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Drivers of recreational fisher compliance in temperate marine conservation areas: A study of Rockfish Conservation Areas in British Columbia, Canada

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ABSTRACT

Overfishing 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 noncompliance was reported by seven percent of recreational fishers, and accidental noncompliance by 16%. The main reason for noncompliance 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 noncompliance 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 implement a public outreach and education campaign to address the high levels of noncompliance.

Abbreviations: RCAs, Rockfish Conservation Areas; DFO, Fisheries and Oceans Canada; RRT, Randomized Response Technique; GLM, Generalized Linear Model.

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1. Introduction

The last half-century has seen global declines in marine resources, with large-bodied and long-lived species experiencing the most noticeable decreases (Pauly et al., 1998, Molfese et al., 2014). Many countries have started using fisheries closures, harvest refugia, and marine protected areas (MPAs) (hereafter jointly referred to as marine conservation areas) 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, Arias, 2015). For example, a simulation of line fishing infringement in the Great Barrier Reef Marine Park showed that even a few fishers intensively fishing in an area 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 noncompliance could have a significant impact on the success of management areas, especially in popular, and typically overfished coastal areas. However, few studies have attempted to quantify recreational fisher's compliance and its drivers (Bergseth et al., 2013).

Several factors may influence fisher compliance (Pollnac et al., 2010; Bergseth et al., 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). For example, 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). Furthermore, 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 the south of France was found to be dependent on positive perceptions of marine conservation areas (Leleu et al., 2012). Additionally, an Australian study found that a thorough knowledge of marine conservation area existence, regulations, and the possible consequences of noncompliance was essential for high compliance (Read et al., 2011).

Compliance research has focused mainly on commercial and artisanal fishers in tropical MPAs (Gribble and Robertson, 1998; McClanahan et al., 2005; Cinner et al., 2005; Pollnac et al., 2010; Leleu et al., 2012; Bergseth et al., 2013). Very few studies target recreational fisher noncompliance and its drivers (Schill and Kline, 1995, Read et al., 2011, Smallwood and Beckley, 2012, Arias and Sutton, 2013), and recreational compliance studies in temperate environments are rare (Blank and Gavin, 2009; Read et al., 2015). Our 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 (BC), 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). Our 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.

1.1. Case study description: rockfish conservation areas in BC

In BC 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 et al., 2013). Once a fish has been captured, it rarely survives if released unless redescended to depth ((Hannah and Matteson, 2007), 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 (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,b).

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, 2012). 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

Table 1
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, 2014).

Commercial		Recreational	
Permitted fisheries	Prohibited fisheries	Permitted fisheries	Prohibited fisheries
• Hand picking and diving for invertebrates • Prawn and crab trapping • Smelt by gillnet • Scallop trawling • Salmon by seine or gillnet • Herring by seine, gillnet, and spawn-on-kelp • Sardine by gillnet, seine, and trap • Krill by mid-water trawl • Opal squid by seine • Groundfish by mid-water trawl	• Groundfish bottom trawl • Groundfish hook and line for halibut, inside rockfish, outside rockfish, lingcod, dogfish • Sablefish by trap • Salmon Trolling • Opal squid by hook and line or ring net • Shrimp by trawl	• Hand picking of invertebrates • Prawn and crab trapping • Smelt by gillnet	• Groundfish by hook and line • Salmon by hook and line (e.g. Trolling, Jigging, Mooching) • Spearfishing

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 many recreational and commercial fishing activities within their boundaries (Table 1), with recreational fishing limited to invertebrate trapping and hand picking, and smelt gillnetting (all other recreational fishing is restricted). 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. The commercial Groundfish fishery jointly manages all Groundfish stocks (e.g. halibut, rockfish, sablefish) and sets catch restrictions. Thus, these recent dramatic reductions on rockfish total allowable catch quotas ($\geq$50% reductions) mean rockfish stocks could be rebuilding both inside and outside RCAs. 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 even as bycatch, and on-board and dockside observer programs, in tandem with GPS tracking on commercial fishing vessels, means commercial fishing compliance is extensively monitored and believed to be nearly 100% (Haggarty, 2014). Although commercial fishers could be negatively impacting rockfish populations through habitat degradation or rockfish prey reduction, commercial noncompliance is a lesser concern in RCAs. However, very little 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.

2. Methods

We carried out structured interviews with recreational fishers in the southern Canadian Salish Sea (Southern Gulf Islands and Victoria area) (Appendix A). This region was selected for its high density of RCAs, popularity amongst 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) (Fig. 1). We used clustered convenience sampling to conduct structured 5-min 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-min voluntary survey on Rockfish Conservation Areas.

2.1. 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 knowledge of RCA existence before beginning the survey and if they felt confident of RCA boundary locations. We explained all permitted fishing activities to participants and then used charts of RCA locations as a visual aid when asking respondents if they had accidentally fished using prohibited techniques in an RCA in the past 2 years. We asked respondents to locate their typical fishing area(s) on the charts and then asked if they had ever accidentally fished using prohibited techniques in nearby RCAs. We reminded respondents that surveys were completely anonymous and that the researchers were exclusively associated with the University of Victoria.

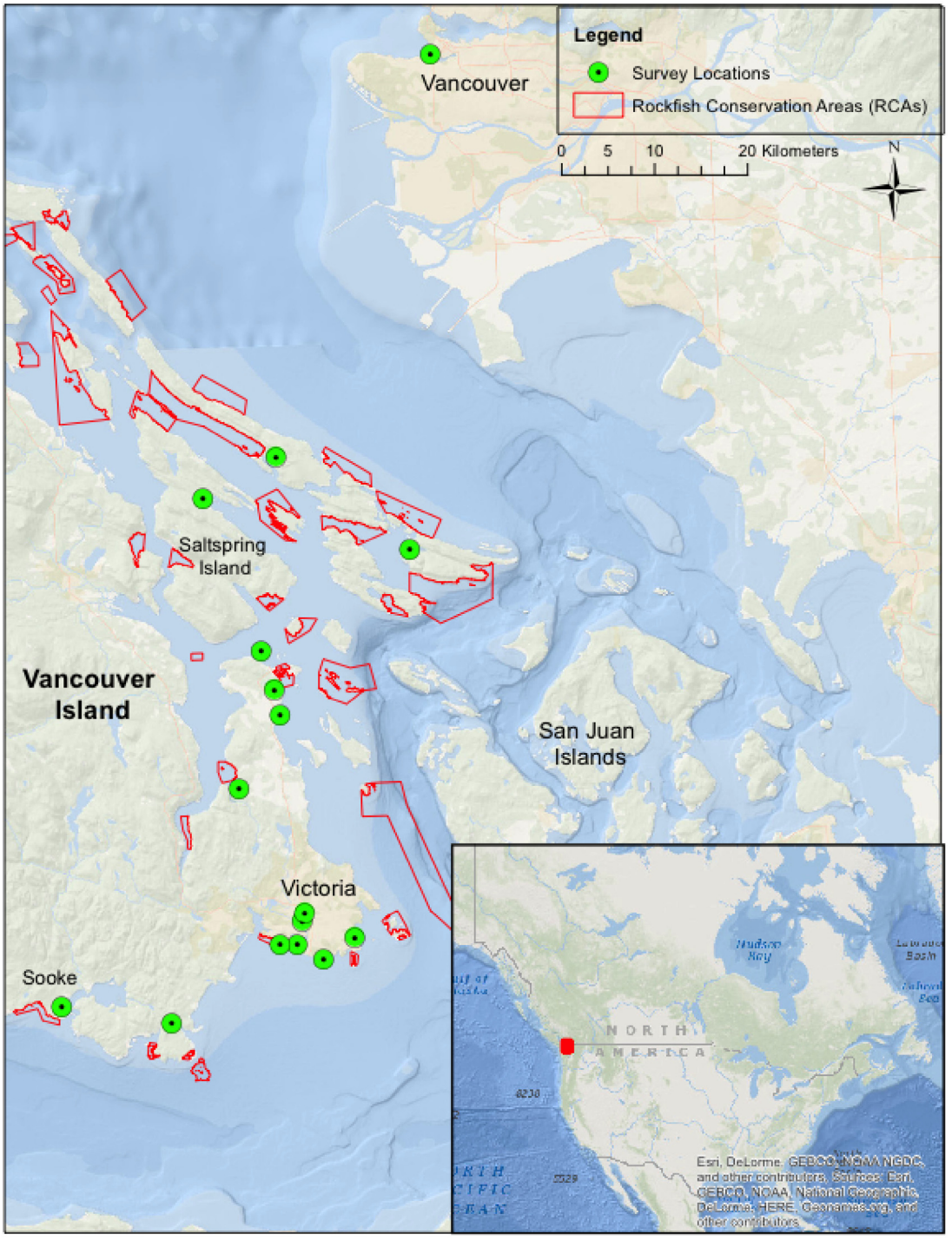

Fig. 1. Recreational fisher survey locations at marinas and boat launches. Red square on locator map marks study region. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

We used two techniques to assess levels of intentional noncompliance. 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, using prohibited techniques, in a Rockfish Conservation Area in the past two years?". This technique is considered non-sensitive since it does not ask respondents if they have personally illegally fished and it does not ask them to identify who they know that has illegally fished. However, by tallying the number of people who know someone who illegally fishes in RCAs, intentional noncompliance can be estimated indirectly. For example, given a large and varied sample, if

ten respondents personally know someone who has intentionally illegally fished in an RCA this method assumes that there are ten people who intentionally illegally fish in RCAs. However, since this technique does not ask respondents to specify the number of people they know illegally fish in RCAs, this method could underestimates levels of intentional noncompliance. 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, using prohibited techniques, in an RCA in the past 2 years. RRT is effective at obtaining more honest answers from respondents by assuring them response anonymity (i.e. the interviewer does not know if participants are telling the truth). 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 instructed to answer the question with "yes". If they rolled a 2 they were instructed to answered "no". If they rolled any other number from 3 to 20, they were instructed to answer the sensitive question honestly: "Have you ever intentionally fished, using prohibited techniques, in a Rockfish Conservation Area in the past 2 years?". The noncompliance rate can then be estimated statistically using the known, "assumed" probabilities for predetermined responses (Krumpal, 2012; Arias and Sutton, 2013). We call these "assumed" probabilities because they depend upon participants following the RRT instructions without error. For our study, the assumed probability of an honest answer was $P1 = 0.9$, the assumed probability of a predetermined "yes" answer was $P2 = 0.05$, and the assumed probability of a predetermined "no" answer was $P3 = 0.05$. The expected value θ of observing a "yes" answer can be calculated as $\theta = P2 + P1\pi$, where π is the – in this case unknown – proportion of survey respondents who agree with the sensitive question (i.e. respondents who answer the sensitive question with a yes). Since π is unknown, we can use the observed yes responses as an estimate of θ to calculate $\hat{\pi}$ (*estimated* proportion of respondents who answer the sensitive question honestly with yes):

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

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

$$\mathrm{Var}(\hat{\pi}) = \frac{\hat{\theta}(1-\hat{\theta})}{nP1^2}.$$

We tallied participant responses to three knowledge-based survey questions: (1) knowledge of RCA boundaries; (2) knowledge of RCA fishing restrictions; (3) knowledge of rockfish bag limits (see Appendix A for full questions). Responses to these questions were first converted to binomial variables. For example, only fishers who stated they were confident of RCA boundaries were given a knowledge point. Fishers who thought they knew RCA boundaries or were unsure of boundaries were not given a knowledge point. Fishers who answered all three questions 100% correctly received a score of 3. Fishers who answered 2 of 3 questions 100% correctly received a score of 2, etc. We combined participant responses to these questions to create a gradient of fisher RCA and rockfish regulation knowledge.

2.2. 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 illegal fishing in RCAs, and (5) personally knowing someone who had intentionally illegally 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, 1934). 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.

2.3. 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 (DFO, 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:

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

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.

2.4. 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. Results

3.1. 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 (Fig. 2) showed that 44% of fishers did not correctly answer any RCA regulation questions and less than one percent of fishers ($n = 2$) answered all three knowledge questions correctly.

Using maps of RCAs as a reference, 16% of fishers admitted to accidentally illegally fishing within an RCA in the last two years. Seven percent of fishers answered yes to the non-sensitive direct question, "Do you personally know anyone who has intentionally fished, using prohibited techniques, in a Rockfish Conservation Area in the past two years?". We combined the percent of accidental noncompliers and intentional noncompliers (estimated from the percent of respondents who know someone who has intentionally illegally fished in an RCA) for an overall, estimated (accidental and intentional) noncompliance rate of 23% within RCAs. We did not include the results of our RRT compliance question in this estimate.

Of 318 fishers who completed the RRT section, only eight answered the question "Have you ever intentionally fished, using prohibited techniques, in a Rockfish Conservation Area in the past two years" with a yes, including predetermined responses. Using the RRT probability equation to account for predetermined "yes" and "no" responses, the RRT question showed no intentional noncompliance ($\hat{\pi} = -0.028$) in RCAs. The variance was <0.001. This negative intentional noncompliance rate is the result of the probability calculation which assumes that if a 20 sided die is rolled 318 times, it will land on each number $\sim$16 times. We had only eight yes responses, which is lower than the necessary 16 yes responses required to arrive at a positive number. However, three of the eight yes responses we received were confirmed intentional fishing based on unprompted admission of intentional illegal fishing activity from survey participants.

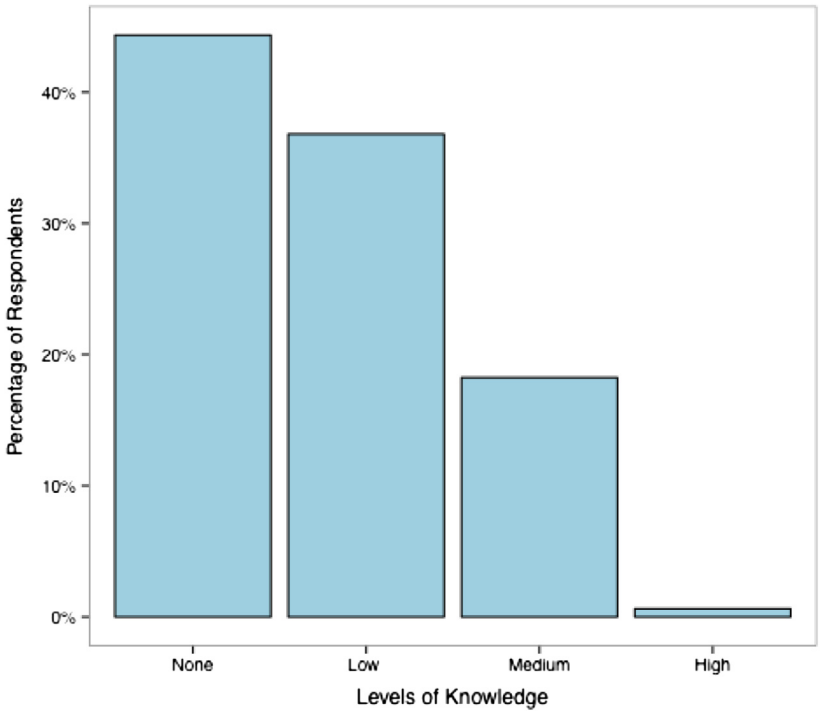

Fig. 2. Knowledge of RCA regulations based on fisher responses to three knowledge based questions.

Table 2
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 illegal 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 illegally fished in an RCA	No significant independent variables			

3.2. 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 2).

Knowledge of RCA existence and RCA boundaries was 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

Table 3
Summary of main differences between hierarchical clustering fisher groups.

Variable	Group 1 (novice fishers) $n = 20$	Group 2 (average fishers) $n = 246$	Group 3 (intensive fishers) $n = 52$
Years fishing	2.5	31	28
Days fishing (*past 2 years*)	5	25	154
Percent of time fishing rockfish (*past 2 years*)	0.2%	13%	12%
Number of accidentally caught rockfish (*past 2 years*)	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 (*past 2 years*)	5%	16%	21%
Composite knowledge variable (*zero knowledge to high knowledge*)	Zero = 60 Low = 35% Moderate = 5% High = 0	Zero = 44% Low = 39% Moderate = 17% High = 1%	Zero = 40% Low = 29% Moderate = 29% High = 2%

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).

More time spent fishing rockfish was significantly correlated with accidental illegal fishing in RCAs, as was gender, with women admitting to accidental illegal fishing in RCAs more frequently than men. Women comprised less than 10% of fishers surveyed and 33% of female fishers admitted to accidental illegal fishing in RCAs, compared to 15% of male fishers. No factors were significantly correlated with personally knowing someone who intentionally illegally 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 illegally 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 noncompliance); Group (2) Average fishers (Moderate fishing effort, knowledge, accidental rockfish bycatch, and accidental noncompliance); Group (3) Intensive fishers (Highest fishing effort, overall knowledge, accidental rockfish bycatch, and accidental noncompliance) (Table 3).

3.3. 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 (Fig. 3).

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 and Matteson, 2007, Jarvis and Lowe, 2007). 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, 2014). 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. Recreational fisher perceptions of RCAs and recommendations for RCA improvement

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 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. Here poaching is defined as intentional illegal fishing as opposed to accidental illegal fishing. 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 noncompliance in RCAs. Suggested reasonable fines ranged from $50 to $20,000 (mean = $1700). One respondent stated, "We need bigger fines and

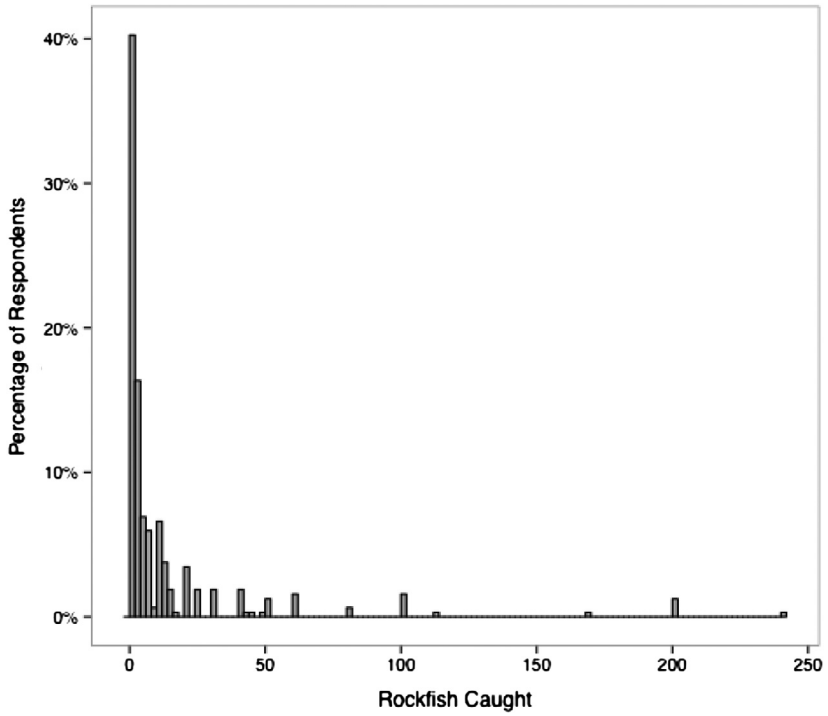

Fig. 3. Histogram of accidentally caught rockfish in the past 2 years.

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 noncompliance. One respondent stated, "We should encourage self-reporting, DFO just doesn't have the budget, we need community monitoring".

Fishers suggested accidental illegal 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.

4. Discussion

Noncompliance can compromise the ability of marine conservation areas to protect and rebuild target species, and thus areas with noncompliance – 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. With a combined intentional and accidental noncompliance 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 Robertson, 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 et al., 2013). Support for conservation actions are only useful when fishers know the rules and 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 noncompliance levels do not vary greatly between groups. Knowledge about RCAs was uniformly low, and thus potential drivers of noncompliance 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 RCA are lacking overall. A similar study in the Great Barrier Reef Marine Park (GBRMP) determined that the noncompliance 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

Table 4
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%.

Fisher responses	Response frequency (%)
Question 1: Do you think there is a need for rockfish conservation in British Columbia?	
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%
No idea/not sure	*10%*
Not sure—no data on rockfish	*1%*
Not sure—never heard of rockfish	*>1%*
Other	*13%*
Question 2: What do you think are the best ways to improve rockfish conservation in general?	
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%
Don't know/not sure	*7%*
Other	*22%*
Question 3: Why do you think some recreational fishers fish in Rockfish conservation areas?	
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%
Don't know/not sure	*10%*
Other	*2%*
Question 4: What do you think is the best way to stop recreational fishers from intentionally fishing in Rockfish conservation areas?	
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%
Don't know	*4%*
Other	*6%*
Question 5: What do you think is the best way to stop recreational fishers from accidentally fishing in Rockfish conservation areas?	
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%
Don't know	*4%*
Other	*7%*

(continued on next page)

Table 4 (*continued*)

Fisher responses	Response frequency (%)
Question 6: Do you think the Rockfish conservation Areas are currently an effective conservation tool?	
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%
Not sure	*26%*

percentage of the population that will not respond to education and awareness campaigns so enforcement is still important (Alder, 1996). However, 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 noncompliance. Additionally, education and outreach campaigns are generally less costly than enforcement and monitoring (Alder, 1996).

Reducing noncompliance 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 (DFO, 2012). 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, 2007). 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 permitted fishing activities.

While our study is one of the few to quantitatively assess recreational fisher compliance, 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., indigenous 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 noncompliance rate determined by the RRT question and the non-sensitive, direct noncompliance question, may suggest that survey respondents answered "no" to the RRT question even when the device instructed them to say "yes". This may indicate respondents were either not comfortable answering the RRT question honestly, or did not fully understand how the technique would protect their confidentiality. Arias and Sutton (2013) found comparable intentional noncompliance rates between both techniques. The difference in results across techniques in our study could be the result of random chance or the low degree of confidentiality offered by our RRT design. However, this result may also suggest that people who illegally fish in RCAs are unlikely to participate in a voluntary survey about RCAs. Further RCA research should also quantify illegal fishing effort to determine the overall impact of this high recreational noncompliance on rockfish stocks.

Our study suggests that effective education and outreach is an essential first step in creating marine conservation areas with high compliance. In the case of RCAs, outreach was brief and minimal and regulation information is hard to access or impractical for use on the water (e.g. no hardcopy manuals available) (Haggarty, 2014). We suggest that marine managers designing education materials carefully consider the complex social dynamics and psychological aspects of human behaviour to avoid repercussions from poorly designed outreach material (Arias, 2015). Marine management plans, including outreach initiatives, should integrate local representatives (e.g. sport fish advisors) and interdisciplinary experts (e.g. ecologists, sociologists, psychologists) in decision making processes (Arias, 2015).

5. 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 noncompliance 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 noncompliance rate in RCAs – primarily accidental illegal 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.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.gecco.2015.11.004.

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