g. forests, fisheries), also known as common pool resources, are often overexploited. In these situations, the exploited resource directly benefits individual exploiters while the

costs of over-use are shared amongst a large group (Hardin 1968). It was long thought that common pool resource users could not self-organize and tragedy was inevitable without government or private ownership. However, a growing literature suggests that these systems are capable of collective governance, especially when certain attributes exist within these governance systems (Cox et al. 2010). Ostrom (1990) defined eight of these “design principles” contributing to improved local governance of common pool resources. The presence of these principles is often a good indicator of effectively-run systems (Cox et al. 2010) and recent literature has begun to scale up the design principles for federally-run systems to inform governance decisions and make improvements (Epstein et al. 2013). These kinds of analysis are important for creating and improving marine conservation areas that often involve the protection and regulation of common pool resources.

Marine spatial conservation in the form of marine protected areas (MPAs) and fisheries closures (hereafter jointly referred to as marine conservation areas) has become a popular method of protecting and rebuilding depleted marine resources (Allison et al. 1998, Marinesque et al. 2012). These areas have been shown to effectively protect species and rebuild depleted populations when combined with other conservation measures like catch limits and monitoring (Allison et al. 1998, Pauly et al. 1998, Mosquera et al. 2000, Halpern 2003, Babcock et al. 2010). However, marine conservation areas are not a panacea and they often face numerous ecological and social challenges. Developing marine conservation areas with clear ecological goals that also consider and accommodate stakeholder needs and preferences is a complicated and time consuming process (Pollnac et al. 2011), which is unfortunate given the need for urgent action to conserve many marine resources and habitats (Worm et al. 2006).

Beyond the ecological challenges of selecting appropriate sites to maximize conservation of target species (Challenger and Marliave 2009, Haggarty 2014), one of the main challenges facing marine conservation areas is fisher non-compliance (Pollnac et al. 2010). Research has shown that even low levels of non-compliance from any fishing sector can significantly reduce or even negate the effectiveness of conservation areas (Post et al 2002, Little et al. 2005, Sadovy and Domeier 2005, Graham et al. 2010, Edgar et al. 2013, Arias 2015). Social buy-in is crucial to conservation area success. A review

of 127 MPAs internationally found that local perceptions and understanding of the reasons behind and possible benefits of marine conservation was the leading factor contributing to high fisher compliance (see Chapters 2 and 3 for more detail) (Pollnac et al. 2011).

This thesis focuses on the often overlooked recreational fishing sector, specifically tidal waters fishers (Poste et al. 2002). In Canada, recreational fishers are any individuals, not including First Nations, possessing a Canadian recreational fishing license that extract marine/aquatic resources from Canadian waters for personal consumption or sport and not for profit. Unlike commercial fisheries that are often intensively monitored and regulated, especially in North America, recreational fishing is largely unregulated and difficult to monitor (Poste et al. 2002, Haggarty 2014). The individual nature of recreational fishing epitomizes a tragedy of the commons scenario where individual fishers are largely unable to see or imagine the overall scale of their impact on marine resources. However, recreational fishing takes 12% of the total annual marine catch globally, predominantly from heavily exploited coastal regions (Cooke and Cowx 2004, Granek et al. 2008). Intensive fishing, even from small populations of fishers, can be particularly detrimental to long-lived, sedentary species such as rockfish (*Sebastes*) that are easily fished out locally with concentrated effort (Parker et al. 2000, Love et al. 2002, Little et al 2005). Despite this, studies of recreational fisher compliance in marine conservation areas are rare, especially in temperate marine waters (Schill and Kline 1995, Read et al 2011, Smallwood and Beckley 2012, Arias and Sutton 2013, Haggarty et al. in review).

### **1.3 Rockfish Biology**

Rockfish (*Sebastes*) are a genus of long-lived, primarily coastal fish found throughout the world. BC is host to ~37 unique species of rockfish, including the Rougheye (*Sebastes aleutianus*) rockfish, which can live over 200 years (Love et al. 2002). The slow maturation and longevity of rockfish make them particularly vulnerable to intensive fishing pressure. Their high site fidelity – many rockfish live on the same boulder for their entire lives – also means localized overfishing can have serious impacts on specific

rockfish stocks (Parker et al. 2000, Love et al. 2002). Additionally, incidentally caught rockfish typically suffer fatal barotrauma due to their closed (physoclistic) swimbladders which trap expanding gasses and cause internal injury when they are rapidly pulled to the surface in nets or on lines (Parker et al. 2006). Rockfish bycatch is a major cause of rockfish mortality (Yamanaka and Logan 2010).

These biophysical characteristics make rockfish particularly vulnerable to fishing pressure and, after the creation of a rockfish specific commercial fishery in the 1970s many rockfish populations experienced large declines (COSEWIC 2009a, COSEWIC 2009b, Yamanaka and Logan 2010, Haggarty 2014). Rockfish are popular locally as well as internationally, especially in the Asian live fish market where they are prized for their perfect “whole fish” plate size and for their firm filets and delicious taste (Love et al. 2002). This popularity has negatively impacted many stocks with Yelloweye (*Sebastes ruberrimus*) rockfish reduced to 12% of their historic 1918 abundance (DFO 2011). Quillback rockfish (*Sebastes malinger*) are currently listed as Threatened by the Committee on the Status of Endangered Wildlife in Canada, and Yelloweye rockfish are listed as a Species of Concern by the Species At Risk Act (COSEWIC 2009b, SARA 2015).

#### **1.4 Creation of the Rockfish Conservation Areas**

In 2002, in response to concerns of rockfish population declines expressed by local stakeholders, fishers, and non-government organizations (NGOs), the Department of Fisheries and Oceans (DFO) began to develop the Rockfish Conservation Strategy (Yamanaka and Logan 2010). The strategy’s aim was to protect and rebuild five inshore species of rockfish through bycatch and total catch reductions, spatial protection, and increased monitoring (See chapter 2 for more detail) (Yamanaka and Logan 2010). This thesis focuses on the strategy’s spatial component.

Between 2003 and 2007, 164 RCAs were created along the entire coast of British Columbia, protecting 4847.2 km<sup>2</sup> of ocean (Yamanaka and Logan 2010). RCAs were selected after 61 regional consultations with stakeholders and various fishers across BC (Yamanaka and Logan 2010). These areas were selected in an attempt to avoid impacting

important fishing grounds for commercial and recreational fishers. Commercial and recreational fishing restrictions were designed to limit activities that frequently impact rockfish such as bottom trawling and hook and line fishing (Yamanaka and Logan 2010). RCAs do not restrict aboriginal fishing activities (DFO 2014a). This was a precedent setting move by DFO, spurred largely by the action of concerned stakeholders and NGOs, to swiftly implement changes on multiple levels to protect a genus of concern. However, the strategies' spatial protection program has also been critiqued for its RCA habitat selection model and its lack of thorough education and outreach post-implementation (Challenger and Marliave 2009, Haggarty 2014). RCAs also do not fall under the traditional definition of an MPA because they are not permanent closures with the primary goal of biodiversity protection (Robb et al. 2011). However, the RCAs still represent an impressive effort to incorporate spatial protection into Canada's fisheries management, and study of this program can offer valuable insight into future Canadian MPA projects that will also hinge upon conservation area keystones such as stakeholder support and compliance (e.g. Lien, 1999; White et al., 2002; Clifton, 2003; Himes, 2007a).

## **1.5 Study Area**

The Salish Sea (Strait of Georgia, Puget Sound, and Strait of Juan de Fuca) and surrounding area is unique to Canada as the warmest and wettest region in the country. It plays host to some of the most biologically diverse, rare and unique ecosystems in the country (Davenne and Masson, 2001). This area's desirable climate also makes it a magnet for human populations. For example, nearly 20% of BC's population lives on Vancouver Island (primarily in the Victoria area) despite the fact that the island makes up only three percent of BC's total area. This intense clustering of human activity makes the Salish Sea particularly vulnerable to human caused marine impacts (Grey 2002). This region experiences some of the most intensive recreational fishing in all of BC, particularly around the Southern Gulf Islands and Victoria area. Not surprisingly, inshore rockfish are most critically threatened here (Haggarty 2014). The commercial sector in this region is heavily monitored and levels of rockfish bycatch are intensively regulated

through the Integrated Groundfish Management Plan (See Ch. 2 for more detail). Most intensive commercial fishing takes place outside the Salish Sea (Haggarty 2014).

Although 2/3 of RCAs are located in this region, the lack of thorough post-implementation education and outreach makes suspected recreational fisher non-compliance a serious concern (Haggarty 2014). An analysis of DFO aerial fly-over data found that recreational compliance was low (Haggarty et al. in review). The recreational fishery is hard to monitor and, aside from annual Creel surveys, which do not ask RCA specific questions, little is known about recreational fisher rockfish catch, compliance with regulations, or perceptions of RCAs.

## **1.6 Study goals and objectives**

This thesis had two primary goals: 1) contribute to knowledge about, and develop methods of assessing, non-compliance within marine conservation areas, and 2) address the immediate problem of suspected recreational non-compliance in RCAs. This study had the following objectives:

1. Assess overall ecological and social RCA effectiveness to date, using existing RCA assessments and a framework for improving governance from the literature on common pool resources.
2. Assess recreational fisher knowledge and perceptions of RCAs.
3. Quantify non-compliance and social and ecological compliance drivers in RCAs.

## **1.7 Methodology**

I chose a case study approach to meet my thesis goal of contributing knowledge and new methods of assessing non-compliance in marine conservation areas. Recreational fisher compliance has been under-studied. The RCAs in BC provided an opportunity to begin filling in this specific knowledge gap and also allowed me to directly study the place I live. My choice to research a place I am deeply invested in focused my work and drove me to seek tangible solutions to a problem I could see in my day-to-day life. This focus

on addressing problems in their real life context is the backbone of case study research and one of the method's strengths (Yin 1992). Although the results of my thesis may not be generalized for all regions, my case study can offer valuable suggestions for managing RCAs throughout BC and will contribute to a growing body of case study knowledge on conservation area compliance.

I chose a mixed method approach to assess compliance and its influencers. The use of mixed methods allows for comparison of results across methods that can help pinpoint problem areas or highlight methodological errors (Yin 1992, Creswell 2005). Existing compliance studies seldom use quantitative methods and the use of multiple quantitative methods to assess compliance is even more rare. In a review of compliance literature, Bergseth et al. (2013) found only five percent of quantitative analysis used multiple methods to assess compliance. This study uses both a quantitative survey and direct observation using trail cameras to cross check data and provide more reliable compliance estimates (Bergseth et al. 2013). Additionally, we included a short qualitative section in our survey to assess recreational fisher perceptions of RCAs. I felt this was crucial to include given the multitude of studies that cite stakeholder support, understanding, and engagement as key to marine conservation area success (Pollnac et al. 2010). The integration of quantitative and qualitative methods is useful for addressing the who, what, when, where, and why's of a problem with both breadth and depth (Henderson and Bendini 1995).

This study also recognizes the importance of assessing both social and ecological aspects of conservation issues, and my research analyzes both ecological and social compliance drivers. Marine conservation areas epitomize the mingling of ecological and social concerns and emphasize the need to integrate interdisciplinarity into compliance research (Arias 2015).

## **1.8 Thesis Structure**

This thesis addresses several different aspects of recreational non-compliance, and thus chapters 2 – 4 have been designed as stand-alone manuscripts aimed at publication in peer-reviewed journals.

Chapter 1 offers a brief introduction to the topics and issues related to the thesis research (e.g. history of marine spatial protection, non-compliance, creation of RCAs). This chapter also outlines the thesis goals and objectives, thesis structure, and rationale for a mixed methods approach.

Chapter 2 provides a literature review of existing studies on the social and ecological impacts of the RCAs. I use the Design Principles for effective management of common pool resources, developed by Ostrom (1990) and modified by Cox et al. (2010), to evaluate the RCA management of the commercial and recreational fishery and highlight current strengths and weaknesses.

Chapter 3 uses a structured survey (n=325), including a Random Response Technique, to assess the drivers of recreational non-compliance and quantify levels of fisher knowledge of RCAs and compliance to RCA boundaries. This chapter also assesses fisher perceptions of RCAs and offers their suggestions for improvement.

Chapter 4 visually quantifies recreational fisher compliance in 29 sites in 14 different RCAs using a novel trail camera monitoring technique. I also assess geographic and ecological compliance influencers and compare my findings to previous assessments of recreational compliance in RCAs.

Chapter 5 synthesizes the key results of my research and offers management suggestions, discusses limitations, and concludes the thesis.

## Chapter 2: Pacific Canada's Rockfish Conservation Areas: using Ostrom's design principles to assess management effectiveness<sup>1</sup>

### 2.1 Abstract

International declines in marine biodiversity have led to the creation of marine protected areas and fishery reserve systems. In Canada, 164 Rockfish Conservation Areas (RCAs) were implemented between 2003 and 2007 and now cover 4847.2 km<sup>2</sup> of ocean. These reserves were created in response to widespread concern from fishers and non-governmental organizations about inshore rockfish population declines. We used the design principles for effective common pool resource management systems, originally developed by Elinor Ostrom, to assess the social and ecological effectiveness of these conservation areas more than 10-years after their initial implementation. We assessed the relative presence or absence of each design principle within current RCA management. We found that two of the eleven design principles were moderately present in the recreational fishery. All other design principles were lacking for the recreational sector. We found that two design principles were fully present and five were moderately present in the commercial sector. Four design principles were lacking in the commercial sector. Based on this analysis, we highlight four main areas for management improvement: 1) Create an education and outreach campaign to explain RCA rules, regulations, boundaries, and the need for marine conservation; 2) Increase monitoring of users and resources to discourage non-compliance and gather the necessary data to create social buy-in for marine conservation; 3) Encourage informal nested governance through stakeholder organizations for education and self-regulation (e.g. fisher to fisher); 4) Most importantly, create a formal, decadal RCA review process to gather stakeholder input and make amendments to regulations and RCA boundaries. This information can be used to inform management of proposed and existing marine conservation networks both in

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<sup>1</sup> This chapter has been accepted with minor revisions as Lancaster, D., D.R. Haggarty, N.C. Ban. (in review). Pacific Canada's Rockfish Conservation Areas: using Ostrom's design principles to assess management effectiveness. *Ecology and Society*.

Canada and internationally. This analysis also contributes to a growing literature on effectively scaling up small-scale management techniques for large-scale, often federally run, common-pool resource systems.

## **2.2 Introduction**

Declines in marine biodiversity and biomass are a concern for fisheries and conservation, with spatial management – including marine conservation areas and fisheries closures – recommended as key tools to recover depleted populations (Pauly et al. 2002, Worm et al. 2009). Fishing is one of the primary human causes of marine degradation (Norse 1993, Pauly et al. 1998, Jackson 2001, Lotze et al. 2006). Despite the high fecundity of many marine fishes, overfishing of target species can reduce populations and induce trophic cascades throughout marine ecosystems (Hutchings 2001, Pauly et al. 2002, Hutchings and Reynolds 2004, Essington et al. 2006, McGilliard et al. 2010). In recent decades, marine conservation areas and other spatial management tools have become popular for conserving threatened marine populations (Kritzer 2004). When implemented in tandem with catch limitations and fishing fleet reductions, spatial management has been shown to effectively protect marine species and recover depleted populations (Allison et al. 1998, Pauly et al. 1998, Mosquera et al. 2000, Halpern 2003, Babcock et al. 2010).

Assessments of the effectiveness of spatial closures are important to ensure that management measures are meeting their goals. Biological effectiveness is commonly assessed (e.g., biomass, abundance, density), although there is a growing recognition that social factors are crucially important in determining biological effectiveness (e.g., compliance, monitoring, enforcement) (Pollnac et al. 2010). One framework relevant for examining ecological and social effectiveness in common pool resource systems (including fisheries) is the design principles developed by Ostrom (1990). This framework was re-examined and expanded from 8 to 11 principles by Cox et al. (2010) to address more of the complexity of managing these systems. They include principles such as clearly defined boundaries and monitoring of the common pool resource. Based on a review of 91 studies conducted by Cox et al. (2010), the presence of these design principles appears to promote long-lasting, socially and ecologically effective common

pool resource management systems (Ostrom 2009). The design principles originally emerged from studies examining community-based systems (i.e., where communities organize themselves to manage their resources), but its relevance to larger systems is an area of active study. For example, the design principles have been scaled up for large systems like the Great Barrier Reef Marine Park, the International Commission for the Conservation of Atlantic Tunas, and the BC Carbon Tax (Epstein et al. 2013, Lacroix and Richards 2015).

### **2.2.1 Rockfish biology**

Rockfish (genus *Sebastes*) on the west coast of North America are particularly vulnerable to fishing pressure, with large declines having been observed and closures implemented to stem these population reductions (Parker et al. 2000, Love et al. 2002, Williams et al. 2010, Yamanaka and Logan 2010). British Columbia (BC) is host to over 30 species of rockfish (Love et al. 2002). Inshore species (Table 2.1) aggregate over coastal, rocky environments, which can make them vulnerable to intensive coastal fishing (Parker et al. 2000, Love et al. 2002). Inshore rockfish are also long-lived (from 50 to 120 years) and have a relatively slow maturation rate (Love et al. 2002). Some species take up to 20 years to reach sexual maturity (Table 2.1), and many species reach market size before reproducing (Love et al. 2002). Additionally, because of their closed (physoclastic) swim bladder, rockfish suffer severe, often fatal, barotrauma when caught in traps or on lines that are rapidly pulled to the surface (Parker et al. 2006). This makes recreational and commercial catch and release techniques largely ineffective at reducing incidental rockfish mortality (Parker et al. 2000, Yamanaka and Logan 2010). Subsequently, intensive fishing in rocky reef environments can deplete local rockfish populations, making it difficult for species to rebuild even after fishing has stopped (Parker et al. 2000). However, because inshore rockfish are typically sedentary with very small home ranges (Table 2.1) (Love et al. 2002), spatial protection should be highly effective, and indeed has been along the US West Coast where rockfish conservation areas had significantly larger populations of rockfish and greater species richness than nearby open areas (Keller et al. 2014).

**Table 2.1. Life history characteristics of common Inshore rockfish species in BC.****(Haldorson and Love 1991; Love, Yoklavich et al. 2002; Haggarty 2014)**

<b>Common Name</b>	<b>Scientific Name</b>	<b>Depth Range</b>	<b>Maximum Size</b>	<b>Typical Age</b>	<b>Home Range</b>
Copper	<i>Sebastes caurinus</i>	0-183m (typically around 90m)	66cm	50 years	10m <sup>2</sup>
Quillback	<i>Sebastes maliger</i>	0-274m (typically between 41-60m)	61cm	95 years	Typically less than 10m <sup>2</sup>
Black	<i>Sebastes melanops</i>	0-366m (typically at or above 55m)	69cm	50 years	67 m <sup>2</sup>
China	<i>Sebastes nebulosus</i>	3-128m (typically at or below 10m)	45cm	79 years	10m <sup>2</sup> or less
Tiger	<i>Sebastes nigrocinctus</i>	18-298m	61cm	116 years	High site fidelity
Yelloweye	<i>Sebastes ruberrimus</i>	15-549m (typically between 91-180m)	91cm	118 years	High site fidelity

### **2.2.2 Rockfish Conservation Areas in British Columbia**

In the waters of Pacific Canada - off the coast of BC - inshore rockfish population declines are a major concern (Yamanaka and Logan 2010, Haggarty 2014). After the creation of an inshore rockfish hook-and-line fishery in the 1970s, stocks began to dramatically decline with catches peaking in the 1980s and subsequently decreasing (COSEWIC 2009a, COSEWIC 2009b, Yamanaka and Logan 2010, Haggarty 2014). In response to these declines, non-government organizations (NGOs) and fishers began lobbying in 2001 for changes to management of inshore rockfish by Fisheries and Oceans Canada (DFO) (Yamanaka and Logan 2010). These efforts led to the creation of the Rockfish Conservation Strategy that identified four goals for enhanced rockfish protection. The strategy aimed to: 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 Logan 2010).

In this paper, we focus on the Rockfish Conservation Strategy's spatial component (goal 3: establishing areas closed to all fishing), implemented through Rockfish Conservation Areas (RCAs). Implemented between 2003 and 2007, the RCAs encompass 4847.2 km<sup>2</sup> (Haggarty 2014). The RCAs are fisheries closures intended to rebuild rockfish stocks implemented under the Fisheries Act. RCAs lack the permanency that marine protected area legislation such as the Oceans Act would provide. They are not marine protected areas (MPAs), which are intended to conserve and rebuild biological diversity (Robb et al. 2011). The original closed area targets were intended to protect 30% of rockfish habitat in inside waters (all waters east of Vancouver Island to the mainland) and 20% of rockfish habitat in outside waters (all other Pacific Ocean waters within Canadian jurisdiction). The 164 final RCAs protect 28% of inside and 15% of outside rockfish habitat (Yamanaka and Logan 2010). Although RCAs allow some fishing within them (i.e., they are not no-take areas), fishing activities have been significantly reduced to protect inshore rockfish (Table 2.2) (Yamanaka and Logan 2010, Haggarty 2014).

The RCAs were selected based on a public consultation process that included over 60 coastal community and regional meetings with fishers, NGOs, government officials and community groups. The selection of RCA locations was based upon reported rockfish habitat, the needs of local stakeholders, and a combination of bathymetry and fisheries data used to identify rockfish habitat (Yamanaka and Logan 2010).

The purpose of this paper is to assess the performance of RCAs, which have been in place for approximately a decade (from 7 to 11 years), and provide recommendations for improvements. We used the design principles, highlighted by Ostrom (1990) as key aspects of sustainable resource management, to assess the ecological and social performance of RCAs based on studies conducted to date. RCAs are faced with many of the same issues as other fisheries closures and marine conservation areas (e.g., social buy-in, compliance, enforcement, monitoring) and hence their assessment has the potential to provide lessons for current and future marine conservation areas. Additionally, this analysis will assess the usefulness and applicability of scaling up the design principles for federally managed resource systems.

**Table 2.2. Permitted and prohibited commercial and recreational fishing activities within RCAs. Aboriginal fisheries are not included in the table as their fishing activities are unrestricted within RCAs due to their constitutional right to harvest (Haggarty 2014, DFO 2014a).**

Commercial		Recreational	
Permitted Fisheries	Prohibited Fisheries	Permitted Fisheries	Prohibited Fisheries
<ul style="list-style-type: none"> <li>• Hand picking and diving for invertebrates</li> <li>• Prawn and Crab Trapping</li> <li>• Smelt by Gillnet</li> <li>• Scallop trawling</li> <li>• Salmon by seine or gillnet</li> <li>• Herring by seine, gillnet, and spawn-on-kelp</li> <li>• Sardine by gillnet, seine, and trap</li> <li>• Krill by mid-water trawl</li> <li>• Opal squid by seine</li> <li>• Groundfish by mid-water trawl</li> </ul>	<ul style="list-style-type: none"> <li>• Groundfish Bottom Trawl</li> <li>• Groundfish Hook and Line for Halibut, Inside Rockfish, Outside Rockfish, Lingcod, Dogfish</li> <li>• Sablefish by trap</li> <li>• Salmon Trolling</li> <li>• Opal Squid by Hook and Line or Ring Net</li> <li>• Shrimp by trawl</li> </ul>	<ul style="list-style-type: none"> <li>• Hand picking of invertebrates</li> <li>• Prawn and Crab Trapping</li> <li>• Smelt by Gillnet</li> </ul>	<ul style="list-style-type: none"> <li>• Groundfish by Hook and Line</li> <li>• Salmon Trolling, Jigging or Mooching</li> <li>• Spearfishing</li> </ul>

### 2.3 Methods

We used the design principles (Ostrom 1990), as re-defined by Cox et al. (2010), as a framework to assess effectiveness of RCAs. We reworded the design principles to make them accessible and directly applicable to RCAs (Table 2.3), and assessed them for two rockfish fisheries: commercial and recreational. The aboriginal fishing sector is also a significant user of rockfish; however, because of their constitutional right to harvest, DFO chose not to restrict their access to fishing within RCAs and, as such, their actions are not governed by RCA regulations (Haggarty 2014). A design principle analysis of

the aboriginal fishery would, therefore, not be applicable in most cases. Additionally, information on aboriginal fishing habits within RCAs is largely unavailable. However, the aboriginal fishery is mentioned throughout the analysis when applicable information was available.

**Table 2.3. Design principles as originally created by Ostrom, then modified by Cox et al. and further reworded for an RCA analysis.**

<b>Ostrom's Original Design Principles</b>	<b>Cox's Modified Design Principles</b>	<b>Modified RCA Design Principles</b>
<b>1. Well-defined boundaries:</b> Clearly defined boundaries (effective exclusion of external un-entitled parties)	<b>1a. Clearly defined boundaries:</b> Individuals or households who have rights to withdraw resource units from the common-pool resource (CPR) must be clearly defined.	<b>1a. Clear User Boundaries:</b> Users must clearly understand who may utilize the resource and why (i.e. Who can fish within RCAs).
	<b>1b. Clearly defined boundaries:</b> The boundaries of the CPR must be well defined.	<b>1b. Clear Resource Boundaries:</b> The physical boundaries should be easily visible (e.g. marker buoys, fences) or well defined (e.g. clear signs and maps in prominent locations).
<b>2. Congruence between appropriation and provision rules and local conditions:</b> Rules regarding the appropriation and provision of common resources that are adapted to local conditions	<b>2a. Congruence between appropriation and provision rules and local conditions:</b> Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions.	<b>2a. Appropriate Resource Regulations:</b> Regulations must match local resource conditions. The rules regarding when, how, and where resources can be used or taken must be based on the limitations of the resource itself. (e.g. RCAs must be designed to effectively protect rockfish based on habitat and biological characteristics)
	<b>2b. Congruence between appropriation and provision rules and local conditions:</b> The benefits obtained by users from a CPR, as	<b>2b. Positive Cost/Benefit Perception:</b> Effort expended on resource protection should equal the real and perceived benefits to users and resources. (e.g. Compliance monitoring in

	determined by appropriation rules, are proportional to the amount of inputs required in the form of labor, material, or money, as determined by provision rules.	RCA leads to increased levels of rockfish)
<b>3. Collective-choice arrangements:</b> Collective-choice arrangements that allow most resource appropriators to participate in the decision-making process	<b>3. Collective-choice arrangements:</b> Most individuals affected by the operational rules can participate in modifying the operational rules.	<b>3. Collective Choice:</b> Users may participate in rule modification.
<b>4. Monitoring:</b> Effective monitoring by monitors who are part of or accountable to the appropriators	<b>4a. Monitoring:</b> Monitors are present and actively audit CPR conditions and appropriator behavior.	<b>4a. Resource Monitoring:</b> Monitors are present and actively monitor resource conditions. (e. g. Monitoring rockfish stocks inside and outside RCAs)
	<b>4b. Monitoring:</b> Monitors are accountable to or are the appropriators.	<b>4b. User Monitoring:</b> Monitors regulate user behaviour and are accountable to or are resource users. (e. g. Monitoring fishing effort within RCAs)
<b>5. Graduated Sanctions:</b> A scale of graduated sanctions for resource appropriators who violate community rules	<b>5. Graduated sanctions:</b> Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, officials accountable to these appropriators, or both.	<b>5. Graduated Sanctions:</b> The severity of penalties must match the severity of violations: resource users who violate operational rules are assessed graduated sanctions by socially accountable monitors.
<b>6. Conflict-resolution mechanisms:</b> Mechanisms of conflict resolution that	<b>6. Conflict-resolution mechanisms:</b> Appropriators and their	<b>6. Access to conflict resolution:</b> Resource users and monitors have easy access to

are cheap and of easy access	officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.	low-cost methods of resolving conflicts among users or between users and monitors.
<b>7. Minimum recognition of rights</b> Self-determination of the community recognized by higher-level authorities	<b>7. Minimal recognition of rights to organize:</b> The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.	<b>7. Rights to organize:</b> Ability to organize local, small-scale governance groups: the rights of resource users to create their own rules are not challenged by external governmental authorities.
<b>8. Nested Enterprises:</b> In the case of larger common-pool resources, organization in the form of multiple layers of nested enterprises, with small local CPRs at the base level.	<b>8. Nested enterprises:</b> Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.	<b>8. Nested Governance:</b> Multiple, nested governance groups from small-scale to large-scale manage all aspects of the SES.

The commercial fishery within British Columbia consists of many different sectors (Table 2.4). Many of these sectors are affected by RCA regulations to varying degrees and are held accountable under Groundfish Integration regulations and the Rockfish Conservation Strategy (Davis 2008, Yamanaka and Logan 2010). For the purposes of our paper the sectors that are impacted by RCA regulations (Table 2.4) are assessed as one fishery and hereafter referred to as the commercial fishery. RCAs also impact many other non-fishing stakeholders including non-consumptive users like scuba divers and boaters and the environmental sector that has an interest in protecting and rebuilding ecosystems and biodiversity. However, we only assessed the relative presence and absence of the design principles for recreational and commercial fisheries because RCAs are fisheries closures and there is a lack of information on RCA impacts on non-consumptive sectors.

**Table 2.4. This table lists the commercial fishery sectors (by target species) in British Columbia and the gear types each fishery uses. \*The use of these gear types is prohibited in Rockfish Conservation Areas. (Davis 2008, Haggarty 2014).**

<b>Commercial Fishery Sector (by target species)</b>	<b>Gear Type</b>
Dogfish	*Long Line, *Hook and Line
Lingcod	*Hook and Line
Rockfish (Inside waters)	*Hook and Line
Rockfish (Outside waters)	*Hook and Line
Groundfish	*Bottom Trawl, Mid-water Trawl
Halibut	*Long Line, *Hook and Line
Sablefish	*Long Line, *Trap
Salmon	*Trolling, Seine, Gillnet,
Opal Squid	*Hook and Line, *Ring Net, Seine
Sardine	Seine, Gillnet, Trap
Krill	Mid-water Trawl
Herring	Seine, Gillnet, Spawn on Kelp
Invertebrates	Hand Picking, Diving
Prawn/Crab	Trap
Smelt	Gillnet
Scallop	Trawl
Shrimp	*Trawl

An analysis of the extent to which RCAs meet the design principles allows us to highlight current strengths and weaknesses of this conservation system approximately a decade after implementation, and to assess the applicability of the design principles for a federally-designated conservation system.

We conducted a thorough review of existing RCA literature to assess RCA social and ecological effectiveness to date and look for evidence of the key elements of the design principles (Table 2.5, Appendix A).

**Table 2.5. Summary of key literature on social and ecological impacts of RCAs. See Appendix A for a more in-depth summary.**

Key RCA Literature	Ecological Summary	Social Summary
Yamanaka and Logan (2010)	<p><b>RCA Site Selection:</b> Fisheries consultations and bathymetry data were used to locate likely rockfish habitat.</p>	<p><b>Collective Choice:</b> Extensive consultations with fishers, community members and NGOs prior to RCA site selection.</p> <p><b>Commercial Fishers:</b> The Rockfish Conservation Strategy (implemented in tandem with Groundfish integration) significantly altered commercial groundfish fishing practices.</p>
Haggarty (2014)	<p><b>Remote Operated Vehicle (ROV) Survey Results:</b> No statistically significant reserve response. Mean inshore rockfish density higher inside than outside RCAs.</p> <p><b>SCUBA Survey Results:</b> Non-significant trend towards greater copper rockfish density both inside and outside the RCA in the Broken Islands Group as compared to other locations within Barkley Sound.</p>	<p><b>Recreational Fishers:</b> Many recreational fishers do not know about RCAs or do not know who can fish in them. Tension between recreational fishers and aboriginal fishers who are permitted to fish within RCAs as a traditional harvesting right. Recreational fishing compliance was found to be low in some RCAs.</p> <p><b>Commercial Fishers:</b> Supportive of RCAs but not their expansion. Understand that RCAs offer the chance for “spill-over” benefits, which could improve future fishing activities. Concern over recreational fisher behaviour and a perceived lack of compliance to RCA regulations.</p> <p><b>Aboriginal Fishers:</b> Supportive of RCAs as an ecological insurance policy. Feel they were not consulted, or not adequately consulted during RCA creation. Some feel that fishing pressure has decreased in RCAs, some feel that recreational fishing remains unchanged. Some fishers feel a</p>

		pressure not to fish in RCAs despite their constitutional right. They desire better information on RCA effectiveness and education for other sectors on First Nations right to harvest.
Challenger and Marliave (2009)	<p><b>Scuba Survey Results:</b> No reserve effect. Reserve effect not expected as the RCAs were newly established. Intended to serve as baseline data for future assessments of RCA effectiveness.</p> <p><b>Side-Scan Sonar Results:</b> Rockfish are strongly associated with piled boulder habitats not easily detected by original bathymetry data.</p>	<b>Collective Choice:</b> RCA selection influenced by needs/desires of fishing sectors. Occasionally resulted in the protection of sub-optimal rockfish habitat.
Cloutier (2010)	<b>Scuba Survey Results:</b> RCAs had an average of 1.6 times more rockfish than unprotected sites. No correlation between rockfish density and age of RCAs.	<b>Not Applicable</b>
Chalifour (2012)	<b>Scuba Survey Results:</b> Rockfish density higher outside the RCAs, however, habitat variability was not considered in the research design, which could impact results. Some RCAs are located in unsuitable rockfish habitat.	<b>Recreational Fishers:</b> Lack of RCA boundary/regulation knowledge can lead to tension between monitors and users.

Each design principle was then broken down into its key elements. We then rated RCAs on a four-point scale to evaluate the relative presence or absence of each design principle (Table 2.6, Appendix B). Rankings were based on the following definitions: Present – All elements of the design principle’s definition have been met; Moderately Present – The majority of the design principle’s definition has been met, although some elements could be improved; Lacking – The majority of the design principle’s definition has not been met, with few elements of the principle reflected in the management system; Absent – No elements of the design principle’s definition have been met. Scores were based on both the number of design principle elements reflected in each fishery sector, as well as the extent to which those elements were present. For example, all three elements

of design principle 2a (appropriate resource regulations) were present to some degree in the recreational and commercial sector, however, all of these elements could be improved or enhanced. As such, both the commercial and recreational fisheries score for design principle 2a. was “moderately present”. A more thorough example of this ranking process can be found in Appendix B. For the purposes of this report, we systematically evaluated the recreational and commercial fishing sectors in order to provide recommendations for improving RCA effectiveness.

**Table 2.6. Analysis of relative presence or absence of the design principles in the structure of BC’s network of RCAs.**

<b>Design Principles</b>	<b>Recreational Fishery</b>	<b>Commercial Fishery</b>
<b>1a. Clear User Boundaries:</b> Users must clearly understand who may utilize the resource and why (i.e. Who can fish within RCAs)	Lacking	Present
<b>1b. Clear Resource Boundaries:</b> The physical boundaries should be easily visible (e.g. marker buoys, fences) or well defined (e.g. clear signs and maps in prominent locations).	Lacking	Moderately Present
<b>2a. Appropriate Resource Regulations:</b> Regulations must match local resource conditions. The rules regarding when, how, and where resources can be used or taken must be based on the limitations of the resource itself. (e.g. RCAs must be designed to effectively protect rockfish based on habitat and biological characteristics)	Moderately Present	Moderately Present
<b>2b. Positive Cost/Benefit Perception:</b> Effort expended on resource protection should equal the real and perceived benefits to users and resources. (e.g. Compliance monitoring in RCAs leads to increased levels of rockfish)	Lacking	Lacking
<b>3. Collective Choice:</b> Users may participate in rule modification.	Lacking	Lacking
<b>4a. Resource Monitoring:</b> Monitors are present and actively monitor resource conditions. (e. g. Monitoring rockfish stocks inside and outside RCAs)	Lacking	Lacking
<b>4b. User Monitoring:</b> Monitors regulate user behaviour and are accountable to or are resource users. (e. g. Monitoring fishing effort within RCAs)	Lacking	Present
<b>5. Graduated Sanctions:</b> The severity of penalties must match the severity of violations: resource users who violate operational rules are assessed graduated sanctions by socially accountable monitors.	Moderately Present	Moderately Present

<b>6. Access to conflict resolution:</b> Resource users and monitors have easy access to low-cost methods of resolving conflicts among users or between users and monitors.	Lacking	Lacking
<b>7. Rights to organize:</b> Ability to organize local, small-scale governance groups: the rights of resource users to create their own rules are not challenged by external governmental authorities.	Lacking	Moderately Present
<b>8. Nested Governance:</b> Multiple, nested governance groups from small-scale to large-scale manage all aspects of the SES.	Lacking	Moderately Present

## 2.4 Results

### 2.4.1 Summary of ecological effectiveness

RCAs have now existed in BC for approximately a decade. Although there is currently no formal strategy for monitoring the impacts of RCAs on rebuilding rockfish populations, a variety of independent studies have attempted to evaluate the performance of RCAs (Table 2.5, Appendix A) (Challenger and Marliave 2009, Cloutier 2010, Chalifour 2012, Haggarty 2014). These studies are limited by a lack of historic baseline data and, subsequently, primarily use a control-impact model, whereby sites within RCAs are compared to nearby unprotected sites (Haggarty 2014). This can be an effective tool for assessing response within protected areas, and is commonly used for marine conservation areas (Claudet et al. 2008, Claudet and Guidetti 2010). However, given the variety of new fisheries management initiatives developed over the past years in BC, including the integration of all commercial groundfish fisheries, significant reductions in Total Allowable Catch (TAC) quotas for commercial inshore rockfish, and the creation of RCAs, it is difficult to isolate the impacts of each of these initiatives on rockfish populations. The confounding effects of these different management measures could make the control-impact method of studying RCA response less effective (Haggarty 2014).

Most of the studies to date did not show significant statistical differences in rockfish densities compared to areas outside RCAs. For example, Remote Operated Vehicle (ROV) surveys did not produce a statistically significant reserve response,

although there was a slight trend towards higher mean rockfish density within RCAs (Haggarty 2014). In contrast, another study surveyed 15 different locations throughout the Strait of Georgia and found that RCAs had, on average, 1.6 times more rockfish than nearby, unprotected sites (Cloutier 2010). Although there is some evidence to suggest that RCAs are beginning to rebuild rockfish stocks (Cloutier 2010, Haggarty 2014), at this stage, the ecological results are largely inconclusive. This could be due in part to the relative infancy of the RCAs given the long-lived nature of rockfish. Additionally, the lack of a consistent monitoring program makes it difficult to control for variability and compare data across studies.

#### **2.4.2 Summary of social effectiveness**

Information on the social impacts of RCAs is still minimal, with only one published study to date examining fisher support for RCAs (Table 2.5, Appendix A). Haggarty (2014) found that both the recreational and commercial fishing sector were supportive of RCAs, although both groups commented on the lack of empirical evidence indicating that RCAs are an effective conservation tool. Both sectors were reluctant to fully support the RCAs or any future expansion until scientific evidence could evaluate the contribution of RCAs to the rebuilding of rockfish stocks. Additionally, the commercial sector expressed concern over a perceived lack of recreational fisher compliance to RCA regulations, which could be significantly impacting the ability of RCAs to protect rockfish stocks. Aerial fly-over data analyzed by Haggarty (2014) supports the commercial sectors' perception of non-compliance, and recreational fishing levels appear to be nearly unchanged within RCAs. Similarly, the recreational fishing sector expressed concern over the ability of aboriginal fishers to practice their traditional right to harvest within RCAs. Aboriginal fishers were generally unhappy with their perceived lack of consultation in the RCA development process, and the lack of fisher understanding of their traditional rights to harvest (Haggarty 2014). Overall, despite the recreational fishery's support of RCAs, there is a lack of understanding and awareness of RCA goals and regulations. Additionally, there are high levels of tension and distrust among the different fishing sectors regarding RCA regulations and compliance (Haggarty 2014).

As yet, no information exists about other social impacts of RCAs. It is not known whether RCAs negatively affected livelihoods of commercial fishers, or whether they have substantially impacted enjoyment of fishing by recreational fishers. Furthermore, RCAs have the potential to affect non-fishing populations such as recreational boaters, property owners, NGOs, and many other organizations who may have a vested interest in protecting marine ecosystems for aesthetic, touristic, and economic reasons. To date, there are no studies on the impacts of RCAs on non-fishing communities.

### **2.4.3 Design Principle Analysis of RCAs**

Here we use the design principles to assess the performance of RCAs (Ostrom 1990, Cox et al. 2010). We first list the design principle, and then present our assessment and evidence of that principle for recreational and commercial fishing sectors. Some design principles are not as relevant as others because RCAs are a federally managed system, not a community-based initiative. However, for the purposes of this assessment, they have been included in the analysis as they can be useful for highlighting the challenges and weaknesses of federally managed systems. Design principles that are less applicable on a federal scale have been marked with an asterisk (\*). The problems they present are discussed in more detail in the discussion.

*1a. Clear user boundaries: users must clearly understand who may utilize the resource and why (i.e. Who can fish within RCAs)*

The recreational fishing sector lacks a strong understanding of user boundaries (Haggarty 2014). Although RCA regulations clearly state what activities are permitted in these closed areas (Table 2.2) and it is the responsibility of recreational fishers to learn and understand these rules, RCA regulations do not explicitly list which fishing activities are prohibited. In a recent study with over 300 fishers, this was consistently mentioned as a source of RCA regulation confusion (See Chapter 3). This lack of specificity means that recreational salmon or halibut fishers may believe that fishing within RCAs is permitted (See Chapter 3) (Cloutier 2010, Chalifour 2012, Haggarty 2014). Additionally,

recreational fishers expressed concern over aboriginal fishers' traditional right to harvest within RCAs (Haggarty 2014).

Commercial fishers are informed of fisheries regulations, including spatial restrictions, by DFO and fishery associations (e.g. Canadian Groundfish Research and Conservation Society) (Davis 2008, CGRCS 2010, Haggarty 2014). The existence of 100% at-sea observation (in the trawl fishery) and electronic monitoring via global positioning systems (GPS) (in the hook and line fishery) emphasizes the importance of following regulations within RCAs (Haggarty 2014).

*1b. Clear resource boundaries: the physical boundaries should be easily visible (e.g. marker buoys, fences) or well defined (e.g. clear signs and maps in prominent locations).*

It is the responsibility of recreational fishers to learn and understanding recreational resource extraction rules. However, despite this responsibility, recreational knowledge of RCA regulations is low, there is little DFO enforcement of regulations on the water, and many recreational fishers find DFO regulations hard to understand and difficult to access (see Chapter 3) (Haggarty 2014). Thus, the recreational fishing sector lacks clear resource boundaries for RCAs (Chalifour 2012, Haggarty 2014). RCA boundaries are clearly and strictly defined online using GPS coordinates, landmarks, and charts (DFO 2014a). However, hard copy versions of these closed areas are difficult to obtain (Chalifour 2012, Haggarty 2014). Additionally, there are very few, highly visible charts in prominent locations such as boat launches and marinas (Chalifour 2012, Haggarty 2014). There are also no physical markers or reminders of RCA boundaries on the water. The impracticality of placing physical markers and signs in a marine environment makes it impossible for fishers to know if they are within one of these closed areas unless they had previous knowledge of their existence (See Chapter 3).

Intensive monitoring of the commercial fishery makes adhering to RCA boundary restrictions essential to commercial success (Design Principle 4b) (Yamanaka and Logan 2010, Haggarty 2014). All commercial fishing boats are equipped with GPS tracking and on-board/video observers, and as such, any unauthorized entrance of commercial vessels into closed RCAs can be reported and penalized (F. Snelgrove. pers. comm. Oct.

14, 2014). It is still the responsibility of commercial vessels to input RCA boundaries manually into navigation software. However, in order to avoid penalty, most commercial fishers take measures to ensure they do not accidentally enter into RCAs (CGRCS 2010).

*2a. Appropriate resource regulations: regulations must match local resource conditions. The rules regarding when, how, and where resources can be used or taken must be based on the limitations of the resource itself (e.g. RCAs must be designed to effectively protect rockfish based on habitat and biological characteristics).*

Appropriate resource regulations are moderately present in both the recreational and commercial fishing sector (Marliave 2009, Cloutier 2010, Favaro et al. 2010, Yamanaka and Logan 2010, Chalifour 2012, Challenger and Haggarty 2014). The majority of activities permitted within the RCAs do not negatively affect inshore rockfish populations (Yamanaka and Logan 2010, Haggarty 2014). However, there is evidence to suggest that prawn trapping within RCAs could cause significant rockfish bycatch, as rockfish are often found in recovered prawn traps (Favaro et al. 2010). Additionally, prawns are a key food source for rockfish and the continued removal of their prey from RCAs could limit rockfish recovery (Cloutier 2010, Haggarty 2014). Conversely, reducing prawn densities could also cause trophic cascades if rockfish begin to intensively target other species (Cloutier 2010). However, recent research within RCAs did not find a significant trend towards rockfish-induced trophic cascades (Cloutier 2010).

Although the RCAs were not designed as a network, research has shown that their current placement, especially within the Strait of Georgia, could promote important larval recruitment between protected areas and create spillover effects (Lotterhos et al. 2014). However, more research is necessary to confirm that RCAs are adequately positioned to maximize this network effect (Gaines et al. 2010a, Gaines et al. 2010b, Haggarty 2014, Lotterhos et al. 2014). There is also some evidence to suggest that the bathymetry data used to inform RCA site selection was not detailed enough to locate optimal rockfish habitat (Challenger and Marliave 2009). This means some RCAs may be protecting

suboptimal rockfish habitat while other key rockfish habitats may be unprotected (Challenger and Marliave 2009, Chalifour 2012).

*2b. Positive cost/benefit perception: effort expended on resource protection should equal the real and perceived benefits to users and resources (e.g. Compliance monitoring in RCAs leads to increased levels of rockfish).*

Positive cost/benefit perception is lacking in the recreational sector (Haggarty 2014). Without empirical data to illustrate that RCAs are helping to rebuild rockfish stocks or provide spillover benefits to fishers (see Design Principle 4a) (Gaines et al. 2010a, Gaines et al. 2010b), many recreational fishers are currently reluctant to fully support RCAs (Haggarty 2014). Additionally, many recreational fishers have expressed their concern over a lack of enforcement of RCA regulations (See Chapter 3).. Although the majority of recreational fishers surveyed currently support the idea of RCAs (Haggarty 2014), a perceived lack of enforcement and data to measure RCA effectiveness makes it difficult for fishers to assess the cost/benefit of maintaining RCAs.

Cost/benefit perception is similarly lacking in the commercial sector with a dearth of empirical data again making it difficult for commercial fishers to assess the ability of RCAs to rebuild rockfish stocks and provide spillover benefits to fishers (Haggarty 2014). Additionally, the fact that RCAs were implemented in tandem with rockfish catch restrictions in the commercial fishery makes it difficult to determine the cause of changes within rockfish populations (Haggarty 2014).

*\*3. Collective choice: users may participate in rule modification.*

Collective choice arrangements within the recreational fishery are currently lacking (Davis 2008). The recreational fishery was actively included in consultation during RCA creation and site selection, although final RCA selection rested with DFO (Yamanaka and Logan 2010, Davis 2008, Granek et al. 2008). Since final implementation, RCAs have not been reopened for amendments (Davis 2008). Additionally, with Canadian

fisheries being federally managed ( Davis 2008, Yamanaka and Logan 2010), RCAs are not currently designed to be co-managed by the users (fishers).

Collective choice arrangements are also lacking in the commercial sector (Davis 2008). Like the recreational sector, commercial fishers were actively consulted during RCA creation (Yamanaka and Logan 2010). Additionally, the Commercial Industry Caucus (CIC), which represents members from all groundfish fishing sectors as well as DFO and provincial representatives, still holds meetings to refine the groundfish integrated fisheries management plan (IFMP) (Davis 2008). Although the CIC (a consensus-based decision-making group) cannot directly modify RCA regulations, they can propose significant changes to the groundfish integration plan, which can impact BC's rockfish stocks. DFO has also worked with commercial, recreational, and First Nations fishers on various other adaptive management projects like the Pacific North Coast Integrated Management Area (PNCIMA) and coral and sponge reef closures (DFO 2013). However, in the case of RCAs, as in the recreational sector, commercial fishers have been unable to modify regulations since implementation (Haggarty 2014).

*4a. Resource monitoring: monitors are present and actively monitor resource conditions (e.g. Monitoring rockfish stocks inside and outside RCAs).*

Resource monitoring was ranked as lacking as there is currently no RCA monitoring plan federally or independently organized by fishing sectors or independent organizations (e.g. NGOs) (Haggarty 2014). Although independent research has been ongoing (Challenger and Marliave 2009, Cloutier 2010, Chalifour 2012, Haggarty 2014), the lack of consistency among studies makes it difficult to compare data. Additionally, RCAs were implemented without determining baseline rockfish populations, which makes it difficult to determine if there is a significant reserve effect in RCAs (Challenger and Marliave 2009, Haggarty 2014). DFO did partner with academic scientists to survey RCAs using Remotely Operated Vehicles (ROVs); however results are pending and no follow-up surveys are planned (Haggarty 2014).

*4b. User monitoring: monitors regulate user behaviour and are accountable to or are resource users (e.g. Monitoring fishing effort within RCAs).*

Monitoring of the recreational fishing sector is generally lacking, although the amount of enforcement varies by area (Haggarty 2014). A recent study using DFO aerial survey data found that recreational fishing within RCAs has remained primarily unchanged since implementation, with some RCAs showing increased fishing effort over time (Haggarty 2014). This could be due to a lack of DFO monitoring in many of these areas (Haggarty 2014).

The commercial fishing sector is extensively monitored for fisheries violations (Yamanaka and Logan 2010, Haggarty 2014). 100% electronic or on-board observer/video monitoring ensures that commercial violations of RCA boundaries will be noted and penalized (Haggarty 2014). As such, commercial compliance to RCA regulations is known to be high (Haggarty 2014). Additionally, DFO officers are accountable to users (both recreational and commercial) in the same way as police officers. Disputes between users and monitors can be addressed through the Canadian court system (see design principle 5) (F. Snelgrove, Pers. Comm. Oct. 14, 2014). The monitoring of the commercial sector is an example of excellent user monitoring where the monitors are not the users themselves.

*5. Graduated sanctions: the severity of penalties must match the severity of violations: resource users who violate operational rules are assessed graduated sanctions by socially accountable monitors.*

Graduated sanctioning is moderately present within the recreational fishery (Government of Canada 2014a). All official sanctions are handled by DFO Fishery Officers.

According to British Columbia Sport Fishing Regulations (a subsection of the Fisheries Act), recreational violations of RCA rules are subject to a \$250 fine (Government of Canada 2014a). However, DFO officers may also issue a verbal or written warning, or provide educational materials in place of a voluntary penalty ticket (tickets issued at the discretion of DFO officers on a case-by-case basis) (F. Snelgrove, Pers. Comm. Oct. 14,

2014). Once issued, these sanctions are under the jurisdiction of the Canadian Criminal Code (Government of Canada 2014c). However, due to the lack of user monitoring (See Design Principle 4b), sanctions are rare and some recreational fishers have stated that officers typically issue warnings instead of penalties (See Chapter 3).

Sanctioning within the commercial sector is moderately present (Government of Canada 2014a). As in the recreational sector, the severity of sanctions is left to the discretion of DFO officers and varies for each offence (F. Snelgrove, pers. comm. Oct. 14, 2014). The high level of commercial compliance due to intensive monitoring means commercial sanctioning is rare (Haggarty 2014). Information on the perceived appropriateness of commercial graduated sanctions was not available. As such, the relative presence of this design principle was listed as “moderately present” as all other aspect of the definition were met.

*\*6. Access to conflict resolution: resource users and monitors have easy access to low-cost methods of resolving conflicts among users or between users and monitors.*

Conflict resolution mechanism are lacking within the recreational fishing sector (F. Snelgrove, pers. comm. Oct. 14, 2014). All Canadian citizens have access to the court system to resolve conflicts. However, entering disputes into the court system is not regarded as a particularly easy or low cost method of resolving conflicts. All formal user-to-user disputes, or user-to-monitor disputes (e.g. contesting a voluntary penalty ticket) must utilize the court system. Research has shown that when conflict resolution mechanisms are not easily accessible, the management of common-pool resources can be difficult (Cox et al. 2010).

The commercial sector’s conflict resolution mechanisms were also ranked as lacking (IPHC 2014). As above, fishery violations can be contested in the Canadian court system. As a federally run system, disputes between commercial fishers and DFO officials can be appropriately and officially addressed in court. Additionally, the International Pacific Halibut Commission (IPHC) – an independent international organization designed to advise federal and state fisheries managers – acts as a platform for conflict resolution between all halibut fishery sectors (i.e. commercial, recreational,

and aboriginal) from both Canada and the United States. Any conflicts between these user groups, RCA related or otherwise, can be addressed at the annual meeting of the Conference Board. However, as an advisory body, the IPHC has no official power to resolve conflicts and acts as a discussion platform rather than a formal conflict resolution mechanism (IPHC 2014).

*\*7. Rights to organize: ability to organize local, small-scale governance groups; the rights of resource users to create their own rules are not challenged by external governmental authorities.*

The right to create rules is lacking in the recreational fishery (Davis 2008). All fishers and community members have the right to create independent, fisheries related groups. The Sport Fish Advisory Board (SFAB) is a long-standing example of one of these. The SFAB played a large role in the selection of RCA sites (DFO 2014b). However, neither the SFAB nor any other independent fishery organization has the right to officially modify RCA rules or regulations (see design principle 3). They do, however, have the right to lobby DFO for changes and make recommendations. Nevertheless, a recently interviewed SFAB member expressed disappointment when DFO ignored a request for an RCA boundary change (Haggarty 2014). This lack of official, independent decision-making power is indicative of a federally-run common pool resource as opposed to a community-based resource management regime (Cox et al. 2010). However, despite the federally-run structure of Canadian recreational fisheries, there is still a high level of independent organization and community consultation (Yamanaka and Logan 2010, Davis 2008).

The commercial fishery's right to organize is moderately present (Haggarty 2014, Davis 2008). As discussed in design principle 3 (collective choice), commercial groundfish fisheries have established independent organizations that meet regularly as part of the Commercial Industry Caucus (CIC) to suggest revisions to the groundfish integrated fisheries management plan. The impact of this plan on rockfish fishing is significant (Davis 2008, Yamanaka and Logan 2010). However, commercial fishers do not have the ability to modify RCA regulations at this time and may only propose

changes through independent group lobbying. The SFAB also has the capacity to lobby and propose changes, however, it does not offer full membership to recreational fishers in the way all commercial fishery license holders hold formal membership in at least one fishery organization (Davis 2008, DFO 2014b). This makes it difficult for SFAB representatives to accurately present the different interests of the entire recreational fishing sector. As such, the presence of design principle 7 (rights to organize) and in the following section, design principle 8 (nested governance), was ranked as “moderately present” for the commercial sector and “lacking” for the recreational sector.

*\*8. Nested governance: multiple, nested governance groups, from small-scale to large-scale, manage all aspects of the SES.*

Nested governance within the recreational fishing sector is lacking (Davis 2008). The Canadian recreational fishery is federally managed, and thus the SFAB has the ability to lobby for changes to recreational fishing regulations, but not to manage or monitor recreational fishers. Additionally, recreational fishers are able to suggest changes to current management schemes through the annual meeting of the Conference Board for the IPHC (IPHC 2014). However, without a strong DFO presence on the water (Haggarty 2014), this lack of community-based monitoring could lead to low compliance. For example, a Victoria-based angling association representative described a case where a member was removed from their club after repeated violation of fisheries laws. However, despite his removal from the angling association, the offending individual was able to continue fishing independently and eventually joined a different fishing association in the region. Cases like this highlight how community-based governance could have an important role in fisheries management. For example, if angling association membership were mandatory and these regional groups were granted the authority to revoke licenses, this offending fisher could have been penalized by other local fishers who understood his offences and how they affected their shared resources.

Nested governance in the commercial fishery is moderately present (Davis 2008, CGRCS 2010, IPHC 2014). A moderate level of collaborative management is achieved through organizations like the CIC, IPHC, and Canadian Groundfish Research and

Conservation Society (CGRCS). These organizations assist in the management of the commercial fishery through stock assessments, annual meetings, and yearly regulatory suggestions (Davis 2008, CGRCS 2010, IPhC 2014). However, these independent organizations act only as advisory bodies with the official decision-making power resting at the federal level (Davis 2008). Nevertheless, the involvement of the commercial sector in the decision making process is extensive and constitutes a significant level of informal nested governance.

## **2.5 Discussion**

RCAs in BC are currently struggling to attain maximum social and ecological success. Some ecological studies suggest that RCAs are having a positive impact on rockfish populations within protected area boundaries (Cloutier 2010); however, the majority of studies are currently inconclusive. When compared to the ecological success of RCAs created in 2002 on the US West Coast (Keller et al. 2014), Canadian RCAs have considerable room for improvement. Research is required to understand the differences in the ecological success of RCAs in each country, but the management challenges we address in this paper may play a role in the limited success of Canadian RCAs to date. Additionally, although there is a dearth of information on the social impacts of RCAs, existing research suggests that there is tension between fishing sectors, a desire for ecological data on RCA impacts, a lack of recreational fisher understanding of RCA regulations, and a potential problem with low-recreational compliance (Haggarty 2014).

We used an analysis of design principles to identify areas of improvement for RCA management. Although the design principles are not meant to be a panacea or check-list (Ostrom 1990), they nevertheless point to suggestions for improved management. We identified eight key recommendations. Many of our recommendations for RCA improvement are also identified by Haggarty (2014), highlighting the importance of these suggestions.

First, managers should clarify social and ecological boundaries. Although it is the responsibility of fishers to understand resource extraction regulations, recreational low knowledge suggests that more accessible information is necessary or more education on the importance of learning regulations is required. User boundaries (Design Principle 1a)

can be clarified through a public education and outreach campaign and facilitated meetings with fisheries representatives from the commercial, recreational, and aboriginal sectors. This education campaign should not only address why some gear types are prohibited, but also explain RCA goals, regulations, and why rockfish need protection. Resource boundaries (Design Principle 1b) can be clarified through prominent posting of local RCA locations at boat launches and marinas in tandem with increased awareness of RCAs through public outreach (See Chapter 3). Additionally, a popular recommendation from recreational fishers (See Chapter 3) is to place physical marker buoys or highly visible signs on the water in areas of high fishing effort. However, implementing this recommendation is challenging because many RCAs are in navigable waters, and buoys could be navigation hazards. Where possible, shoreline markers, similar to boundary signs demarking fishery areas could be implemented. Additionally, and more feasibly, boundaries could be clarified through the creation of electronic maps (e.g. an App for smartphones) and posting maps with RCA boundaries at docks and marinas.

Second, resource regulations (Design Principle 2a) should be reassessed to determine if activities such as prawn trapping are detrimental to rockfish populations and should be prohibited. The cost/benefit of making RCAs fully no-take should also be considered. Additionally, an assessment of rockfish habitat quality within RCAs should be conducted and amendments made where necessary to protect the most important habitats for inshore rockfish.

Third, to improve cost/benefit perceptions (Design Principle 2b), resource and user monitoring (Design Principle 4a and 4b) should be increased. Improving resource and user monitoring would give managers the important social and ecological information necessary to create social buy-in, which is essential to positive cost/benefit perceptions. This information could be presented as part of the previously mentioned outreach campaign. Members from each fishing sector expressed an acute interest in the current status of rockfish stocks and the ecological impacts of RCAs. A consistent resource monitoring program should be developed to assess current rockfish densities within RCAs and measure the changes and patterns that occur over time (Haggarty 2014). This information is extremely important for assessing the effectiveness of RCAs and will allow researchers to offer fishers and the general public more concrete answers on the

status of current rockfish populations. Furthermore, DFO user monitoring of the recreational fishing sector should be implemented to prevent non-compliance that could be significantly impacting the ability of rockfish populations to rebuild, especially within the Strait of Georgia. Monitoring plays an important role in compliance, with more heavily patrolled areas showing lower levels of fishing effort than relatively unpatrolled locations (Haggarty 2014). As such, if DFO does not have sufficient funds to monitor RCAs, local stewardship committees could be organized to voluntarily monitor RCAs and report illegal activities. The Gitga'at Stewardship Program has already created a Gitga'at Coastal Guardian Watchmen program to monitor sustainable practices on Gitga'at territory (Coastal 2015). Similar volunteer programs should be considered along the coast of BC and DFO should offer funding and/or training for these programs wherever possible.

Fourth, while collective choice agreements (Design Principle 3) are less applicable in a federally run resource management system, DFO should consider initiating a regular 10-year review program – beginning now, approximately a decade after implementation – to address the concerns of all user groups and make revisions to RCA regulations as necessary. In this way, collective choice could be scaled up to a federal system that still maintains a top-down approach but offers stakeholders the opportunity to amend these regulations on a decadal cycle. This review process should also include local scientists and NGO representatives who can offer important information and suggestions on regional ecological and social challenges and concerns.

Fifth, graduated sanctions (Design Principle 5) should be reassessed after gathering data on recreational fisher compliance. If non-compliance is a significant problem in RCAs, DFO should encourage harsher sanctioning systems to discourage illegal fishing activities in these closed areas. Similarly, a review of commercial sanctioning should assess if current penalties are appropriate.

Sixth, easy access to conflict resolution (Design Principle 6) is a challenge for federally run systems that rely on the court system to handle disputes. Although the court system is an appropriate tool for user-to-monitor conflicts in a federally run fisheries system, it would be valuable – in an ideal scenario – to create a community-based group to address disputes between fishers and between different fishing sectors (e.g.

recreational vs. aboriginal or recreational vs. commercial). Such a group could utilize professional facilitators and consensus decision making to resolve minor disputes and provide more accessible conflict resolution. This kind of community-based conflict resolution could be a first step towards promoting better communication and relieving decades of tension between these typically disconnected groups (Davis 2008, O'Connell 2012, Dedaul et al. 2013).

Seventh, the rights to organize (Design Principle 7) could be improved. This is a difficult principle to scale up to a federal level. Nevertheless, the fact that the CIC exists and successfully developed a DFO approved groundfish integration plan through consensus-decision making suggests that a similar committee could be organized to review RCAs. DFO should consider creating an official RCA collaborative fisheries planning committee, not unlike the CIC, with representatives from commercial, recreational, and aboriginal sectors as well as community groups, NGOs, and academics. This group could serve as an independent organization to monitor and reassess RCAs periodically for both social and ecological effectiveness. Although the tensions between these different groups often originates from outside of the realm of RCA management (Davis 2008, O'Connell 2012), an official RCA collaborative committee – in combination with better conflict resolution – could start a valuable shift towards communication and collaboration between these groups (Dedaul et al. 2013).

Eighth, nested governance (Design Principle 8) could be improved. The commercial fishery maintains a certain level of nested governance through organizations like the CIC and IPHC, while the recreational fishery has very little power to self-regulate on a local scale, which can make it difficult to locate and stop problem fishers who may be consistently violating regulations. If angling associations were granted the authority to revoke fishing licenses, not unlike the recreational fishery in Scotland (UK Government 2014), and recreational fishers were required to maintain a membership, then angling organizations could self-regulate within the bounds set by the federal management agency. In the absence of funds for intensive DFO enforcement, community groups (e.g. angling associations) could take on the role of monitoring local users. Although this proposal would be complex to implement and is not immune to corruption, as a big picture idea, it warrants future consideration by the SFAB and DFO.

While we highlight many challenges, the RCAs were implemented rapidly and accounted for the diverse needs of many groups. As such, they serve as an excellent and rare example of immediate, consultation-based action to protect a threatened population. RCA managers should continue in the same inclusive and timely style and reassess these conservation areas to ensure they adequately protect both resources and user needs.

### **2.5.1 Challenges to scaling up design principles for a federal resource management system**

The design principle assessment of the RCAs effectively highlighted areas for improvement. However, certain design principles were less applicable to a federally run system than the community-managed areas from which they originated (Ostrom 1990). In particular, design principle 3 (collective choice), is less applicable to a federally managed common pool resource because management structure was not designed with on-going, participatory rule modification in mind. Nevertheless, the RCAs were created through an extensive consultation process and this design principle highlights how a 10-year review process could periodically incorporate collective choice even in a federally run system. Similarly, design principle 7 (rights to organize) and design principle 8 (nested governance), are difficult to fully incorporate into a federally run system. For large systems, it is unclear how the right to organize is different from participation in collective choice processes. Nested governance is challenging because, by definition, a federally run system concentrates decision-making at the federal level, leaving less room for nested governance, although co-management arrangements and other linkages are possible.

Challenges with some design principles at large scales also reflect the conclusions of Social-Ecological Systems Meta-Analysis Database (SESMAD) case studies (Epstein et al. 2013, Fleischman et al. 2013, Cox 2014, Evans et al. 2014). The SESMAD project seeks to determine if important variables, including the design principles, for small-scale systems can be effectively scaled up for large-scale governance systems (Cox et al. 2010). For example, an analysis of the Great Barrier Reef Marine Park similarly identified collective choice and rights to organize as problematic design principles for large-scale systems (Evans et al. 2014). The SESMAD case study of the International Commission for the Conservation of Atlantic Tunas (ICCAT) also found that collective

choice, rights to organize, and nested governance were either absent or unsuccessful on a large scale (Epstein et al. 2013). However, the authors posit that other mechanisms available at a federal scale, such as political dynamics and civil society interactions, may help to mitigate against governance failures (Epstein et al. 2013, Fleischman et al. 2013, Evans et al. 2014). While some design principles were less applicable on a large-scale, the majority of these attributes were equally applicable for small and large-scale systems, indicating that they can be useful to assist in making management recommendations.

This analysis of Canadian RCAs contributes to a growing literature on scaling up small-scale governance variables for large-scale systems. This information can help inform the creation of effective spatial management systems both in Canada and internationally. This report offers important recommendations for projects that will also require high levels of social buy-in, ecological assessment, and monitoring. Internationally, information on scaling up successful common pool resource management techniques could also offer guidance for existing RCA networks and spatial management systems.

## **2.6 Conclusion**

Spatial management systems that address only one aspect of a conservation issue are consistently less effective than plans that consider a variety of social and ecological factors (Cox et al. 2010, Pollnac et al. 2010). This analysis of BC's RCAs suggests that there is room for much social and ecological improvement of the management of RCAs. As a federally run system, these suggestions can be applied not only to RCAs but also existing marine conservation areas. Furthermore, many countries are currently in the process of implementing federally run marine spatial management and this analysis can serve as a guide for creating socially and ecologically effective marine conservation.

## **Chapter 3: Drivers of recreational fisher compliance in temperate marine conservation areas: A study of Rockfish Conservation Areas in British Columbia, Canada <sup>2</sup>**

### **3.1 Abstract**

Over fishing has impacted marine species over the last century, with many large-bodied and long-lived species declining to critical levels. Marine conservation areas are a popular management tool to protect and recover marine species and their habitats from intensive fishing pressure and human caused marine degradation. However, many marine conservation areas are thought to have low levels of compliance from diverse fishing populations. Little research exists that quantifies recreational fisher compliance and its drivers within marine conservation areas. We used the Rockfish Conservation Areas (RCAs) in British Columbia as a case study to investigate drivers of compliance. Our objectives were to (1) assess levels of recreational fisher RCA knowledge and compliance, (2) explore factors influencing fisher RCA knowledge and compliance, (3) quantitatively assess levels of fisher rockfish bycatch and release rates, (4) elicit fisher perceptions of RCAs, and (5) obtain fishers' suggestions for improving rockfish conservation. We conducted 325 structured dockside interviews with recreational fishers in 16 locations. Intentional non-compliance was reported by seven percent of recreational fishers, and accidental non-compliance by 16%. The main reason for non-compliance was lack of knowledge: recreational fishers were almost uniformly unknowledgeable of RCAs and their regulations across fishing experience levels. We found that 25.5% of recreational fishers had never heard of RCAs and ~60% were unsure of RCA locations. However, 77% of fishers believed that rockfish conservation is necessary. The high recreational non-compliance rate in RCAs - primarily accidental fishing - is likely compromising the ability of these marine conservation areas to protect inshore rockfish. The ecological usefulness of marine conservation areas hinges upon users knowing about, and understanding, conservation area rules and regulations. We recommend managers

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<sup>2</sup> This chapter will be submitted for publication with co-authors Dr. Philip Dearden and Dr. Natalie C. Ban.

implement a public outreach and education campaign to address the high levels of non-compliance.

### **3.2 Introduction**

The last half-century has seen global declines in marine resources, with large-bodied and long-lived species experiencing the most noticeable decreases (Cook et al. 1997, Lauck et al. 1998, Pauly et al 2002, Molfese et al. 2014). Many countries have started using fisheries closures, harvest refugia, and marine protected areas (MPAs) in an effort to protect and recover depleted marine resources. Although such conservation areas vary in size, distribution, and protection levels, their growing prevalence highlights increasing concern and actions around marine resource conservation (Allison et al. 1998, Marinesque et al. 2012).

Spatial management is an important tool in marine conservation, but lack of compliance, even from comparatively small recreational fisher populations (Post et al 2002), may reduce effectiveness significantly (Little et al. 2005, Sadovy and Domeier 2005, Graham et al. 2010, Arias 2015). For example, a simulation of line fishing infringement in the Great Barrier Reef Marine Park showed that even small amounts of non-compliance made marine reserves ineffective at conserving fish species biomass (Little et al. 2005). With continued fishing activity in conservation areas, fish populations often fail to recover (Kritzer 2004). While many commercial fisheries have on-board observers, recreational fisheries are difficult to monitor. Recreational fishing makes up 12% of annual global marine fish catches (Cooke and Cowx 2004, Granek et al. 2008) and has been implicated in fish stock collapses (Post et al. 2002. Lewin et al. 2006). Recreational fisher non-compliance could have a large impact on the success of management areas, especially in areas where it is popular. However, few studies have attempted to quantify recreational compliance and its drivers (Bergseth et al. 2013).

Several factors may influence fisher compliance (Gribble and Robinson 1998, McClanahan et al. 1999, Cinner et al. 2005, Pollnac et al. 2010, Read et al. 2011, Leleu et al. 2012, Mason et al. 2012, Smallwood and Beckley 2012, Arias and Sutton 2013,

Bergseth et al. 2013, Pita 2013). Consultation, education, and communication enhance positive perceptions of marine conservation areas and help to foster high fisher compliance (Cinner et al. 2005, Read et al. 2011, Pita et al 2013). In a review of 127 international MPAs, local perceptions and understanding of marine reserves was the main factor leading to high compliance (Pollnac et al. 2010). In the south of France, the involvement of fishing guilds in MPA planning and communication between fishers and scientists led to high levels of social acceptance and compliance (Leleu et al. 2012). Compliance in this region was found to be dependent on positive perceptions of marine conservation areas, and thorough knowledge of both their existence and regulations, and the possible consequences of non-compliance (Read et al. 2011).

Compliance research has focused mainly on commercial and artisanal fishers in tropical MPAs (Gribble and Robinson 1998, McClanahan et al. 1999, Cinner et al. 2005, Pollnac et al. 2010, Leleu et al. 2012, Bergseth et al. 2013). Very few studies target recreational fisher non-compliance and its drivers (Schill and Kline 1995, Read et al. 2011, Smallwood and Beckley 2012, Arias and Sutton 2013), and none of these studies look at marine conservation areas in temperate environments. My study fills an important knowledge gap by assessing recreational fisher compliance and its drivers in non-tropical marine conservation areas.

This study uses Rockfish Conservation Areas (RCAs) in British Columbia, Canada as a case study of drivers of compliance in marine conservation areas. RCAs are a network of Canadian fisheries closures that were implemented rapidly with minimal public outreach after the fact (Haggarty 2014). My case study objectives were to (1) assess levels of recreational fisher (hereafter referred to as fisher) RCA knowledge and compliance, (2) explore factors influencing fisher RCA knowledge and compliance, (3) quantitatively assess levels of fisher rockfish bycatch and release rates, (4) elicit fisher perceptions of RCAs, and (5) obtain fishers suggestions for improving rockfish conservation.

### **3.2.1 Case study description: Rockfish Conservation Areas in BC**

In British Columbia (BC), Canada, many marine fishes – especially those susceptible to overfishing such as rockfish – have declined substantially over the past fifty years (Love

et al. 2002, Post et al, 2002, Cooke and Cowx 2004, Granek et al. 2008, Hutchings et al. 2012). Rockfish (*Sebastes*) are a long-lived (inshore species live from 50 to 120 years), benthic genus that experience severe barotrauma when captured at depth and brought to the surface (Lotterhos 2013). Once a fish has been captured, it rarely survives if released unless redescended to depth (Hannah and Matteson 2006, Parker et al. 2006, Jarvis and Lowe 2007). The ~37 species of rockfish found along the coast of BC play an important role in both predator and prey relationships within a variety of food webs (Merrick 1997, Love et al. 2002). Rockfish are primarily non-migratory, with most individuals occupying a single reef. Their low mobility means that they should respond well to spatial protection (Love et al. 2002, Haggarty 2014).

Between 2003 and 2007, a network of 164 Rockfish Conservation Areas (RCAs) was created to protect rockfish populations as part of the Rockfish Conservation Strategy (Yamanaka and Logan 2010). The Rockfish Conservation Strategy addressed concerns of fishers and NGOs that inshore rockfish populations had been greatly depleted by the development of a successful commercial rockfish fishery in the 1980s (Marliave and Challenger 2009, Yamanaka and Logan 2010). The RCAs were designed to protect five inshore rockfish species: Yelloweye (*Sebastes ruberrimus*), Quillback (*Sebastes malinger*), Tiger (*Sebastes nigrocinctus*), Copper (*Sebastes caurinus*), and China (*Sebastes nebulosus*) rockfish (Yamanaka and Logan 2010). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) currently lists Quillback rockfish as threatened and Yelloweye rockfish as a species of concern (COSEWIC 2009a, COSEWIC 2009b).

Rockfish populations have seen the most dramatic declines in the Salish Sea (Strait of Georgia, Puget Sound, and Strait of Juan de Fuca), with Yelloweye rockfish at 12% of their 1918 biomass (DFO 2011). The Salish Sea also experiences the highest levels of recreational fishing pressure. Recreational rockfish catch accounts for 89% of the total annual rockfish catch within the Strait of Georgia (Data from Fisheries and Oceans Canada in Haggarty 2014). As such, two thirds of RCAs were placed in this region to address special concerns for rockfish. RCAs restrict recreational and commercial fishing activities within their boundaries (See Chapter 2. Table 2.2), with recreational fishing limited to invertebrate trapping and hand picking, and smelt

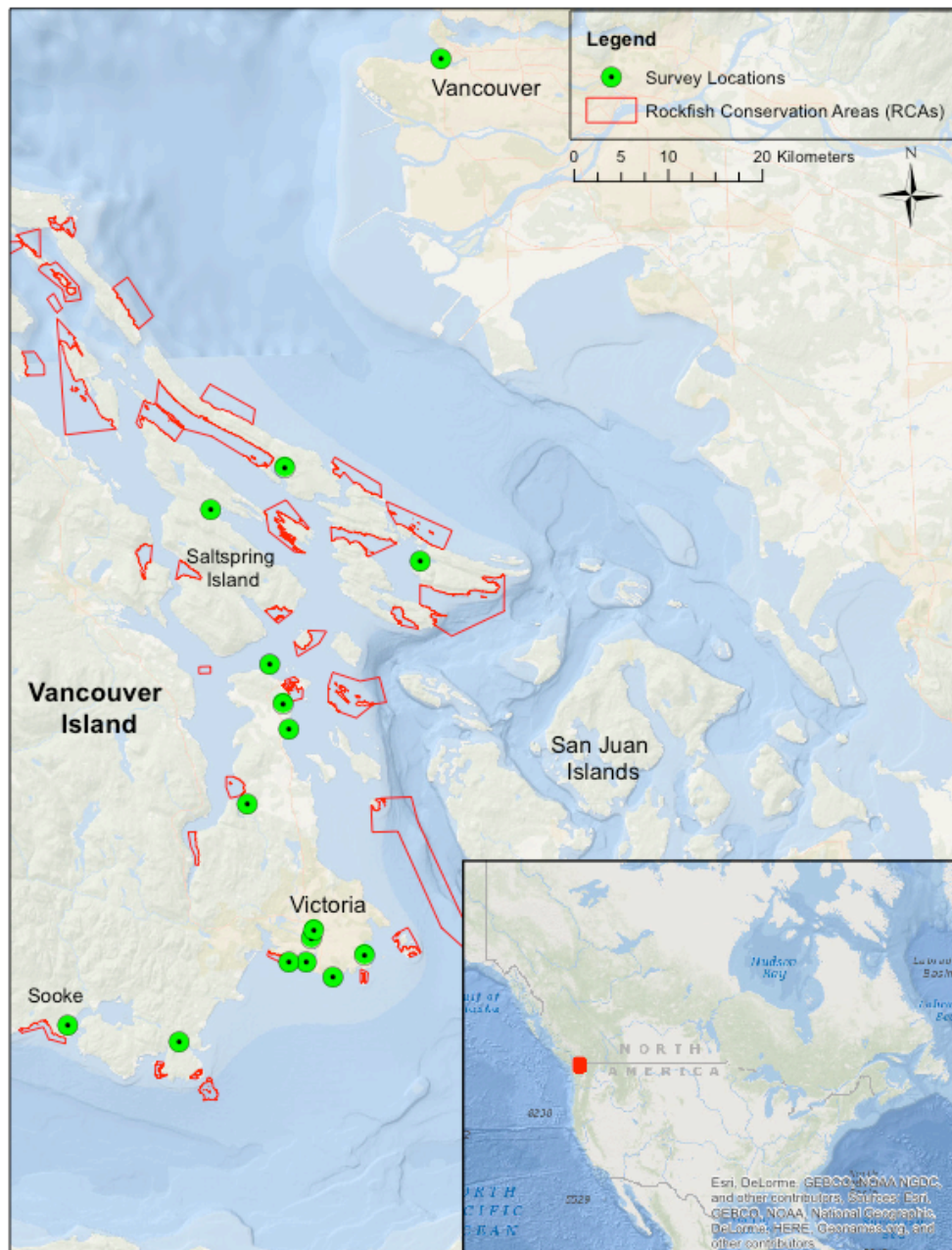
gillnetting. The Rockfish Conservation Strategy also reduced total allowable commercial rockfish catches in all inside waters (all waters between Vancouver Island and the mainland) by 75%, and recreational fisher bag limits were reduced from five to one rockfish per day in the Strait of Georgia (Yamanaka and Logan 2010).

Despite these conservation measures, preliminary studies on the effectiveness of RCAs at rebuilding inshore rockfish populations have not consistently shown a significant difference inside and outside RCAs (Challenger and Marliave 2009, Cloutier 2010, Chalifour 2012, Haggarty 2014). The introduction of rockfish total allowable catch reductions and the integration of the commercial groundfish fishery that occurred simultaneously with RCA creation could be confounding these results. However, low levels of recreational compliance to RCA regulations could also be significantly impacting the ability of RCAs to effectively rebuild rockfish populations (Haggarty et al. in review). Commercial rockfish total allowable catch reductions limit the ability of commercial fishers to catch rockfish in inside waters, and on-board and dockside observer programs, in tandem with GPS tracking on commercial fishing vessels, means commercial fishing compliance is believed to be nearly 100% (Haggarty 2014). Much less is known about recreational fisher compliance (Haggarty 2014). Research by Haggarty et al. (in review), using Fisheries and Oceans Canada (DFO) aerial fly over data, suggested that suspected low levels of recreational fisher compliance could be significantly impacting the effectiveness of RCAs in the Salish Sea.

### **3.3 Methods**

We carried out structured interviews with recreational fishers in the southern Canadian Salish Sea (Southern Gulf Islands and Victoria area). This region was selected for its high density of RCAs, popularity amongst recreational fishers (hereafter referred to as fishers), its accessibility, and concerns about high, localized rockfish declines. Surveys were conducted in 16 locations at marinas, docks and boat launches during the peak recreational fishing season (July and August 2014) (Figure 3.1). We used clustered convenience sampling to conduct structured 5-minute interviews with saltwater fishers. Individuals who were likely fishers – based on boat type, fishing gear, or presence at

popular fishing sites – were approached by one of two researchers and asked to participate in a 5-minute voluntary survey on Rockfish Conservation Areas.



**Figure 3.1. Recreational fisher survey locations at marinas and boat launches. Red square on locator map marks study region.**

### 3.3.1 Quantifying RCA knowledge and compliance

We assessed levels of RCA knowledge and compliance through structured (closed and open) questions and the randomized response technique (RRT). Questions about RCA knowledge asked, for example, if fishers had previous knowledge of RCA existence and if they were confident of RCA boundary locations (see Appendix C for full questions). We used charts of RCA locations as a visual aid when asking respondents if they had accidentally fished in an RCA in the past 2 years. We asked respondents to locate their typical fishing area on the charts. We then showed the location of RCAs in those areas and asked if they had ever accidentally fished in any of them. We reminded respondents that surveys were completely anonymous and that the researchers were exclusively associated with the University of Victoria.

We used two techniques to assess levels of intentional non-compliance. First, we used a non-sensitive direct question technique (Arias and Sutton 2013). We asked the question, “Do you personally know anyone who has intentionally fished in a Rockfish Conservation Area in the past two years?”. Second, we used the Randomized Response Technique (RRT) (Horovitz and Greenburg 1976, Fox and Tracey 1986, Arias and Sutton 2013) to ask respondents if they had personally intentionally fished in an RCA. RRT has been shown to be effective for obtaining honest answers from respondents by assuring them complete response anonymity, enabling truthful responses. We used a 20-sided die inside an opaque cup. Out of sight of the interviewer, respondents were instructed to shake the cup and look at the number they rolled. If they rolled a 1 they were to answer the question with “yes”. If they rolled a 2 they answered “no”. If they rolled any other number from 3 to 20, they answered the question honestly: “Have you ever intentionally fished in a Rockfish Conservation Area in the past 2 years?”. The non-compliance rate can then be determined statistically by using known probabilities for predetermined responses (Krumpal 2012, Arias and Sutton 201). For our study, the probability of an honest answer was  $P_1=0.9$ , the probability of a predetermined “yes” answer was  $P_2=0.5$ , and the probability of a predetermined “no” answer was  $P_3=0.5$ . The expected value  $\theta$  of obtaining a “yes” answer can be calculated as  $\theta = P_1 + P_2\pi$ , where  $\pi$  is the, in this case unknown, proportion of survey respondents who agree with the sensitive question (e.g. respondents who answer the sensitive question honestly with a yes). Since  $\pi$  is unknown,

we can use the observed yes responses as an estimate of  $\theta$  to calculate  $\hat{\pi}$  (*estimated* proportion of respondents who answer the sensitive question with yes):

$$\hat{\pi} = \frac{\hat{\theta} - P1}{P2}$$

Where  $\hat{\theta}$  is the observed number of yes responses (including both forced and honest yes responses). The variance can be calculated using:

$$Var(\hat{\pi}) = \frac{\hat{\theta}(1 - \hat{\theta})}{nP2^2}$$

We created a composite variable of overall RCA knowledge by combining three knowledge-based survey questions: 1) knowledge of RCA boundaries; 2) knowledge of RCA fishing restrictions; 3) knowledge of rockfish bag limits. Fishers who answered all three questions correctly received a score of 3. Fishers who answered 2 of 3 questions correctly received a score of 2, etc... This variable provides a gradient of RCA and rockfish regulation knowledge amongst respondents.

### **3.3.2 Factors contributing to RCA knowledge and compliance**

We used the following dependent variables – included as questions in the survey – as measures of RCA and rockfish fishing knowledge and compliance: 1) knowledge of RCA boundaries, 2) knowledge of rockfish bag limits in the Strait of Georgia, 3) previous knowledge of RCA existence, 4) admission of accidental fishing in RCAs, and 5) personally knowing someone who had intentionally fished in an RCA. We hypothesized that the following independent variables would lead to higher knowledge of RCAs and/or higher compliance: 1) greater number of years fishing, 2) greater number of days fishing (past 2 years), 3) higher percentage of time fishing rockfish (past 2 years), 4) obtaining fishing information directly from the fisheries management agency (Fisheries and Oceans Canada, DFO), 5) residence nearby (Vancouver Island or in British Columbia), 6) gender, and 7) previous knowledge of RCAs.

We used several analyses to assess factors that influence RCA knowledge and compliance. First, we used generalized linear models (GLMs) in R (R Core Team 2013), using the package MASS (Venables and Ripley 2002) and the function `glm` with binomial errors and logit-link (Crawley 2007), to identify significant contributors to RCA compliance and knowledge. We removed seven partially completed surveys from our GLM dataframe (n=318) to facilitate accurate comparison. We used a subtractive method and the Akaike Information Criterion (AIC) to create models with the lowest AIC score for the greatest number of significant predictor variables. We used the standard alpha level 0.05 (Fisher 1935). We calculated the deviance explained for each GLM with significant predictor variables using the equation:

$$de = \frac{(nd - rd)}{nd}$$

Where *de* is deviance explained, *nd* is null deviance, and *rd* is residual deviance.

We used deviance explained, effect size, and p-value to determine how well our models predicted RCA knowledge and behaviour.

Second, we used two methods to assess whether fisher characteristics align with high or low RCA knowledge and compliance. We used multi-dimensional scaling (MDS) in R to determine if RCA knowledge was clustered with other fisher characteristics. We used the package `vegan` (Oksanen et al. 2015) and the function `vegdist` to create a dissimilarity matrix, which we then used to calculate the MDS using the function `metaMDS`. We also ran a hierarchical cluster model in R, using the package `clustsig` (Whitaker and Christman 2014) and the function `simprof`, to determine if the characteristics: years fishing, days fishing, percent of time fishing rockfish, number of accidentally caught rockfish, place where fishing regulations are obtained, gender, age, First Nations status, and place of residence were clustered into meaningful groups.

### 3.3.3 Rockfish bycatch and release rates

We assessed levels of recreational fisher rockfish bycatch and release rates with survey questions. We extrapolated rockfish bycatch rates for the recreational fishing population in BC based on the number of annual, 5 day, 3 day, and 1 day fishing licenses sold in

2014. Our study region is one of the more intensive recreational fishing regions in BC (Haggarty et al. in review), but many of our survey participants fished in multiple regions throughout BC. Inshore rockfish populations are also more depleted in the Salish Sea (Haggarty 2014), thus, although there are fewer recreational fishers in other regions, chances of catching rockfish in these less depleted areas is likely higher. We assumed that the number of rockfish caught as bycatch per year was representative of other regions. We accounted for limitations on fishing time among 5-day, 3-day, and 1-day fishing licenses with the following formula:

$$RC = \left( \left( \frac{ARC}{365days} \right) DF \right) NL$$

Where  $RC$  is accidentally caught rockfish per year per fishing license type (e.g. 1 day license),  $ARC$  is average number of accidentally caught rockfish per fisher per year,  $DF$  is number of days fishing annually as determined by license type (e.g. 1 day), and  $NL$  is number of specific fishing licenses sold annually (e.g. 1 day licenses). We then summed the  $RC$  totals for each license type to calculate the total annual recreational rockfish bycatch in BC.

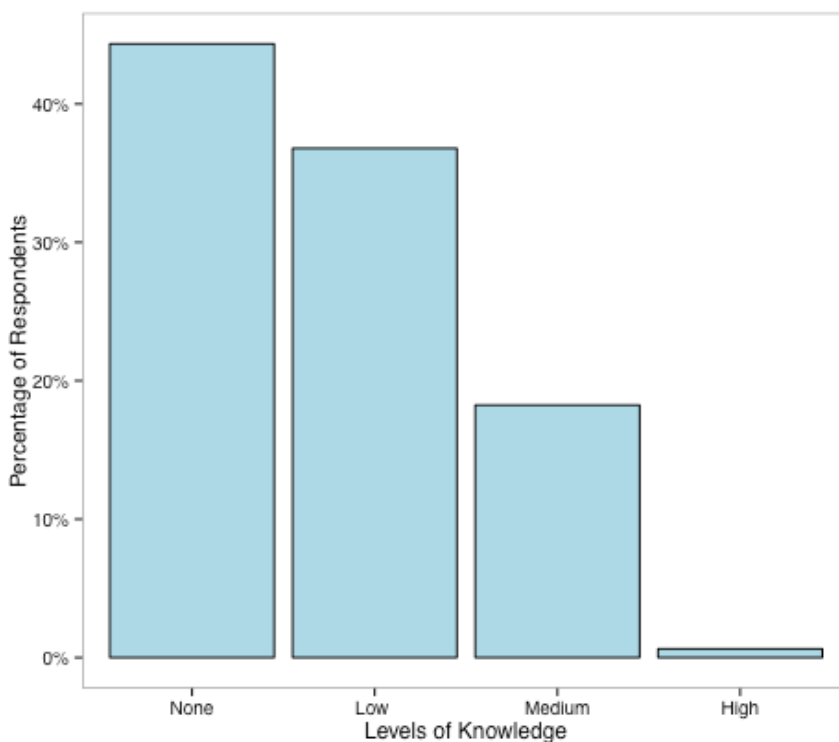
### 3.3.4 Fisher perceptions and recommendations for RCAs

We elicited fisher perceptions of RCAs and obtained suggestions for improvements through six open-ended short-answer survey questions. We coded categories of answers to highlight important themes and patterns among responses. We then calculated the proportion of participants mentioning each category, providing an overview of RCA perceptions and suggestions for improvement. We also selected direct quotes from survey respondents to highlight a variety of different viewpoints.

### 3.4 Results

#### 3.4.1 Quantifying RCA knowledge and compliance

We found that 25.5% of fishers had never heard of RCAs before taking our survey, and 59% of fishers were not confident of RCA boundaries in the places they typically fish. Thirty eight percent of fishers incorrectly believed that salmon fishing is permitted in RCAs and 23% of fishers believed that halibut fishing is permitted in RCAs. Knowledge of permitted fishing activities within RCAs is very low with less than one percent (n=3) of fishers knowing all permitted activities. We found that 67% of fishers did not know rockfish bag limits (1 rockfish per day) in the Strait of Georgia. Our composite variable (Figure 3.2) showed that 44% of fishers did not correctly answer any RCA regulation questions and less than 1% of fishers (n=2) answered all three knowledge questions correctly.



**Figure 3.2. Knowledge of RCA regulations based on fisher responses to three knowledge based questions.**

Using maps of RCAs as a reference, 16% of fishers admitted to accidentally fishing within an RCA in the last two years, and seven percent of fishers stated that they personally knew someone who had intentionally fished in an RCA. The estimated non-compliance rate within RCAs is thus 23%.

Using the RRT equation to account for predetermined “yes” and “no” responses, the RRT question showed no intentional non-compliance ( $\hat{\pi} = -0.028$ ) in RCAs. The variance was  $<0.001$ . Of 318 fishers who completed the RRT section, only 8 answered the question “Have you ever intentionally fished in a Rockfish Conservation Area” with a yes, including predetermined responses. However, 3 of the 8 yes responses we did receive were confirmed intentional fishing based on unprompted admission of intentional illegal fishing activity from survey participants.

### **3.4.2 Factors contributing to RCA knowledge and compliance**

We used GLMs to determine what factors may contribute to better RCA and rockfish regulation knowledge, as well as higher RCA compliance. We created a GLM for each of our measures of knowledge and compliance (Table 3.2).

Knowledge of RCA existence and RCA boundaries were significantly correlated with greater years fishing and obtaining information directly from Fisheries and Oceans Canada (DFO), the government agency that manages fisheries, either through their website or printed materials. Knowledge of rockfish bag limits was negatively significantly correlated with years fishing, with those who fished more years more frequently mistaking rockfish bag limits. However, in the same GLM, greater days fishing was significantly correlated with increased knowledge of rockfish bag limits. Female fishers and fishers who reside outside of British Columbia are significantly less likely to be confident of RCA boundaries. The deviance explained for each of these GLMs was low (Sechrest and Yeaton 1982).

**Table 3.1. Overview of final GLMs for each dependent variable.**

RCA knowledge/ compliance GLMs (dependent variable)	Final model (independent variables)	P-values	Effect Size	Deviance Explained
Knowledge of RCA boundaries	Years fishing	<0.05	0.014	7%
	Place where fishing information is obtained	<0.01	-0.94	
	Gender	<0.05	-1.44	
	Residence (Canada outside BC)	<0.05	-1.849	
	Residence (USA)	<0.05	-1.727	
Knowledge of rockfish bag limits in the Strait of Georgia	Years fishing	<0.05	-0.016	11%
	Days fishing	<0.001	0.009	
	Previous knowledge of RCAs	<0.001	1.667	
Previous knowledge of RCA existence	Years fishing	<0.01	0.022	6%
	Place where fishing information is obtained	<0.001	-1.032	
Admission of accidental fishing in RCAs	Days fishing	Not significant		9%
	Percent of time fishing rockfish	<0.001	0.021	
	Previous knowledge of RCAs	Not significant		
	Gender	<0.05	1.112	
Personally knowing someone who has intentionally fished in an RCA	No significant independent variables			

More time spent fishing rockfish was significantly correlated with accidental fishing in RCAs, as was gender, with women admitting to accidental fishing in RCAs more frequently than men. Women comprised less than 10% of fishers surveyed and 33% of female fishers admitted to accidentally fishing in RCAs, compared to 15% of male fishers. No factors were significantly correlated with personally knowing someone who intentionally fished in an RCA.

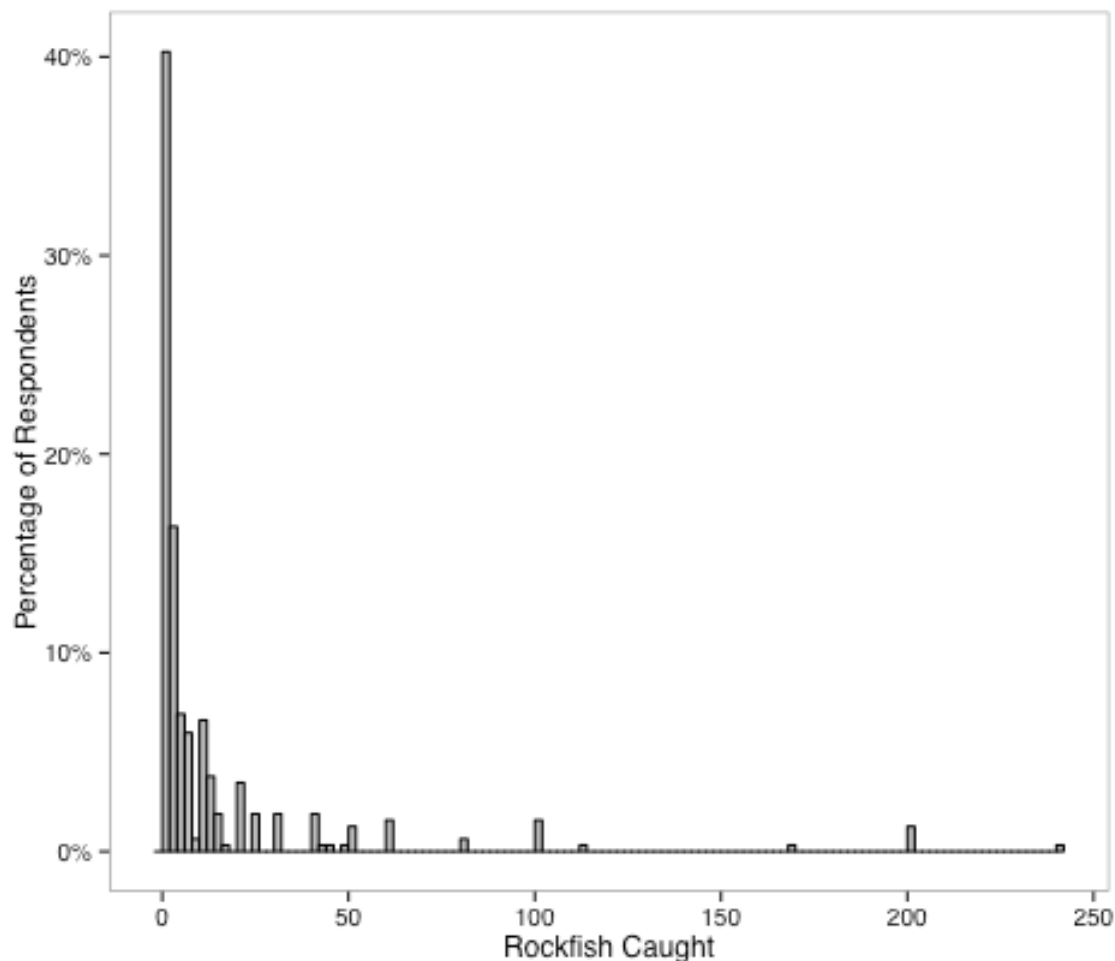
Multi-dimensional scaling of the survey data did not reveal any clear clustering of fisher characteristics associated with our five measures of knowledge and compliance (knowledge of RCA boundaries, knowledge of rockfish bag limits in the Strait of Georgia, previous knowledge of RCA existence, admission of accidental fishing in RCAs, and personally knowing someone who had intentionally fished in an RCA). However, a hierarchical cluster analysis identified three main groups of fishers based on the number of days spent fishing, amount of time spent fishing rockfish, and the number of accidentally caught rockfish. We identified these clusters as: Group 1) Novice fishers (Low fishing effort, knowledge, accidental rockfish bycatch, and accidental non-compliance); Group 2) Average fishers (Moderate fishing effort, knowledge, accidental rockfish bycatch, and accidental non-compliance); Group 3) Intensive fishers (Highest fishing effort, overall knowledge, accidental rockfish bycatch, and accidental non-compliance) (Table 3.2).

**Table 3.2. Summary of main differences between hierarchical clustering fisher groups.**

<b>Variable</b>	<b>Group 1 (novice fishers) n=20</b>	<b>Group 2 (average fishers) n=246</b>	<b>Group 3 (intensive fishers) n=52</b>
Years fishing	2.5	31	28
Days fishing ( <i>past 2 years</i> )	5	25	154
Percent of time fishing rockfish ( <i>past 2 years</i> )	0.2%	13%	12%
Number of accidentally caught rockfish ( <i>past 2 years</i> )	1	9	39
Accidental rockfish caught per day fishing (rockfish caught/days fishing)	0.2	0.36	0.25
Had no previous knowledge of RCAs	60%	23%	23%
Was not confident of RCA boundaries	85%	56%	61%
Does not know fisher bag limits	70%	70%	48%
Gets fishing information directly from DFO	60%	84%	75%
Had fished in an RCA accidentally ( <i>past 2 years</i> )	5%	16%	21%
Composite knowledge variable ( <i>zero knowledge to high knowledge</i> )	Zero =60% Low =35% Moderate =5% High =0%	Zero =44% Low =39% Moderate =17% High =1%	Zero =40% Low =29% Moderate =29% High =2%

### **3.4.3 Fisher rockfish bycatch and release rates**

We found that 59% of fishers never deliberately target rockfish, with less than 11% of fishers spending between 50-100% of their fishing time specifically targeting rockfish. In the past two years, fishers had accidentally caught, on average, 14 rockfish (7 rockfish per year per fisher). One individual accidentally caught approximately 240 rockfish in the past two years (Figure 3.3).



**Figure 3.3. Histogram of accidentally caught rockfish in the past 2 years.**

Sixty percent of fishers who accidentally caught rockfish released them 100% of the time. However, less than three percent of fishers redescended rockfish to their capture depth, a practice that has been associated with decreased rockfish mortality after accidental capture (Hannah et al. 2007, Jarvis and Lowe 2008). Most fishers had never heard of rockfish recompression and needed the question explained before responding.

In the 2013/2014 fishing license year, 307,157 recreational fishing licenses were sold, including annual, 5-day, 3-day, and 1-day resident and non-resident licenses (DFO 2014c). Extrapolating the fisher average of 7 accidentally caught rockfish per year, there were approximately 1,438,388 rockfish accidentally caught by fishers in Canadian Pacific waters in the 2013/2014 license year.

### 3.4.4 Recreational fisher perceptions of RCAs and recommendations for RCA improvement

**Table 3.3. Full results of open ended, short answer question coding analysis. Respondents often offered more than one answer to each question, and thus responses do not add up to 100%.**

<b>Question 1: Do you think there is a need for rockfish conservation in British Columbia?</b>	
<b>Fisher Responses</b>	<b>Response Frequency (%)</b>
Yes	77%
Yes – Overfished/Depleted Stocks	45%
Yes – Biologically Sensitive Fish	16%
Yes – Need for all conservation	10%
Yes – Because of this survey	5%
Yes – Poaching	4%
Yes – Asian depletion of stocks	4%
No	4%
No – populations are stable	3%
Probably	6%
<i>No Idea/Not Sure</i>	10%
<i>Not Sure – no data on rockfish</i>	1%
<i>Not sure – never heard of rockfish</i>	>1%
<i>Other</i>	13%
<b>Question 2: What do you think are the best ways to improve rockfish conservation in general?</b>	
Advertising of RCAs	23%
Education (rockfish bio and significance/overfishing concerns)	19%
Monitoring	17%
Moratorium (mention permanent or temporary full closures of rockfish fishing)	17%
RCAs (as currently implemented – also includes mention of protected areas in general)	16%
Dock Signs	10%
Target Asian overfishing	6%
Fines/Penalties	5%
More RCAs	4%
Lower catch limit	4%
Information with fishing license (info and quizzes)	4%
Commercial fishery is the problem	3%
Marker Buoys	1%
<i>Don't know/Not sure</i>	7%
<i>Other</i>	22%
<b>Question 3: Why do you think some recreational fishers fish in Rockfish Conservation Areas?</b>	
Ignorance	55%
Poaching/Don't care about conservation	36%
Better fishing in RCAs	16%
Asian populations targeting them	6%
Targeting other fish in RCAs (i.e. Salmon)	4%
Aboriginal fishing in RCAs	1%
<i>Don't Know/Not sure</i>	10%
<i>Other</i>	2%
<b>Question 4: What do you think is the best way to stop recreational fishers from intentionally fishing in Rockfish Conservation Areas?</b>	
Monitoring	46%
Fines	33%
Confiscations	17%

Advertising/Signage	12%
Education	9%
Citizen reporting/patrolling	6%
Intentional fishing is not occurring	3%
Clearer Regulations	2%
Jail	1%
<i>Don't Know</i>	4%
<i>Other</i>	6%
<b>Question 5: What do you think is the best way to stop recreational fishers from accidentally fishing in Rockfish Conservation Areas?</b>	
Advertising/Info with Licence	32%
Signs on Docks/Marinas	31%
Education	22%
Monitoring	18%
Marker Bouys	12%
Clearer Website/Regulations	12%
Fines/Penalties	7%
Warnings	7%
App/Navionics Overlay	4%
<i>Don't Know</i>	4%
<i>Other</i>	7%
<b>Question 6: Do you think the Rockfish Conservation Areas are currently an effective conservation tool?</b>	
Yes	40%
Partially	13%
Good Start	5%
What else can be done	3%
Hopefully	3%
Mostly	2%
Better than nothing	2%
No	8%
No, nobody knows about them	3%
<i>Not Sure</i>	26%

Most fishers (77%) believe that there is a need for rockfish conservation in BC, and only four percent indicated that there is not a need for conservation (Table 3.4). Many fishers suggested rockfish conservation could be improved through increased knowledge and awareness through signage, education campaigns, and general advertising as well as permanent or temporary rockfish fishing moratoriums. Fishers cited ignorance and poaching as the most common reasons why fishers would fish in RCAs. Rockfish are an important fish in many Asian cultures, and specific reference to Asian communities poaching rockfish was mentioned by 6% of respondents.

Fishers suggested more monitoring and frequent fines were necessary to reduce intentional non-compliance in RCAs. Suggested reasonable fines ranged from \$50 to \$20,000 (mean = \$1700). One respondent stated, “We need bigger fines and we need to

take their boats. A few big cases like that will get people talking”. Six percent of respondents also suggested citizen reporting and patrolling as a solution to intentional non-compliance. One respondent stated, “We should encourage self-reporting, DFO just doesn't have the budget, we need community monitoring”.

Fishers suggested accidental RCA fishing could be reduced with signage and advertising in addition to more monitoring. Twelve percent of fishers thought DFO should improve and simplify their website and make fishing regulations clearer and simpler. One respondent stated, “The DFO website is bad. The information is bad too. It's too hard to understand. We need postings on marinas, an area-specific regulations booklet, an App with RCA notifications”. Most fishers (54%) believed that the RCAs are currently either a fully or partially effective conservation tool.

Many fishers were surprised that RCAs restrict nearly all fishing since the name seems to imply that only rockfish fishing is prohibited. Many salmon and halibut fishers had heard of RCAs while looking at DFO fishing regulations and assumed, based on the name, that RCA regulations would not apply to them.

### **3.5 Discussion**

Non-compliance has a significant impact on the success of conservation areas, and thus areas with non-compliance – intentional or unintentional – are unlikely to protect and recover target species (Bergseth et al. 2013). We found that knowledge of RCAs and RCA regulations by recreational fishers in BC is low, likely contributing to relatively high levels of accidental fishing within RCAs. Small amounts of consistent intentional or unintentional non-compliance can compromise the ability of marine conservation areas to protect and rebuild target species (Kritzer 2004, Little et al. 2005, Sadovy and Domeier 2005, Graham et al. 2010). With a non-compliance rate of 23%, RCAs are unlikely to fulfill their mandate to protect inshore rockfish stocks (Yamanaka and Logan 2010), especially in regions with high levels of recreational fishing pressure (Haggarty 2014).

The relatively few studies that have investigated factors contributing to compliance found that education and positive perceptions of marine conservation areas are essential for high compliance (Alder 1996, Gribble and Robinson 1998, Cinner et al.

2005, Pollnac et al. 2010, Read et al. 2011, Leleu et al. 2012, Smallwood and Beckley 2012, Arias and Sutton 2013, Bergseth et al. 2013, Pita 2013). Support for conservation actions are only useful when fishers know about the locations of marine conservation areas (Read et al. 2011). Our data showed that low levels of RCA knowledge are present across all recreational fishers (occasional to expert), and accidental and intentional compliance levels do not vary greatly between groups. Knowledge about RCAs was uniformly low, and thus potential drivers of non-compliance did not explain much of the variation. Although knowledge increased slightly with more days spent fishing, accidental fishing also increased, indicating that outreach and education about RCAs are lacking overall. A similar study in the Great Barrier Reef Marine Park (GBRMP) determined that the non-compliance rate within no-take zones in the park was eight percent (Arias and Sutton 2013). In the GBRMP, managers have gone to great lengths to educate fishers and other stakeholders over the past four decades with television advertisements, radio, signage, and public seminars (Alder 1996). There may always be a small percentage of the population that will not respond to education and awareness campaigns (Alder 1996). Given that the majority of fishers we surveyed (77%) already believe rockfish conservation is necessary, a thorough outreach campaign, similar to that in the GBRMP, could significantly reduce accidental non-compliance. Education and outreach campaigns are generally less costly than enforcement and monitoring (Alcock 1991, Bergin 1993, Alder 1996).

Reducing non-compliance within conservation areas is an urgent priority. Our research showed that bycatch of rockfish by recreational fishers was high and knowledge of re-descenders negligible. Given the low levels of awareness of RCAs, many of the rockfish caught as bycatch annually (~1,400,000) may be caught in RCAs. The mortality of rockfish with barotrauma released on the surface is assumed to be 100% by DFO (Haige and Yamanaka 2011). Although rockfish survival rates after being re-descended vary greatly depending on species, survival rates of 97% were found for Black rockfish (Parker et al. 2006). Many rockfish with severe barotrauma, typically assumed to be dead by fishers, were alive and able to swim away without major behavioural impairment after being re-descended (Hannah and Matteson 2011). Given the high bycatch rate, and low knowledge of rockfish re-descenders, an education program should include information

about RCA locations and regulations, rockfish biology, their susceptibility to barotrauma, and how to re-descend rockfish after capture. Simple and clear naming of RCAs could be an easy and important first step towards higher levels of voluntary compliance, as many fishers were confused about allowable fishing activities.

While our study is one of the few to quantitatively assess recreational fisher compliance – and the first of its kind in BC – it has several limitations. First we focused on only one region. Thus our findings may not be representative of all recreational fishing demographics. However, we provide a snapshot of recreational fishing knowledge and compliance in a relatively new and little-studied network of marine conservation areas. Further research could examine recreational fishing patterns and RCA knowledge in other regions and other fishing groups (e.g., First Nations fishers). Second, our study focused on individual recreational fishers, not guided fishing tours. In other regions of BC, recreational fishers often use fishing guides, and thus a study of knowledge and compliance of guides should be considered. If guides are not knowledgeable and compliant, they could be an important focus of education and enforcement efforts. Conversely, if they are knowledgeable and compliant, they could act as RCA educators. Third, the discrepancy between the non-compliance rate determined by the RRT question and the non-sensitive, direct non-compliance question, may suggest that survey respondents were either uncomfortable answering the RRT question honestly, or did not fully understand how the technique would protect their confidentiality. Arias and Sutton (2013) found comparable intentional non-compliance rates between both techniques. The difference between techniques in our study could be a result of random chance, or that people who illegally fish in RCAs are unlikely to participate in a voluntary survey about RCAs.

### **3.6 Conclusion**

This study emphasizes the need for education of recreational fishers about regulations in, and locations of, marine conservation areas (Read et al. 2011). Knowledge about RCAs was uniformly low, and thus potential drivers of non-compliance did not explain much of the variation, although fishing experience, source of information about regulations,

gender and nearby residence contributed to knowledge about RCAs. The high recreational non-compliance rate in RCAs - primarily accidental fishing - is likely compromising the ability of these marine conservation areas to protect inshore rockfish stocks in BC. The ecological usefulness of marine conservation areas hinges upon users knowing about, and understanding, protected area rules and regulations. Even a perfectly designed network of conservation areas cannot be effective if users are not informed through education, outreach, and enforcement. Additionally, managers should take care to make protected area names and regulations as clear and easy to understand as possible. Although recreational fishing populations take a smaller percentage of the total global fish catch than commercial fishers (Cooke and Cowx 2004, Granek et al. 2008), they can heavily impact near-shore fish stocks and, as such, should not be ignored (Post et al. 2002, Cooke and Cowx 2004). Efforts to educate and involve this fishing sector in marine conservation efforts should be a management priority. Compliance research, especially on recreational fisher populations in temperate regions, has received little research attention. We recommend researchers continue to explore compliance and its drivers in order to maximize both the social and ecological effectiveness of marine conservation areas.

## **Chapter 4: Effectiveness of shore-based remote camera monitoring for quantifying recreational fisher compliance in marine conservation areas.**<sup>3</sup>

### **4.1 Abstract**

Marine conservation areas require high levels of compliance to meet conservation objectives, yet little research has assessed compliance quantitatively, especially for recreational fishers. Recreational fishers take 12% of global annual fish catches. With millions of people fishing from small boats, this fishing sector is hard to monitor, making accurate quantification of non-compliance an urgent research priority. We tested a novel technique of shore-based remote camera monitoring for quantifying recreational non-compliance in near-shore Rockfish Conservation Areas in the Salish Sea, Canada. We used high definition trail cameras to monitor 42 locations between July and August 2014. Of these, 79% of monitored conservation area sites showed confirmed or probable fishing activity, with no significant difference in fishing effort inside and outside Rockfish Conservation Areas. We used fixed effects generalized linear models to explore the environmental and geographic factors influencing compliance. Sites with greater depth had significantly higher fishing effort. This widespread non-compliance could compromise the ability of Rockfish Conservation Areas to protect and rebuild rockfish stocks. More education, advertising, and enforcement are necessary to increase compliance. Our results were similar to aerial fly-over compliance data from 2011, suggesting that trail camera monitoring is an accurate and affordable alternative method of assessing non-compliance in coastal conservation areas, especially for community-based organizations wishing to monitor local waters.

### **4.2 Introduction**

Fishing has depleted marine resources, with large and long-lived marine species particularly affected (Cook et al. 1997, Pauly et al 2002, Molfese et al. 2014).

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<sup>3</sup> This chapter will be submitted for publication with co-authors Dana R. Haggarty, Dr. Philip Dearden, Dr. John P. Volpe and Dr. Natalie C. Ban.

Governments use marine spatial management tools, such as marine protected areas (MPAs) and fisheries closures, to stem declines and promote recovery (Marinesque et al. 2012). Management efforts to recover marine ecosystems require high levels of compliance to be ecologically effective (Little et al. 2005, Sadovy and Domeier 2005, Graham et al. 2010, Edgar et al 2014, Arias 2015). Even low levels of non-compliance may impact effectiveness significantly (Little et al. 2005, Graham et al. 2010).

Monitoring exists for many commercial fisheries (e.g., fishery observers/electronic monitoring), but little monitoring exists for recreational fishers (Cooke and Cowx 2004, Haggarty 2014). Recreational fishers take 12% of total annual global marine catch, primarily in coastal areas where the majority of small conservation areas are located (Cooke and Cowx 2004, Marinesque et al. 2012). Non-compliance from this sector could jeopardize the ability of marine conservation areas to protect target species and their habitats (Edgar et al 2014).

Despite research showing the need for high compliance, very little quantitative assessment exists generally (Bergseth et al. 2013), with even less emphasis on recreational fisher non-compliance specifically (Davis et al. 2004, Smallwood and Beckley 2012, Arias and Sutton 2013, Watson et al. 2014, Greenburg and Godin 2015). Studies on compliance have used several methods, all with associated challenges: direct questioning through surveys, law enforcement records, expert opinion, and indirect and direct observations (Bergseth et al. 2013). Although direct questioning is an affordable and relatively reliable method of assessing compliance, response bias – the desire to answer questions in a socially acceptable way – can lead to underestimation of non-compliance (Daw et al. 2011, Arias and Sutton 2013). Law enforcement records offer valuable on-the-water data but sanctioning is typically discretionary, with many violators receiving warnings leading to underestimates of non-compliance (Bell 1997, Robbins et al. 2006). Expert opinion relies on managers or community leaders with extensive knowledge of specific conservation areas and activities within them, but is subject to expert bias (Martin et al. 2012). Indirect observation involves quantifying signs of illegal activity, such as crater blasts on coral reefs or discarded fishing line. These techniques are rarely used, and quantifying non-compliance during specific temporal periods is challenging (Williamson et al. 2014). Direct observations typically use air, vessel, or

shore-based methods (Bergseth et al. 2013). Aerial fly-over and vessel-based methods can be expensive and typically only offer a snapshot of non-compliance (Cudney-Bueno and Basurto 2009, Smallwood and Beckley 2012). Identification of non-compliant activities can also be difficult from the air, and vessel-based observations often alarm possible violators who leave or hide their activities when approached (Bergseth et al. 2013). Shore observations are promising for near-shore conservation areas typically used by recreational fishers, yet require long hours of observer monitoring in many sites, which can be expensive and difficult to coordinate with limited personnel (Schindler and Ames 2009, Smallwood and Beckley 2012). Shore-based camera and video monitoring is just beginning to be explored as a compliance monitoring tool. Trail cameras are small and difficult to see, making them less susceptible to observer presence bias (i.e. when fishers alter behaviour based on the presence of an observer) (Bergseth et al. 2013). The Freshwater Fisheries Association of BC uses cameras to monitor recreational fishing effort on small lakes (Greenburg and Godin 2015), and video monitoring has been used to monitor recreational non-compliance in UK MPAs and recreational fishing in Oregon, USA (Schindler and Ames 2009, Watson et al. 2014).

The purpose of our study was threefold. First, we wished to test the efficacy of time-efficient, low cost (~ US \$200 each) trail cameras for near-shore monitoring. We reflect on the promise and challenges of camera monitoring, and suggest improvements and additional applications. Second, using this novel technique we sought to quantify recreational fisher compliance with Rockfish Conservation Area (RCA) boundaries as compliance is low in the region (See Chapter 3) (Haggarty et al. in review). We assess factors that influence fishing effort, and compare our findings to other methods for monitoring compliance (e.g. Haggarty et al. in review). Lastly we wished to interrogate the spatially-specific data using ArcGIS layers to reveal consistent underlying geo-physical factors associated with non-compliant activity.

## 4.3 Methods

### 4.3.1 Case study

Rockfish Conservation Areas (RCAs) were created along the coast of BC between 2003 and 2007 to protect declining inshore rockfish populations (Yelloweye (*Sebastes ruberrimus*), Quillback (*Sebastes malinger*), Tiger (*Sebastes nigrocinctus*), Copper (*Sebastes caurinus*), and China (*Sebastes nebulosus*) rockfish) (Yamanaka and Logan 2010). These are long-lived (50-120 years), slow growing fish found throughout BC waters (Love et al. 2002). They are susceptible to barotrauma (typically fatal injuries associated with ascending rapidly from depth), and have high site fidelity, making them vulnerable to overfishing (Parker et al. 2000). For example, Yelloweye rockfish are currently at 12% of their 1918 abundance and are listed as a species of concern under the Species at Risk Act (SARA) in Canada (DFO 2012, SARA 2014). RCAs were implemented as part of the Rockfish Conservation Strategy that also reduced total allowable catch quotas for commercial fishers by 75% in inside waters (all waters between Vancouver Island and the mainland), and daily bag limits for recreational fishers (reduced from 5 to 1 rockfish in inside waters) (Yamanaka and Logan 2010). RCAs restrict all recreational fishing activity except for invertebrates by hand picking and trapping, and smelt (*Hypomesus pretiosus*) by gillnet (DFO 2014).

This study took place in the Salish Sea (Strait of Georgia, Puget Sound, and Strait of Juan de Fuca). Rockfish are most critically threatened in the Salish Sea, which contains two thirds of all RCAs (Yamanaka and Logan 2010). The Salish Sea is one of the most intensive recreational fishing areas in BC, with 90% of annual rockfish catch taken by recreational fishers (Haggarty et al. in review). Although compliance data are limited for the recreational sector, 100% of commercial groundfish fisheries have on-board observer or electronic monitoring (Yamanaka and Logan 2010). The recreational sector is difficult to monitor, with the Department of Fisheries and Oceans (DFO) relying upon sporadic vessel and plane-based patrols, and annual creel surveys (Haggarty et al. in review).

### 4.3.2 Remote camera monitoring

We utilized six Bushnell HD trail cameras (model #119537C) deployed in 40 shore locations overlooking 14 RCAs and 10 unprotected reference sites in the Southern Gulf Islands and Victoria area (Fig. 4.1) throughout the peak 2014 recreational fishing season (July and August 2014). We prioritized camera locations in RCAs to provide as much coverage of these conservation areas as possible to capture non-compliance events. Camera monitoring sites were selected based on availability (e.g. public land or private property with owners' permission) to maximize coverage of protected and unprotected areas in the study region. Cameras were deployed for a minimum of five and a half days and a maximum of fourteen days per site (mean=six and a half days). The cameras were set to *field scan* function, taking a picture every 5 minutes during daylight hours, from 4:30 am to 10:00 pm daily. Cameras were locked to trees or upright structures with small signs explaining the research project, and noting that no individuals or boats would be identified during the research. We removed three RCA sites and one reference site from the analysis due to poor photo quality or close proximity to another camera site, resulting in 29 RCA and 9 reference sites.

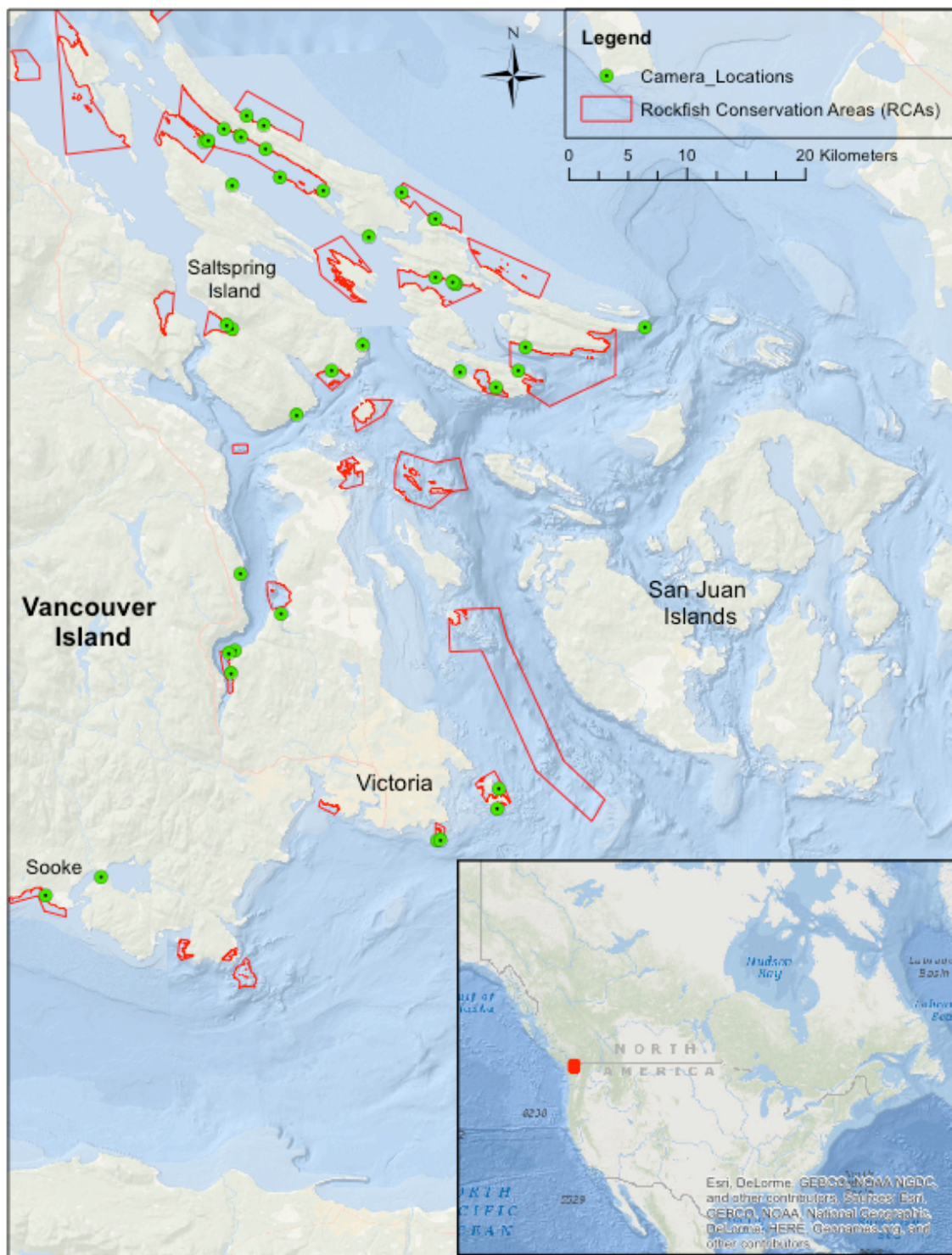


Figure 4.1. Trail camera monitoring locations. Red square on locator map marks the study region.

We visually scanned ~60,000 photos for fishing events. Photos from each site (~1500 photos) could be analyzed in approximately 15 minutes. We identified fishing events based on presence of fishing gear in the water, boat type, boat movement patterns, and wake size. Most cameras were placed in locations where only RCA protected waters were visible or where a geographic marking provided a reference for RCA boundaries. In cases where geographic markers were absent, only boats close enough to shore to ensure 100% confidence of RCA boundary violation were counted. We labeled images as “confirmed fishing” when fishing gear (e.g. rod and line) were clearly visible in the water. We labeled images as “probable fishing” when: 1) fishing-style boats were captured in one or more frames with no wake to imply movement (suggesting jigging); or 2) fishing-style boats repeatedly circled into the camera field of view (suggesting trolling). We recorded information on site location, date, time, and duration of fishing events.

We tested if fishing effort was higher in unprotected reference sites than RCAs and assessed environmental and geographic factors contributing to fishing effort. Using raw count data, we created mixed effect generalized linear models (GLMMs) in the statistical software R (R Core Team 2013) using *glmer* from the package *lme4* (Bates et al. 2014) with a Poisson distribution and log-link to account for variability in monitoring times between sites. GLMMs do not make assumptions about normal (Gaussian) distributions. We used a random effect to link camera sites to fishing events that occurred in those locations, and included environmental and geographic predictor variables to determine whether certain characteristics enhance the likelihood of fishing events. We used ArcGIS layers available from the BC Marine Conservation Analysis (BCMCA 2015) in GIS to create ecological predictor variables and Google maps to determine terrestrial park presence (Table 4.1). We hypothesized that sites with optimal rockfish habitat - high rugosity, steep gradient, hard bottoms, greater depth, and bullkelp presence would attract higher fishing effort (Cloutier 2007). We further hypothesized that monitoring locations within terrestrial parks would have fewer fishing events due to park outreach activities. We also used a separate GLMM with a random effect linking RCAs (not individual sites) to fishing events to test if the area of the RCA influenced compliance as it did in Haggarty et al. (in review).

**Table 4.1. GLMM ecological and geographic predictor variables at monitoring sites within each camera's field of view (FOV = 50 degrees to a distance of 1km). Classification categories set by GIS layers from the BC Marine Conservation Analysis and Google maps.**

<b>Ecological predictor variable</b>	<b>Classification parameters</b>
Rugosity	High = >50% of FOV Low = <50% of FOV
Bottom Type	Dominant bottom type in FOV: Muddy Sandy Hard
Depth	Dominant depth range in FOV: 0-20m 20-50m 50-200m +200m
Bullkelp Bioband	Presence or absence in FOV
Terrestrial Park	Presence or absence of terrestrial park at camera location (e.g. BC Parks/Parks Canada)

We used subsampling to improve statistical confidence for the unbalanced research design (e.g. 29 RCA sites and 9 reference sites). Subsampling is particularly effective in reducing sampling error of results drawn from small datasets (Politis et al. 1999). We subsampled the data 1000 times with replacements to create new datasets reflecting the subsample mean. We created both balanced and unbalanced RCA and reference datasets to compare GLMM results for possible discrepancies.

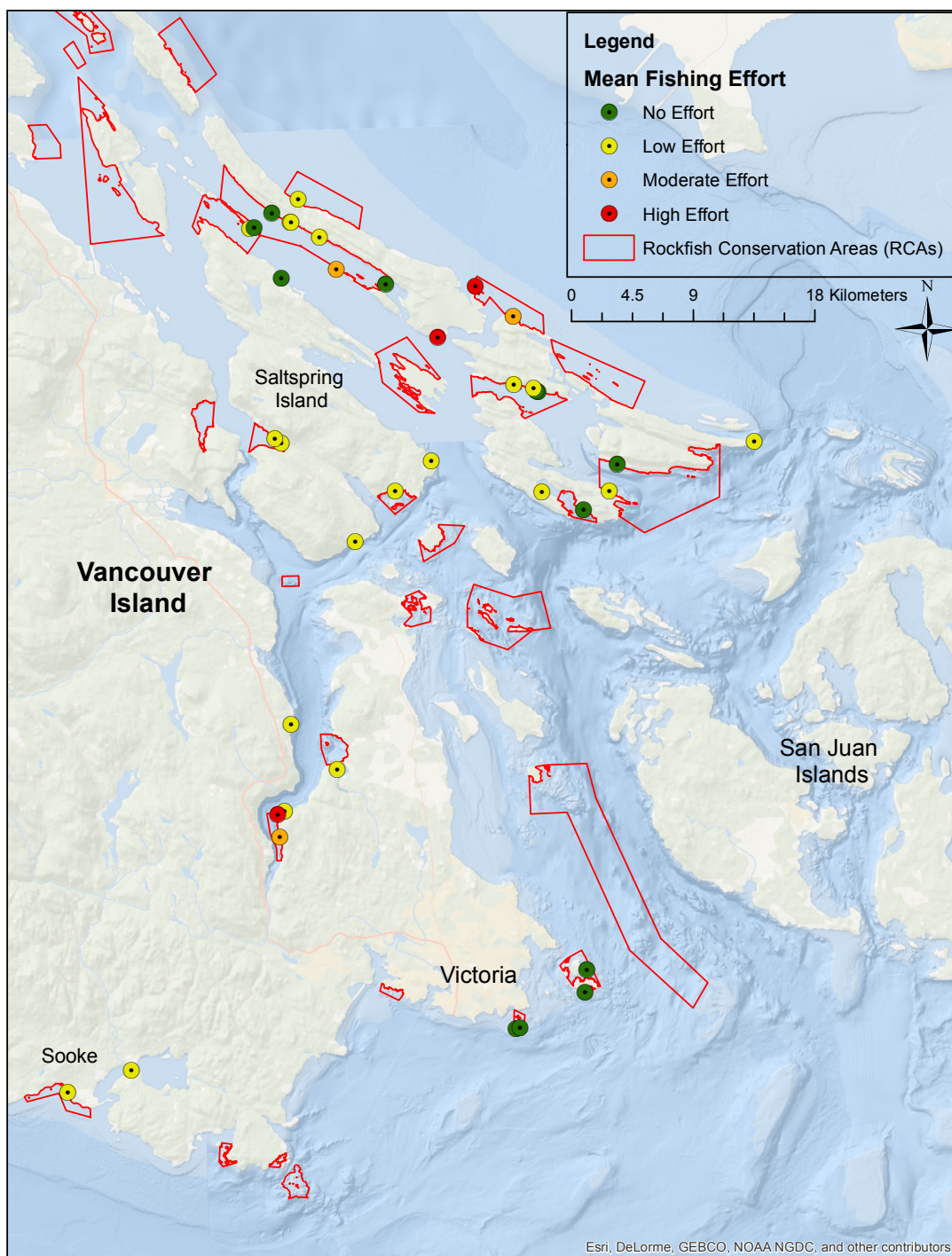
We used a subtractive approach of testing our GLMMs, removing predictor variables with the highest *p*-value from the model. Each GLMM was compared against the previous model with the R function *anova* to check for significant changes between models that could signal model errors. We selected models with the greatest number of significant variables in combination with lowest Akaike Information Criterion (AIC) score (Akaike 1974). We calculated  $R^2$  values for models with significant variables using a method developed by Nakagawa and Schielzeth (2013).

We also calculated the percentage of RCAs and reference sites with fishing activity, and the mean number of fishing events per half day monitored. Number of fishing events was used as a measure of compliance instead of fishing duration due to the camera's small field of view (FOV = 50 degrees to a distance of 1km), which cannot

capture prolonged fishing events in adjacent areas. Half days were chosen as the unit of measurement to ensure that data captured on a set-up or collection day could still be used. To determine the mean number of fishing events per RCA per month, we used the mean number of fishing events per half day monitored per site. Some RCAs had more than one camera monitoring site. To account for this, we summed all the mean number of fishing events per half day monitored per site within a single RCA and divided this by the number of camera sites in that RCA. We then multiplied this number by 62 (the number of half days in both August and July when we monitored). We also compared our data to the aerial survey estimates from July and August 2011 used by Haggarty et al. (in review) to look for patterns in fishing effort in RCAs that may validate the use of compliance monitoring with trail cameras. Haggarty et al. (in review) digitized and georeferenced aerial survey data from DFO creel surveys (6-10 surveys per month) to measure RCA compliance. We standardized the mean number of fishing events per month per RCA for trail camera and aerial data in R using the package *arm* and function *rescale* (Gelman and Su 2015). We performed a Wilcoxon signed-rank test to compare the standardized means from each data set. We then ranked RCA fishing effort for each year numerically and categorically (i.e. low, medium, high).

#### **4.4 Results**

There was no significant difference in fishing effort between RCAs and unprotected sites (Figure 4.2). Fishing effort was significantly correlated ( $p < 0.001$ ,  $R^2 = 0.1$ ) with sites that have a dominant depth range of 50-200m. We only sampled one site with a dominant depth range greater than 200m, so fishing effort could be correlated with greater depth, not specifically the depth range of 50-200m. Because the cameras were shore-mounted and have a 1km field of view, this correlation indicates that fishing effort is higher in areas of high relief. No other environmental predictors were consistently associated with fishing pressure.



**Figure 4.2. Mean fishing effort at camera monitoring locations inside and outside RCAs. Rankings based on mean number of fishing events per half day monitored (No Effort = 0, Low effort =  $>0$  and  $\leq 0.27$ , Moderate effort =  $>0.27$  and  $\leq 0.42$ , High effort =  $>0.42$  and  $\leq 0.92$ ).**

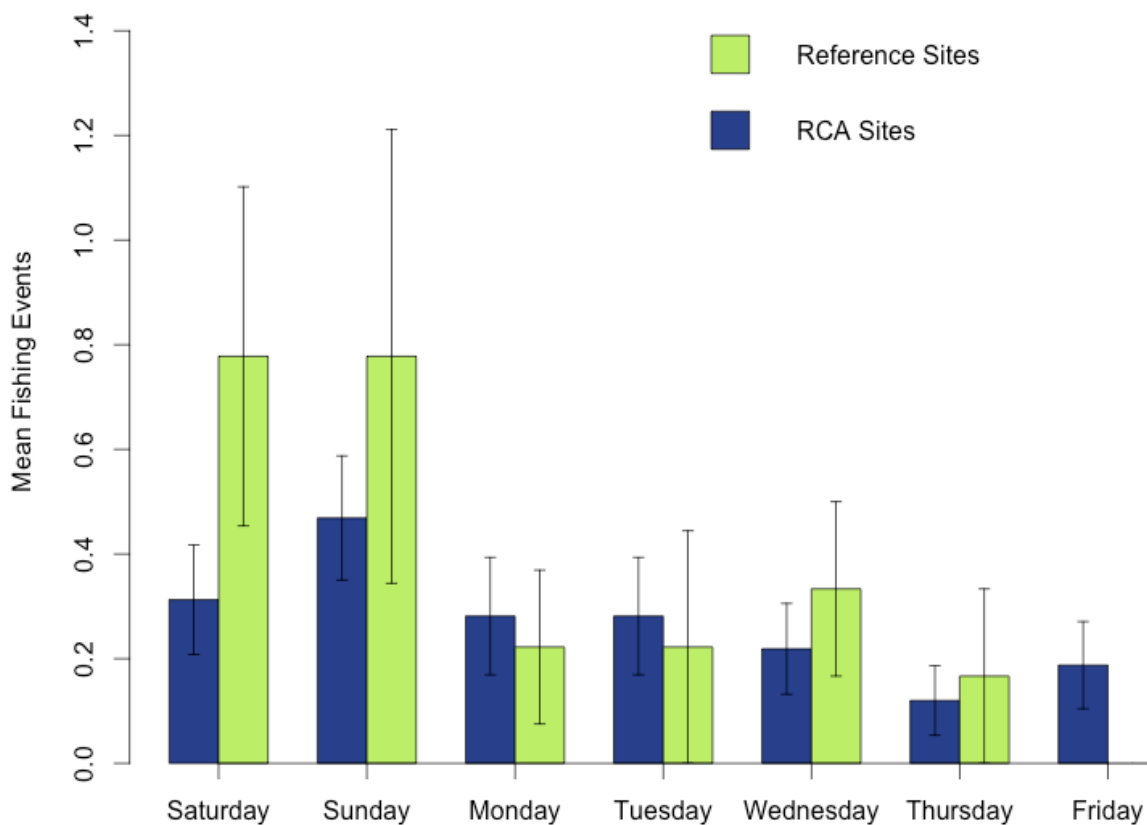
We found no terrestrial park effect on fishing effort despite an almost even distribution of park and non-park sites (18 park, 20 non-park with reference sites included, and 13 park, 16 non-park with reference sites removed). Our model of RCA size as a compliance predictor found that RCA size was significantly, negatively correlated with fishing effort ( $p < 0.001$ ,  $R^2 = 0.03$ ), with smaller RCAs experiencing higher levels of fishing effort. We note that our survey design did not proportionally monitor the total area within small and large RCAs.

We found that 79% of the RCAs monitored and 89% of reference sites showed either confirmed or probable fishing activity. The mean number of fishing events in all RCAs per half day monitored per site was 0.17, with a maximum of 11 fishing events over a weeklong period at one site. Reference sites had a mean of 0.2 fishing events per half day monitored per site and a maximum of 9 events over a weeklong period at one site. The standardized mean number of fishing events per month per RCA was not significantly different between 2011 and 2014. Four of the RCAs monitored had the same categorical ranking in both years and RCAs with low fishing effort remained the most consistent (Table 4.2).

**Table 4.2. Comparison of 2014 trail camera and 2011 aerial estimates of peak season (July-August) fishing activity by RCA. RCAs in bold have the same categorical ranking in both 2011 and 2014. The standardized effort was categorized according to the following scale: Low =  $\leq -0.2$ , Medium =  $> -0.2$  and  $< 0$ , High =  $\geq 0$ .**

RCA Name	Trail Camera 2014				Aerial Survey 2011			
	Mean effort (per month)	Standardized Mean	Rank	Category	Standardized Mean	Rank	Category	
Bedwell H.	0	-0.44	1	LOW	-0.05	4	MEDIUM	
<b>Discovery</b>	<b>0</b>	<b>-0.44</b>	<b>1</b>	<b>LOW</b>	<b>-0.32</b>	<b>1</b>	<b>LOW</b>	
<b>Trial I.</b>	<b>0</b>	<b>-0.44</b>	<b>1</b>	<b>LOW</b>	<b>-0.32</b>	<b>1</b>	<b>LOW</b>	
<b>Navy Ch.</b>	<b>3.88</b>	<b>-0.28</b>	<b>2</b>	<b>LOW</b>	<b>-0.32</b>	<b>1</b>	<b>LOW</b>	
Galiano N.	4.43	-0.26	3	LOW	1.45	8	HIGH	
Sooke	5.17	-0.23	4	LOW	-0.07	3	MEDIUM	
Saturna I.	5.91	-0.2	5	MEDIUM	-0.32	1	LOW	
Trincomali	6.36	-0.18	6	MEDIUM	0.04	5	HIGH	
Saltspring	6.64	-0.17	7	MEDIUM	0.14	6	HIGH	
Russel I.	13.29	0.11	8	HIGH	-0.32	1	LOW	
Burgoyne	14.31	0.15	9	HIGH	-0.12	2	MEDIUM	
<b>Brentwood</b>	<b>16.91</b>	<b>0.26</b>	<b>10</b>	<b>HIGH</b>	<b>0.68</b>	<b>7</b>	<b>HIGH</b>	
Finlayson	31	0.84	11	HIGH	-0.32	1	LOW	
Mayne N.	41.33	1.26	12	HIGH	-0.12	2	MEDIUM	

RCAs and reference sites both experience the highest levels of fishing on weekends, with relatively consistent low levels of fishing throughout the rest of the week (Figure 4.3). Percent fishing effort by day varied slightly between RCA and reference sites, and fishing effort throughout the day (e.g. morning vs. evening) was nearly uniform across all site types.



**Figure 4.3. Mean number of fishing events per day with standard error for RCA and reference site**

## 4.5 Discussion

### 4.5.1 Opportunities and challenges of shore-based camera monitoring

Shore-based camera monitoring was an accurate, efficient and cost-effective way of monitoring near-shore coastal marine conservation areas. Our camera monitoring gave comparable results to Haggarty et al's (in review) analysis of compliance in RCAs from aerial data. Camera monitoring might be more accurate in assessing differences in typical fishing pressure between areas, because trail cameras operate from dawn to dusk, whereas fly-over data are a single temporal snapshot. Further, cameras can also be deployed and maintained year-round enabling continuous data capture from minutes to seasons. Modest cost and ease of use makes cameras a potential tool that local

communities or non-government organizations can effectively employ (Greenburg and Godin 2015). Camera monitoring is significantly less expensive and more time efficient than most other direct observation monitoring techniques, including shore-based observers (Ames and Schindler 2009, Bergseth et al. 2013). Indeed, others have found that a related method, video monitoring, was more accurate than onshore observer monitoring and cut monitoring costs by nearly 2/3, and analysis times by 75% (Ames and Schindler 2009). Camera monitoring has the added benefit of greatly superior battery life compared to video monitoring (Watson et al. 2013). Camera monitoring is thus an appealing option for small NGOs with limited funding interested in monitoring near-shore marine conservation areas.

We found similar mean fishing effort in four of our monitored RCAs compared to aerial fly over data for the same months (Haggarty et al. in review). The differences in some RCA effort rankings between years could be due to: yearly variability; random stochasticity; changes in non-compliance rates at certain sites since 2011; or detection differences across methods. All compliance monitoring techniques come with challenges; however, camera monitoring offers the added benefit of capturing shore-based non-compliance that would typically be missed by aerial and boat-based survey methods (Watson et al. 2013, Greenburg and Godin 2015). For example, we recorded three incidents of shore-based non-compliance during our study where individuals were seen shore-casting (a popular angling method for salmon and rockfish).

A limitation of camera monitoring is the relatively small field of view of each camera and the need to mount cameras on solid ground. Camera monitoring is therefore most appropriate for near-shore, coastal marine conservation areas. Finding locations to place trail cameras can be a challenge, especially for monitoring prime fishing locations and minimizing the risk of camera theft or damage. Cooperation of local park networks is helpful, and developing strong relationships with local area residents can facilitate access to well-situated private land, which often provides more camera security than public areas. Concerns about surveillance of fisher activities can be a sensitive topic, with many people uncomfortable with photographic monitoring (Watson et al. 2013). However, the growing popularity of surveillance technology (e.g., remote controlled drones) may make people more comfortable with such monitoring methods (Watson et al.

2013). Clear signs explaining the purpose of trail cameras and, when applicable, the ensured confidentiality of the collected data, along with contact information for lead researchers, may also alleviate concerns associated with camera monitoring.

#### **4.5.2 Compliance with Rockfish Conservation Areas in BC**

Our monitoring revealed that fishing effort inside and outside RCAs is not significantly different, indicating that either recreational fisher knowledge of RCA rules and boundaries is low, or intentional poaching within RCAs is high. High levels of non-compliance in marine conservation areas are a serious problem, negating the ecological benefits of conservation (Edgar et al. 2014). Over three quarters of monitored RCAs experienced illegal fishing. Similarly, Haggarty et al (in review) found that over 80% of RCAs showed fishing effort in 2007 and 2011 and, in comparison to effort from 2003 (before the RCAs were established), recreational fishing did not decline as a result of implementing the RCAs. A lack of compliance is one factor affecting the performance of RCAs in the Salish Sea with recent survey data demonstrating RCA knowledge among local fishers was low (See Chapter 3). One quarter of surveyed recreational fishers had never heard of RCAs, and 60% were not confident of RCA locations. The accidental non-compliance rate – people who had fished in an RCA without knowledge of its protected status – was 16%, and the intentional non-compliance rate was seven percent (See Chapter 3).

Fisher preferences inside and outside RCAs for rapidly sloping coastal fishing sites, often associated with rockfish populations, may suggest targeted rockfish fishing. The R-squared for this association was low ( $R^2=0.1$ ). Other evidence suggests unintentional non-compliance. Accidental non-compliance by salmon and halibut fishers - who also prefer deep water - is thought to be high (See Chapter 3), and areas that had higher rockfish catches did not have higher non-compliance rates (Haggarty et al. in review). Thus, much fishing effort within RCAs is likely accidental. However, fisher preference for deeper RCAs may increase the rate of fatal barotrauma - which worsens with greater depth (Parker et al. 2006) - in rockfish accidentally caught by fishers in these areas. Fisher-driven rockfish mortality in RCAs is likely to undermine the ability of these areas to rebuild rockfish stocks, especially in the heavily fished waters of the Salish Sea

(Haggarty et al. in review). Given that recreational compliance in RCAs is low and is likely linked to low knowledge (See Chapter 3), an education and advertising campaign to raise awareness of RCAs is urgently needed, coupled with fisher engagement and increased monitoring to target intentionally non-compliant fishers (Alder 1996). It is essential that education be implemented in tandem with increased monitoring to avoid drawing intentional poaching towards the RCAs. Increased awareness of RCAs without increased enforcement may create poaching hotspots if fishers know the risk of penalty is low. These actions should be initiated by DFO, the regulatory agency, but NGOs can also play an important role in education and outreach, and initiating fisher-to-fisher, self-monitoring campaigns in the absence of sufficient DFO enforcement (See Chapter 3).

#### **4.5.3 Opportunities for future shore-based camera monitoring studies**

Shore-based camera monitoring could be useful for a variety of future compliance monitoring studies. First, for projects aimed specifically at quantifying compliance within conservation areas, we suggest a similar research design to ours with a focus on maximum coverage of conservation sites. Image Analyzer software developed for trail camera research should be used to streamline image analysis and minimize coding errors (Greenburg and Godin 2015). Second, camera monitoring could be used to study factors influencing compliance (e.g. environmental, geographic, social predictors) and to predict probable illegal fishing locations. Such studies should select even numbers of protected and unprotected sites, and control for habitat (e.g. depth, rugosity) and geographic variability (e.g. proximity to cities) in site selection. Monitoring periods should also be standardized as much as possible. A promising analysis would be to adapt occupancy modeling techniques, typically used for terrestrial mammals, to assess and predict fisher behaviour in coastal areas. Occupancy modeling for mammals uses knowledge of species habits and habitat preferences and deals with non-detection (Shannon et al. 2014). Fishers targeting different species (e.g. salmon, halibut, rockfish) also target different habitats and use different fishing methods and, as such, occupancy modeling designs could be useful for creating focused fisher behaviour studies. Third, camera monitoring could be used to quantify the impact of education campaigns by measuring non-

compliance in areas before and after an outreach initiative. A pilot study of this application is currently being tested by the Galiano Conservancy Association.

#### **4.6 Conclusions**

BC's RCAs experience low levels of compliance from recreational fisher populations. Fisher targeting of deep, high relief sites, either intentionally or accidentally, is likely negating the ability of RCAs to rebuild rockfish stocks due to high incidental rockfish mortality. An education and outreach campaign, paired with increased monitoring by DFO and engaged fishers is suggested to stem non-compliance in these areas.

Trail camera monitoring is an efficient, accurate, and simple new technique for measuring compliance in coastal marine conservation areas. This technique could easily be adapted and used for a variety of coastal monitoring projects and is a promising development for small NGOs attempting to effectively monitor and patrol marine conservation areas.

## Chapter 5: Discussion and Conclusion

### 5.1 Discussion

This study used a mixed methods approach (literature review, quantitative and qualitative survey data, and novel trail camera monitoring) to meet two thesis goals: 1) contribute knowledge to non-compliance literature and new methods of assessing non-compliance in marine conservation areas; and 2) assess recreational non-compliance levels, compliance influencers, and knowledge and perceptions of Rockfish Conservation Areas (RCAs). I used three objectives to meet the dual aims of my thesis.

*Objective 1: Assess overall ecological and social RCA effectiveness to date, using existing RCA assessments and a framework for improving governance from the literature on common pool resources.*

I conducted a literature review of existing social and ecological RCA assessments to determine the current state of RCA knowledge, and highlight information and research gaps. Existing ecological assessments of RCAs are largely inconclusive, with some studies finding significantly higher populations of rockfish inside RCAs than outside (Cloutier 2010), and other studies finding no significant differences in rockfish densities (Haggarty 2014). These inconclusive findings could be due to the relatively recent implementation of RCAs as marine conservation areas (i.e., not enough time has passed for rockfish to start recovering), non-compliance, inconsistent sampling techniques, and/or concurrent change to rockfish fisheries management measures that could be confounding ecological assessments (i.e., perhaps rockfish are increasing both inside and outside RCAs).

Social assessments of RCAs (e.g., how they affect fishers) are sparse. Haggarty (2014) found that commercial fishers are largely supportive of RCAs and compliance is high. However, fishers commented on the lack of empirical evidence that RCAs are working, tensions between fishing sectors (i.e. commercial, recreational, aboriginal), and suggested that communication and trust between the sectors could be improved. My assessment of the relative presence of the design principles for effective management of

common pool resources highlighted several areas for improvement, some of which I review below in my management suggestions. This design principle analysis provided a comprehensive review of RCAs, and underscored the importance of researching recreational compliance rates, drivers, and perceptions. Although some design principles are less applicable at a federal scale (e.g. rights to organize, nested governance), other mechanisms, such as political dynamics and civil society interactions, are thought to fill some of these gaps at this larger scale (Epstein et al. 2013, Fleischman et al. 2013, Evans et al. 2014). My analysis contributes knowledge, beyond the field of compliance research, and into a wider literature on effective management of large common pool resource systems.

*Objective 2: Assess recreational fisher knowledge and perceptions of RCAs.*

I used a structured survey of recreational fishers (n=325) with a short qualitative section to address this objective. I found that over 25% of fishers had never heard of RCAs and almost 60% of fishers were not confident of RCA boundaries. Additionally, 44% of fishers had no knowledge of RCA regulations and less than 1% had a perfect knowledge of the rules. Across fisher experience levels (occasional to expert), fishers were almost uniformly unknowledgeable of RCA boundaries and regulations. Given that others have found that knowledge of conservation initiatives is essential to effective marine conservation areas (Read et al. 2011), my results suggest that lack of awareness is a leading factor in recreational non-compliance.

Most (77%) fishers I surveyed believed that rockfish conservation is necessary, whereas four percent saw no need for conservation. Previous research has linked this kind of support of conservation to high compliance and effective marine conservation areas when education and awareness is also present (Alder 1996, Pollnac et al. 2010, Read et al. 2011, Leleu et al. 2012, Smallwood and Beckley 2012, Arias and Sutton 2013, Pita 2013). This suggests that an education and outreach campaign targeting recreational fishers could capitalize on pre-existing positive perceptions of rockfish conservation in BC. If recreational fisher awareness of RCAs can be improved, it is likely that compliance rates will also increase. However, a study by Alder (1996) found that there is always a small portion of a population that will remain non-compliant even with

increased knowledge. Knowing this, it is important to improve current enforcement regimes in RCAs. The recreational fishers I spoke with suggested that increased monitoring and penalties in the form of gear confiscations and monetary fines are the best way to target intentionally non-compliant fishers. I recommend addressing recreational non-compliance with a dual strategy of education to target low knowledge, and enhanced enforcement to target intentionally non-compliant populations.

*Objective 3: Quantify compliance rates, and social and ecological compliance drivers, in RCAs.*

I used two methods to quantify non-compliance in RCAs. I conducted surveys (n=325) with recreational fishers at marinas and boat launches to assess intentional and accidental non-compliance rates. I also used shore-mounted trail cameras to monitor fishing effort in 31 RCA sites and 10 reference sites throughout the peak recreational fishing season. I found an intentional non-compliance rate of seven percent and an accidental non-compliance rate of 16%, for an overall non-compliance rate of 23%. The intentional non-compliance rates in RCAs are similar to those in the Great Barrier Reef Marine Park (GBRMP), where there was a recreational non-compliance rate of eight percent in no-take zones (Arias and Sutton 2013). The camera monitoring indicated that 79% of monitored RCAs showed confirmed or probable fishing activity, with no significant difference between fishing effort inside and outside RCAs. These results support my findings of low RCA knowledge. It is likely that increased public awareness of RCAs could lower the current rate of accidental non-compliance. For example, the Great Barrier Reef Marine Park (GBRMP) has been extremely well publicized over four decades, which has likely reduced or eliminated accidental non-compliance in no-take zones within the park (Alder 1996). A wide-reaching and effective public awareness campaign for RCAs could reduce or eliminate the 16% non-compliance rate currently attributed to low knowledge of RCAs.

I also investigated social and ecological compliance drivers. Beyond the obvious link that fishers with no previous knowledge of RCAs were more likely to accidentally fish in RCAs, no hypothesized social compliance drivers (e.g. number of years fishing,

place of residence) were significantly associated with increased compliance. A study of social compliance drivers in Scottish commercial fishers found that greater years fishing was associated with lower compliance, likely due to more positive perceptions of conservation amongst younger generations (Pita et al. 2012). However, in the case of RCAs, difficulties pinpointing social compliance predictors are likely due to the uniformly low knowledge of RCAs across age and experience levels. Ecologically, sites with greater depth were associated with higher fishing effort, suggesting that fishers may target rapidly sloping coastal environments that are typically associated with greater fish species abundance (Cloutier 2010). No other studies have attempted to assess biophysical compliance drivers in RCAs. However, research by Haggarty et al. (in review) found that larger RCAs experienced more fishing effort than small RCAs. I found the opposite trend, with higher fishing effort in small RCAs, which mirrors the modeling results of Kritzer (2004). Differences between my results and Haggarty et al. (in review) could be due to regional and annual variability and the smaller study area covered by my research.

### **5.1.1 Contributions of research**

My research has made several valuable contributions on both a regional and international scale by addressing the two main goals of the thesis: contribute knowledge and methods to non-compliance research and literature; and assess RCA recreational non-compliance and its drivers. On a broad scale, this research fulfills the first goal by contributing valuable knowledge on recreational fisher non-compliance, compliance influencers, and new methods to the field of compliance research. Research on recreational fisher non-compliance is rare despite the large impact this sector can have on coastal areas (Post et al. 2002, Cooke and Cowx 2004). My study emphasized the need for high stakeholder knowledge of rules and regulations when creating and managing marine conservation areas (Read et al. 2011), especially amongst recreational fisher populations who are more isolated from central information than commercial fishers (Post et al. 2002). My results on low compliance levels emphasize the need for more research on often overlooked recreational fishing populations.

My research also contributes a new and effective method of assessing compliance through shore-based trail camera monitoring. Video monitoring has already proven to be more accurate and time/cost effective than shore-based observer programs (Ames and Schindler 2009), and photo monitoring further improves upon this technique with longer battery life and lower data storage demands. Shore-based trail camera monitoring is an important addition to compliance monitoring methods and will allow organizations with minimal budgets to effectively monitor marine conservation areas.

In meeting my second goal, this research offers valuable recommendations for managing BC's RCAs. I quantified levels of recreational non-compliance and identified low knowledge as one of the main contributors. Knowing this, managers and NGOs will be able to focus their efforts where they are most needed to stem non-compliance. Research has shown that even low levels of intensive fishing in marine conservation areas can seriously impact conservation area effectiveness and damage fish populations (Little et al. 2005). The biological characteristics of rockfish make them particularly vulnerable to intensive fishing pressure and extirpation (Love et al. 2002, Parker et al. 2006, Haggarty 2014). My trail camera data highlight fishing hotspots where rockfish may be threatened by non-compliance, information that will be useful for managers designing monitoring and outreach plans and for future researchers assessing the ecological or social impacts of non-compliance in RCAs.

### **5.1.2 Management Recommendations**

The Rockfish Conservation Areas are an excellent and rare example of a federal agency taking swift action to address a conservation concern. However, the current management of RCAs should be reassessed and revised to maximize their effectiveness. My research findings lead to several suggestions for management improvements. First, I suggest implementing an RCA decadal review process, led by Fisheries and Ocean Canada (DFO) with input from stakeholders, fishers from all sectors, scientists, and NGOs. Such a review would allow managers to assess ecological and social weaknesses in managing RCAs, and make amendments. Key issues to address during this review process include: developing an effective and consistent ecological monitoring program for rockfish within RCAs; reevaluating RCA locations and fishing restrictions to maximize rockfish

protection; increasing education and monitoring for the recreational fishing sector; and incorporating consensus-based decision making in the management plan where possible (e.g. decadal review decisions should be consensus-based, and the review committee or board should contain a legitimate representative from each stakeholder group).

Second, an immediate, large-scale ecological assessment of rockfish stocks inside RCAs would provide a measure of current RCA effectiveness, and offer important baseline data to assess RCAs in the future. An ecological assessment would also provide managers with the scientific data necessary to inform fishers and stakeholders on RCA progress towards reaching Rockfish Conservation Strategy targets. Such an ecological study should also assess the quality of rockfish habitat currently protected by RCAs, and the design of RCAs as a network of marine conservation areas that promote rockfish recruitment between sites (Gaines et al. 2010a, Gaines et al. 2010b, Haggarty 2014, Lotterhos et al. 2014). Permitted RCA fishing activities should also be reevaluated based on ecological data to ensure rockfish are adequately protected from harmful fishing gears. For example, prawn trapping causes high rockfish bycatch, yet it is still permitted commercially and recreationally in RCAs (Favaro et al. 2010).

Third, to directly address the issue of recreational fisher accidental non-compliance, I suggest a large-scale education and outreach campaign across coastal BC. This campaign should include information on RCA regulations and locations, as well as a fisher education component explaining why rockfish are threatened, what makes them vulnerable, and how individual fishers can minimize their impacts on rockfish stocks. Although such an education and outreach campaign should be the responsibility of DFO, in the absence of sufficient funding, this kind of project can also be taken on by local NGOs. For example, the Galiano Conservancy Association on Galiano Island is currently running an awareness campaign for RCAs with a Habitat Stewardship Project grant.

Finally, enhanced monitoring and enforcement of recreational fishers is also essential to lowering non-compliance in RCAs. Even with greater knowledge of marine conservation areas, typically a segment of the population will not adhere to rules without consequences (Alder 1996). The recreational fishers I spoke to during my research largely support intensive enforcement and penalties for non-compliers. DFO should

increase monitoring efforts in RCAs, especially RCAs that have been shown to have high levels of fishing effort. Additionally, given a lack of federal funding, NGOs and concerned fishers could take a community-based approach and initiate a fisher-to-fisher self-monitoring campaign.

### **5.1.3 Limitations and areas for future research**

My research has several limitations due to a necessity to limit the scope of a thesis project. Given that I used a case study approach in my thesis, a key limitation is that it is inappropriate to generalize some findings beyond BC's Salish Sea. Many areas of BC experience different levels of recreational fishing pressure, and fisher demographics likely vary significantly across different geographic areas.

The majority of my survey respondents were local (e.g. Gulf Island or Victoria area resident), although I did speak with some non-local fishers (e.g. international, greater BC, and Canada). Thus, my survey results are primarily representative of recreational fisher habits and perceptions in the Southern Gulf Islands and Victoria area. It is also likely that recreational fishers who intentionally fish in RCAs may avoid participating in a voluntary survey about RCAs. Thus, our estimate of 23% non-compliance may be an underestimate, especially from intentional non-compliers. Future research should look at knowledge and compliance throughout BC and assess RCA perceptions across all fishing sectors (i.e., commercial, recreational, aboriginal).

Limitations of my trail camera monitoring study include: 1) the small study area that makes it hard to generalize across BC, 2) the short monitoring period that makes it hard to generalize across seasons and years, and 3) the limited environmental and geographic consistency across monitoring sites. However, as a snapshot of non-compliance, this technique was very effective. Future research could rework the trail camera design to select sites across BC with comparable habitat inside and outside RCAs to more accurately determine if ecological variables impact fishing effort. Occupancy modeling techniques typically used on terrestrial mammals could also be adapted for marine research on fisher behaviour (Shannon et al. 2014).

This thesis focused specifically on the knowledge gap for recreational compliance in RCAs. I used existing ecological data to assess the current ecological success of

RCAs. However, more expansive ecological assessments of RCA effectiveness are also necessary avenues for future research. Studies should look at species abundance and diversity inside and outside RCAs, and use existing compliance data to survey RCAs across a gradient of fishing pressure. Current RCA placement should also be researched to determine if RCAs are located in areas that will maximize rockfish protection and repopulation.

## **5.2 Conclusion**

My research of recreational non-compliance in RCAs provides important conceptual and practical advances to the study of marine conservation. I used multiple methods, both quantitative and qualitative, to assess the social and ecological aspect of non-compliance. Recreational fishers are routinely overlooked in both compliance and marine conservation area research, despite the large impact this sector can have on marine species. Having quantified rates of non-compliance using multiple methods, my research highlights the importance of educating and engaging all fishing sectors equally to avoid creating serious knowledge gaps that can lead to social tensions and conservation challenges. My research also adds to a growing body of literature that recognizes the importance of bridging disciplines and methodologies to effectively address the complex and multifaceted problems facing marine conservation.

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**Appendix A: Ecological and Social Findings: Extended summary from Key RCA Literature (see Table 2.5 for brief summary)**

<b>Key RCA Literature</b>	<b>Ecological Summary</b>	<b>Social Summary</b>
Yamanaka and Logan	<p><b>RCA Site Selection:</b> Information on model used to create RCAs. Use of people to pick out key rockfish habitat</p>	<p><b>Collective Choice:</b> Important consultation process, very good, but no follow up included in RCS</p> <p><b>Commercial Fishers:</b> Initially, the implementation of the RCAs had a large impact on the commercial groundfish industry. In addition to restricting fishing areas, the integration of the entire groundfish fishery and the reduction of TAC rockfish quotas caused major changes in the way the commercial fishery operated (Yamanaka and Logan 2010).</p>
Haggarty	<p><b>Remote Operated Vehicle (ROV) Survey Results:</b> 31 RCAs were surveyed using ROV transects from 300m to 900m in length depending on RCA size. The Control-Impact model was used in this study, whereby transects within RCAs are compared to transects outside RCAs to calculate reserve response. The results of this study did not present a significant reserve response, however, the mean density of inshore rockfish within RCAs was slightly higher than in unprotected areas.</p> <p><b>SCUBA Survey Results:</b> Scuba surveys were conducted in 2010 and 2011 in Barkley Sound. The study used 30m by 3m transects and surveyed 30 sites in 6 locations. The study found a non-significant trend towards greater copper rockfish density both inside</p>	<p><b>Recreational Fishers:</b> Many recreational fishers do not know about RCAs due to a lack of information dissemination. RCA boundaries are clearly marked on fishing manuals but they are often not posted at marinas and are only available as an online resource. RCA guidelines also do not state what fishing activities are prohibited within RCAs, only mentioning what is still permitted. This could lead to the assumption that popular activities such as salmon and halibut fishing are still permitted. There is also tension between recreational fishers and aboriginal fishers who are permitted to fish within RCAs as a traditional harvesting right. Some recreational fishers feel that this could impact the ability of RCAs to rebuild rockfish stocks.</p> <p><b>Commercial Fishers:</b> This user</p>

	<p>and outside the RCA in the Broken Islands Group as compared to other locations within Barkley Sound.</p>	<p>group is generally supportive of the RCAs as a conservation tool, however, they do not appear to support the expansion of RCAs. They also largely understand that RCAs offer the chance for “spill-over” benefits which could improve future fishing activities. Many commercial fishers did express concern over recreational fisher behaviour and a perceived lack of compliance to RCA regulations. They believe this could impact RCAs ability to rebuild rockfish stocks.</p> <p>Overall, a lack of trust, understanding and knowledge among user groups could be impacting the perceptions of RCAs and their real and perceived effectiveness.</p> <p><b>Aboriginal Fishers:</b> Supportive of RCAs as an ecological insurance policy. Feel they were not consulted, or not adequately consulted during RCA creation. Some feel that fishing pressure has decreased in RCAs, some feel that recreational fishing remains unchanged. Some fishers feel a pressure not to fish in RCAs despite their constitutional right. They desire better information on RCA effectiveness and education for other sectors on First Nations right to harvest.</p>
<p>Challenger and Marliave</p>	<p><b>Scuba Survey Results:</b> In 2006 the Vancouver Aquarium surveyed 3 sites in Howe Sound. The surveys did not detect a reserve effect, although this was not expected as the RCAs were newly established. These surveys were intended to</p>	<p><b>Collective Choice:</b> Ardron and Wallace (2005) had shown that final RCA selections for the initial designation series in 2004 reflected the public process, in addition to scientific modeling, and therefore were not as equally representative of</p>

	<p>serve as baseline data for future assessments of RCA effectiveness.</p> <p><b>Side-Scan Sonar Results:</b> This study also determined that rockfish are strongly associated with piled boulder habitats that cannot easily be detected by the type of bathymetry data that was originally used to select RCA sites. This study concluded that these optimal rockfish sites can be detected using side-scan sonar.</p>	<p>optimal rockfish habitat and abundance as the original proposed RCAs based on the model only.</p>
Cloutier	<p><b>Scuba Survey Results:</b> This study was the first to research the effectiveness of RCAs in replenishing rockfish stocks. 15 sites were surveyed in Howe Sound, the Southern Gulf Islands, and the Central Strait of Georgia combined. The study found that RCAs had an average of 1.6 times more rockfish than unprotected sites. This study also accounted for differences in habitat. There was no correlation between rockfish density and age of RCAs. There was a significant difference between regional rockfish density, with Howe Sound showing the lowest levels of rockfish density.</p>	<b>Not Applicable</b>
Chalifour	<p><b>Scuba Survey Results:</b> Two RCAs around Galiano Island were surveyed using the Control-Impact method and 30m by 1m transects. The study found that rockfish density was much higher outside the RCAs, however, habitat variability was not considered in the research design which could impact results. The study also showed that some of the Galiano Island RCAs are located in unsuitable rockfish habitat,</p>	<p><b>Recreational Fishers:</b> In addition to misunderstanding RCA regulations, recreational fishers are often unaware of where RCAs are located due to a lack of information dissemination. This lack of knowledge and understanding has led to confusion and at times ill-will towards the RCAs as fishers are reprimanded by DFO officers or community members for fishing in areas they believe to be open access.</p>

	especially when compared to some unprotected survey sites with optimal rockfish habitat.	
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## Appendix B: Illustrative examples of Design Principle Presence/Absence Rating for RCAs (Design Principles 1a, 1b, and 2a)

Design Principles were ranked on a four point scale: **Present** – All aspects of the design principle’s definition have been met; **Moderately Present** – The majority of the design principle’s definition has been met - there is room for slight improvement; **Lacking** – The majority of the design principles’s definition has not been met – small hints of the principle are reflected in the management system; **Absent** – No aspects of the design principle’s definition have been met.

<b>Design Principles Definition</b>	<b>Design Principle Elements</b>	<b>Recreational Fishery: Elements present and final score</b>	<b>Commercial Fishery: Elements present and final score</b>
<b>1a. Clear User Boundaries:</b> Users must clearly understand who may utilize the resource and why (i.e. Who can fish within RCAs)	1. Regulations are clearly defined. 2. Users know what the regulations are. 3. Users understand why regulations exist.	<b>Elements Present:</b> <i>Only one element of this design principle is present in the recreational sector.</i>  1. Regulations are clearly defined.  <b>Score:</b> Lacking	<b>Elements Present:</b> <i>All elements of this design principle are present in the commercial sector.</i>  1. Regulations are clearly defined. 2. Users know what the regulations are. 3. Users understand why regulations exist.  <b>Score:</b> Present
<b>1b. Clear Resource Boundaries:</b> The physical boundaries should be easily visible (e.g. marker buoys,	1. Physical boundaries are clearly defined in regulations. 2. Physical boundaries are easily accessible in regulations.	<b>Elements Present:</b> <i>Only one element of this design principle is present in the recreational sector.</i>  1. Physical	<b>Elements Present:</b> <i>Only two elements of this design principle are present in the commercial sector.</i>  1. Physical

<p>fences) or well defined (e.g. clear signs and maps in prominent locations).</p>	<p>3. Physical boundaries are clearly defined on site (e.g. signs or bouys)</p>	<p>boundaries are clearly defined in regulations.  <b>Score:</b> Lacking</p>	<p>boundaries are clearly defined in regulations. 2. Physical boundaries are easily accessible in regulations.  <b>Score:</b> Moderately Present</p>
<p><b>2a. Appropriate Resource Regulations:</b> Regulations must match local resource conditions. The rules regarding when, how, and where resources can be used or taken must be based on the limitations of the resource itself. (e.g. RCAs must be designed to effectively protect rockfish based on habitat and biological characteristics)</p>	<p>1. Fishing restrictions adequately protect the resource (rockfish). 2. RCA boundaries protect high quality rockfish habitat. 3. RCAs are positioned to allow for maximum larval recruitment between areas.</p>	<p><b>Elements Present:</b> <i>All three elements of this design principle were present for both the Recreational and Commercial sector. However, they all needed improvement on some level.</i></p> <p>1. Fishing restrictions adequately protect the resource (rockfish). <i>(Area for improvement: Reconsider the use of prawn traps in RCAs)</i> 2. RCA boundaries protect high quality rockfish habitat. <i>(Area for improvement: Possible problems with the model used to predict rockfish habitat.)</i> 3. RCAs are positioned to allow for maximum larval recruitment between areas. <i>(Area for improvement: Further research is necessary to determine if these zones allow max. larval recruitment)</i></p> <p><b>Score:</b> Moderately Present</p>	



7. If you accidentally caught rockfish in the past 12 months, what percent of the time did you release it? *(If you have not accidentally caught rockfish in the past 12 months please circle "Does not apply".)*

(% of time released) \_\_\_\_\_ Does Not Apply

8. If you released accidentally captured rockfish in the past 12 months, what percent of the time did you descend them back to depth? *(If you have not accidentally caught rockfish in the past 12 months, please circle "Does not apply".)*

(% of time descended) \_\_\_\_\_ Does Not Apply

## Section 2: Rockfish conservation.

*These questions ask about your understanding of rockfish conservation measures.*

9. According to Canadian fisheries regulations, how many rockfish do you think you are permitted to catch per day in the Salish Sea *(Strait of Georgia, Puget Sound and Strait of Juan de Fuca)*?

(# of rockfish per day) \_\_\_\_\_

10. Have you ever heard of Rockfish Conservation Areas in British Columbia?

Yes

No

11. What kind of recreational fishing activity do you think is **permitted** in Rockfish Conservation Areas? *(Circle all that apply)*

- Halibut by rod and line
- Rockfish by rod and line
- Lingcod by rod and line
- Salmon (jigging, trolling, and mooching)
- Prawn by trap
- Crab by trap or hand picking
- Spearfishing
- Smelt by gillnet
- Netting (throw, and haul)

12. How confident are you about the location of Rockfish Conservation Areas in the places you like to fish? *(Circle one)*

- I'm confident I know where the boundaries are.
- I think I know where the boundaries are.
- I have no idea where the boundaries are.

### **Section 3: Sensitive Questions (Randomized Response)**

*Please ask your interviewer for instructions before completing the following questions.*

13. In the last 12 months, have you knowingly fished in a Rockfish Conservation Area?

Yes                      No

14. Do you personally know anyone who has knowingly fished in a Rockfish Conservation Area in the last 12 months?

Yes                      No

*Please ask the interviewer for a map and further information before answering the following question.*

15. Have you accidentally fished in a Rockfish Conservation Area in the last 12 months?

Yes                      No

### **Section 4: Demographic Questions**

16. Gender

Female              Male              Other

17. How old are you?

Under 20      20-35      36-50      51-65      Over 65

18. Do you identify as First Nations (Aboriginal)?

Yes                  No

19. Where do you currently live?

City/Town \_\_\_\_\_

Province/State/Region \_\_\_\_\_

Country \_\_\_\_\_

### **Section 5: Open Questions**

*Responses will be recorded by the interviewer.*

20. Why do you think some recreational fishers fish in Rockfish Conservation Areas?
21. What do you think is the best way to stop recreational fishers from intentionally fishing in Rockfish Conservation Areas?
22. What do you think is the best way to stop recreational fishers from accidentally fishing in Rockfish Conservation Areas?
23. Do you think the Rockfish Conservation Areas are an effective conservation tool?
24. What do you think are the best ways to improve rockfish conservation in general?

## Appendix D: Letter of Information for Implied Consent



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### Letter of Information for Implied Consent

#### Assessing Recreational Fisher Compliance in Rockfish Conservation Areas

You are invited to participate in a study on Rockfish Conservation Areas in BC conducted by Darienne Lancaster. Darienne is a Graduate student in the School of Environmental Studies at the University of Victoria and you may contact her if you have further questions at [dlancaster@live.ca](mailto:dlancaster@live.ca). As a Graduate student, Darienne is required to conduct research as part of a Masters of Environmental Studies degree. It is being conducted under the supervision of Dr. Natalie Ban. You may contact her supervisor at [nban@uvic.ca](mailto:nban@uvic.ca). This research is being funded by SSHRC.

<b>Purpose and Objectives</b>	The purpose of this research project is to assess levels of recreational fisher compliance within Rockfish Conservation Areas in the Salish Sea and to receive feedback from fishers on how rockfish conservation could be improved.
<b>Importance of this Research</b>	Research of this type is important because it will help marine managers create more useful conservation plans that more effectively protect marine creatures and the needs of local people.
<b>Participant Selection</b>	You are being asked to participate in this study because you are a recreational fisher.
<b>What is involved</b>	If you consent to voluntarily participate in this research, your participation will include filling out a 5 to 10 minute anonymous survey.
<b>Inconvenience and Risks</b>	Participation in this study should not cause you any inconvenience. <u>There is a possible risk of emotional or psychological discomfort while completing this survey. However, the survey has been designed to minimize this risk. Please speak to the research if you would like more information. There are no other known or anticipated risks to you by participating in this research.</u>
<b>Benefits</b>	Participating in this study could enhance your level of marine conservation knowledge.
<b>Voluntary Participation</b>	Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time during the survey without any consequences or any explanation. If you do withdraw from the study your data will not be used in the results. <u>Due to the anonymous nature of these surveys, once questionnaires are submitted it will be impossible to remove them from the data. If you wish to withdraw from the study you must do so before submitting a completed questionnaire.</u>
<b>Anonymity</b>	In order to completely protect your anonymity your name and signature will not be recorded on any surveys or consent forms. By completing the survey your consent to participate in the study is implied.
<b>Confidentiality</b>	By avoiding names and signatures your confidentiality and the confidentiality of the data will be protected.
<b>Dissemination of Results</b>	It is anticipated that the results of this study will be shared with others through a thesis paper, defense presentation, <u>public community and partner presentations</u> , academic and media presentations, and published scholarly articles.
<b>Storage of Data and Future Research</b>	Data from this study will be saved in a locked, secure location. This data may be used for future research. Data will remain entirely anonymous.
<b>Contacts</b>	Primary Researcher – Darienne Lancaster – <a href="mailto:dlancaster@live.ca">dlancaster@live.ca</a> Supervisor – Natalie Ban - <a href="mailto:nban@uvic.ca">nban@uvic.ca</a>

You may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or [ethics@uvic.ca](mailto:ethics@uvic.ca)).

By completing and submitting the questionnaire, **YOUR FREE AND INFORMED CONSENT IS IMPLIED** and indicates that you understand the above conditions of participation in this study and that you have had the opportunity to have your questions answered by the researchers.

*Please retain a copy of this letter for your reference.*