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Using stakeholder engagement to inform endangered species management and improve conservation

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ABSTRACT

Successful endangered species conservation requires understanding, support, and participation from user groups and stakeholders in conjunction with biological information. A representative survey of the boat-based angling population in Puget Sound, WA, USA, was conducted to provide baseline information regarding angler knowledge about rockfish, fishing practices, perceptions of threats to rockfish, and preferences for recovery measures to inform the recovery plan for three rockfish species listed under the Endangered Species Act. Generalized linear models were used to evaluate the hypothesis that variation in stakeholders' perceived threats to rockfish and preferences for rockfish recovery measures is related to their fishing practices and knowledge of rockfish biology. Knowledge of rockfish longevity and past experience fishing for rockfish were important predictors of support for conservation measures and willingness to take personal action to recover rockfish. These findings highlight the important role education may play in garnering the necessary long-term support for rockfish recovery. Further, locations where anglers fished in Puget Sound were found to shape perceptions of threats to rockfish, suggesting that place-based management options should be considered where biologically appropriate. This study illustrates the complexity of species management in social-ecological systems and provides a framework for comprehensively engaging stakeholders and understanding their relationships with endangered and threatened species prior to the development of a recovery plan. Such engagement may not only better inform management and outreach decisions but also pave the way toward more collaborative and effective endangered species management and conservation.

1. Introduction

Successful endangered species conservation requires understanding, support, and participation from user groups and other stakeholders in conjunction with biological information [1–3]. This stakeholder engagement is fundamental for resource management that relies largely upon self-regulation and self-reporting by user groups, as is the case for many recreational fisheries [4,5]. Recreational fisheries are the dominant or sole users of coastal fish stocks in many developed, temperate regions around the world [6]. In the United States alone, over 11 million recreational saltwater anglers took approximately 72 million fishing trips in 2012, which generated approximately $58 billion in sales impacts to the economy and supported over 381,000 full- and part-time jobs [7]. Recently, there has been increased recognition by the National Marine Fisheries Service (NMFS) that successful management of this large and diverse fishery sector requires greater insight into anglers' attitudes, motivations, and behaviors [8]. In a nationwide survey conducted in 2013, nearly 85% of 9,226 anglers surveyed agreed that "ensuring that the opinions of all recreational fisheries stakeholders are considered in policy-making" is important [8]. Often, policy-makers incorporate participation from stakeholders during planning processes or through solicitation of public comments after draft management plans have been developed. This study presents a systematic way to engage recreational anglers whose actions may affect conservation efforts prior to the outset of planning. This approach lays the foundation for improved understanding of and continued engagement with stakeholders, essential elements of successful endangered species recovery [2].

There are a number of complex, often interrelated, social, cultural, psychological, and economic factors that could affect stakeholders' support for conservation or compliance with management actions. The degree of stakeholder support for conservation policies may be related to stakeholders' knowledge of conservation issues, knowledge

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of potential conservation actions, the extent to which individuals believe they can control events that affect them, stakeholder attitudes, commitment to a particular conservation action, and sense of responsibility [9]. Stakeholder support for a particular conservation strategy may vary based on people's perceptions of the legitimacy of and need for that action [9–11]. Furthermore, the economic, social, and/or cultural value of the focal species [1,12] and the types, sources, breadth, and depth of specific environmental information stakeholders have access to (i.e., their "information environments") may inform their perceptions of and adherence to management and conservation policies [13].

To inform conservation and recovery planning for rockfish (*Sebastes* spp.) in Puget Sound, Washington, USA, this study documented stakeholders' knowledge of rockfish biology and rockfish fishing regulations, perceptions about threats to rockfish, fishing practices, and preferences for recovery measures. In Puget Sound, rockfishes are species of conservation concern that have been historically harvested in both recreational and commercial fisheries. Over-harvest was identified as the main cause of the decline of rockfishes [14,15]. Rockfishes' long-lives and low intrinsic productivity [16] combined with some species' relatively large size and evolutionary distinctiveness all contribute to their vulnerability to fishing [17]. They exhibit sporadic successful recruitment [18], and older female rockfish have healthier young that exhibit a higher chance of survival than those of younger rockfish [19,20]. Rockfish in Puget Sound presently face a number of threats, ranging from degraded habitat and water quality to derelict fishing gear and fisheries bycatch [14,15]. To complicate matters further, rockfishes have swim bladders that keep them at neutral buoyancy, and as rockfish are brought up from deep water they often suffer from barotraumas that may result in injury or death [21,22].

Three rockfish species – yelloweye rockfish (*Sebastes ruberrimus*), canary rockfish (*Sebastes pinniger*), and bocaccio (*Sebastes paucispinis*) – were listed for protection under the Endangered Species Act (ESA) in 2010 in Puget Sound and the Georgia Basin [15] (hereafter referred to as Puget Sound). Thirteen species of rockfishes have been listed as Washington State Species of Concern [23]. In response the rockfish ESA listing, the Washington State Department of Fish and Wildlife (WDFW) released a Puget Sound Rockfish Conservation Plan in 2011, which includes a number of recovery measures [24]. The WDFW conservation plan includes the use of Rockfish Conservation Areas or Marine Protected Areas to protect rockfish from catch and bycatch [25,26], removal and prevention of derelict fishing gear which have been documented to catch rockfish and degrade their habitat [27], the use of artificial reefs to enhance degraded habitats [28], the investigation of hatchery production of rockfish in order to augment wild populations [29], and habitat restoration [30,24]. Despite the moratorium on commercial rockfish harvest in Puget Sound in 1999 [14], the closure of several other commercial fisheries with incidental rockfish catch, and a prohibition of recreational rockfish retention in 2010, rockfish remain vulnerable to incidental mortality in commercial and recreational fisheries [15,31,32]. The commercial rockfish closure in 1999 may also have resulted in decreased economic incentives to recover rockfish [12].

While there are a number of regional studies that examine rockfish biology and the history of the fishery e.g. [14,15,31], few have engaged recreational anglers in the recovery process and examined the underlying knowledge and perceptions that may ultimately affect support for recovery measures. Therefore, a primary objective of this study was to engender stakeholder engagement in the rockfish recovery process by seeking understanding into how anglers' knowledge and practices influence their views of rockfish conservation. Recreational anglers were surveyed to evaluate the hypothesis that variation in stakeholders' perceived threats to rockfish and preferences for rockfish recovery measures are related to their knowledge of rockfish biology and fishing practices. Furthermore, the expectation that stakeholders' perceptions of risk and threats to rockfish correspond to their preferences for rockfish recovery measures was evaluated.

2. Methods

2.1. Study area

Puget Sound makes up the southern arm of an inland sea located on the Pacific Coast of North America and is connected to the Pacific Ocean by the Strait of Juan de Fuca. Puget Sound is a fjord-like estuary covering 6039.3 km^2 (2331.8 square miles). It can be subdivided into biogeographic basins that encompass contiguous, ecologically unique, and spatially isolated freshwater, estuarine, and marine habitats [33,34]. These five interconnected basins include: (1) The San Juan/Strait of Juan de Fuca Basin, (2) Main Basin, (3) Whidbey Basin, (4) South Puget Sound, and (5) Hood Canal. Sills largely define boundaries between the biogeographic basins, except where the Whidbey Basin meets the Main Basin. The sills, in combination with bathymetry, freshwater input, and tidal exchange, influence environmental conditions such as movement and exchange of biota from one basin to the next, water temperatures and water quality, and water exchange [34–36]. In addition, environmental conditions of each basin are influenced by differing levels of human populations and development.

2.2. Respondent selection and survey methods

In-person surveys of recreational anglers ($N=443$) were conducted at public boat launches and marinas with the heaviest boat-based angler traffic throughout Puget Sound [37] between July–September 2011. This period overlapped with fishery openings for salmon and crab, during which the majority of incidental rockfish is caught due to high fishing effort for salmon [14]. This timeframe did not include the season for lingcod or halibut, when anglers may encounter rockfish incidentally due to their co-occurrence in benthic habitats [14].

Anglers were surveyed at 15 public boat launches and marinas in five regions included in the rockfish ESA-listing area (i.e., all Marine Areas (MAs) east of Port Angeles, 6-13): San Juan/North Puget Sound (MAs 6 and 7), Whidbey Basin (MAs 8-1 and 8-2), Main Basin/Central Puget Sound (MAs 9, 10, and 11), South Puget Sound (MA 13), and Hood Canal (MA 12) [15] (Fig. 1).

The number of licensed recreational anglers who fished or planned to fish within the greater Puget Sound region varies from year to year [38]. Therefore, this study utilized the five year average number of anglers from 2006–2011 ($N=182{,}114$) [38] to calculate a target sample size of 598, with a margin of error of 4% and 95% confidence [39]. For the boat-based angling population, the sample size achieved a margin of error of 4.75% with 95% confidence. Anglers at piers, shorelines, and other stakeholders including divers, charter captains, and anglers at recreational angler association meetings were also surveyed. For consistency, and because the largest number of respondents were boat-based, only boat-based anglers were included in this analysis, though some of these anglers also responded they fished in different areas, were divers, or members of associations.

The 41-question survey was designed to enhance understanding of the recreational boat-based angling community's knowledge of rockfish biology, rockfish fishing regulations, and species identification abilities; perceptions of threats to rockfish; fishing practices; and preferences for rockfish recovery planning [40]. For example, survey respondents were asked to select one or more issues they considered to be "the greatest threats to rockfish in Puget Sound/San Juan Islands." They were offered a list of responses including habitat loss, pollution, commercial fisheries, derelict fishing gear, recreational fisheries, predation from marine mammals, predation from lingcod,

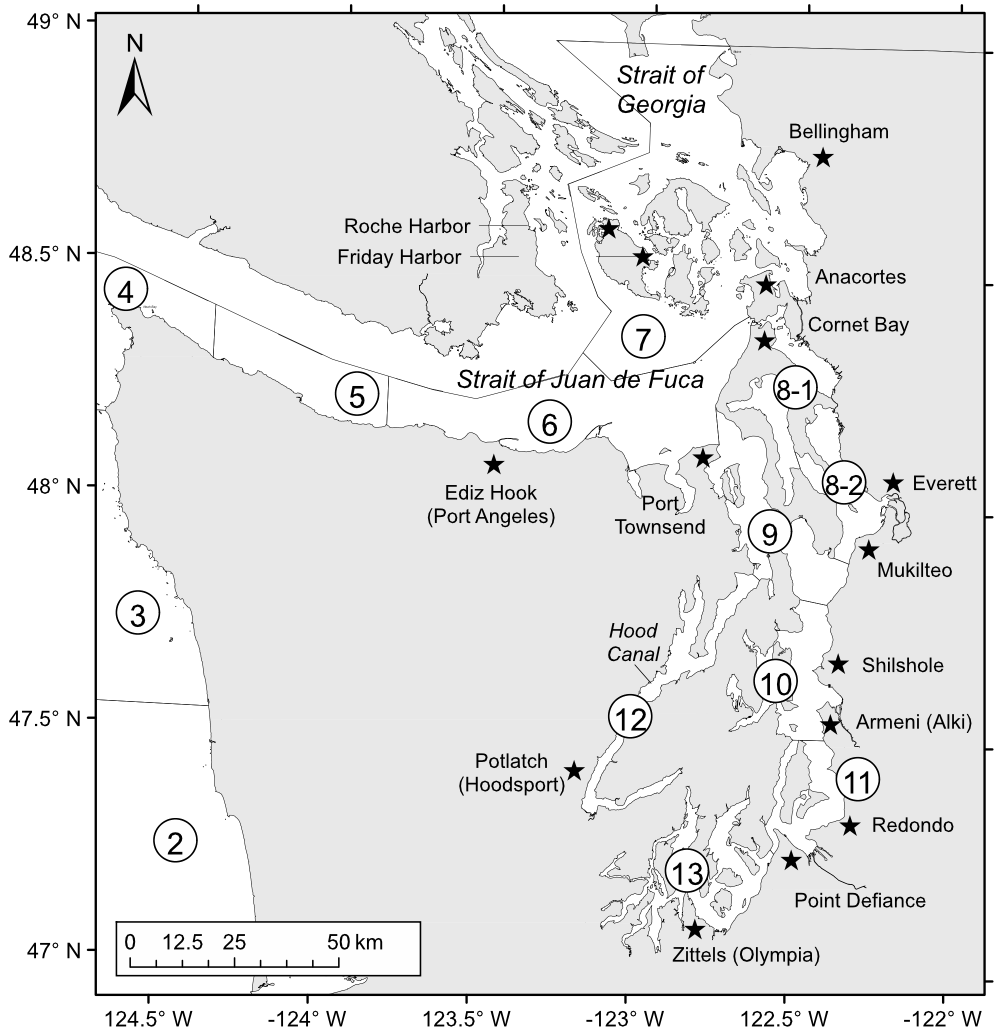

Fig. 1. Puget Sound's five regions included in the rockfish ESA-listing area encompass all Marine Areas (MAs) east of Port Angeles: San Juan/North Puget Sound (MAs 6 and 7), Whidbey Basin (MAs 8-1, 8-2), Main Basin/Central Puget Sound (MAs 9, 10 ,and 11), South Puget Sound (MA 13), and Hood Canal (MA 12). Surveyed public boat launches and marinas are indicated with a star.

and other threats (specify). For purposes of statistical analyses, commercial fishing and derelict gear were combined into a single category ('commercial fishing') because the majority of derelict gear that impose a threat to rockfish are from commercial fisheries [41,42]. Predation from marine mammals and predation from lingcod were combined into a single 'predation' category. Two common 'other' responses—"past effects of commercial fisheries" and "tribal commercial fisheries"—were combined into the commercial fishing category and "spearfishing" was included in the recreational fishing category. Additional 'other' responses were not considered in analyses, as these were small in number.

Respondents were also asked to select one or more recovery measures they "think would best conserve and recover rockfish in Puget Sound/San Juan Islands" from a list that included marine reserves, artificial reefs, hatchery supplementation, derelict gear removal, habitat restoration, and other (specify). Response choices represented the options under consideration by the WDFW [24]. All surveys were administered by the same researcher (Sawchuk) to maintain methodological consistency.

2.3. Statistical analysis

A statistical modeling approach was used to evaluate the hypothesis that variation in stakeholders' (a) perceived threats to rockfish ('perceived threat') and (b) preferences for rockfish recovery measures is related to their knowledge of rockfish biology and their fishing practices. Each of the perceived threats and recovery measures described above was analyzed as a binary variable, coded 1 if it was selected by a given respondent and 0 if was not selected by that respondent. Hypotheses explaining variation in perceived threats and recovery measures were represented as alternative configurations of predictor variables in generalized linear models (GLMs) with a logit link function and binomial error distribution (Eqs. 1–5, below). All GLMs were fit using R statistical software [43]. Perceived threats and recovery measures were analyzed as discrete choices, rather than multiple response categorical variables (i.e., when more than one option is selected) because this analysis did not wish to model dependence among choices for individual respondents [44].

To evaluate the relationship between anglers' perceptions of threats to rockfish and their fishing practices, perceived threats T were modeled as a function of whether anglers had targeted rockfish, their years of fishing experience, and their fishing location(s):

$$T = \beta_0 + \beta_{FR} FR_T + \beta_{YF} YF_T + \beta_R R_T \quad (1)$$

Five sets of models were run, each with a different threat as the dependent variable: habitat loss, pollution, commercial fishing, recreational fishing, and predation. 'Fished rockfish' (*FR*) is a binary variable indicating whether the respondent had targeted rockfish in Puget Sound, 'years fishing' (*YF*) is the total number of years the respondent had fished in Puget Sound, and 'region' (*R*) is a set of categorical variables indicating in which of Puget Sound regions a respondent had fished: Strait of Juan de Fuca (JF), San Juans (SJ), Whidbey Basin (Whidbey), Central Puget Sound (CS), South Puget Sound (SS), and Hood Canal (HC).

For each dependent variable, a set of candidate models was tested that represented all possible combinations of predictor variables. The degree of support for each alternative model was evaluated using Akaike's Information Criterion bias-corrected for small sample size (AICc), which balances model complexity (i.e., number of estimated parameters) with the goodness of fit as determined by likelihood [45]. The Akaike weight (w_i) was calculated for each model, interpreted as the weight of evidence (probability) that model *i* is the best approximating model for the observed data from among the set of candidate models. The relative importance of each predictor variable *j* was determined by summing w_i across all models in the set that included variable *j*; the closer the sum of Akaike weights ($w+(j)$) is to 1, the more important the variable in predicting the response [45]. By convention, the best-fit model or set of models was determined as those with AICc values within 2 units of the lowest AICc across all models. When multiple models provided an equivalent fit according to ΔAICc (≤ 2), parameter estimates and their effect sizes for the model with lowest AICc were reported. Effect sizes of predictors in best-fit models were reported as odds ratios (95% CI) [46]. The odds of a particular outcome are defined as the ratio of the probability that the outcome occurs to the probability that the outcome does not occur.

To evaluate the relationship between anglers' perceptions of threats to rockfish and their knowledge of rockfish, perceived threats *T* were modeled as a function of whether anglers knew that (1) rockfish are long lived and (2) older females produce more robust offspring (i.e., increased larval growth and survival):

$$T = \beta_0 + \beta_L L_T + \beta_H H_T \tag{2}$$

Five sets of models were run, each with a different threat as the dependent variable (threats defined above). 'Long lived' (*L*) and 'healthy offspring' (*H*) are binary variables indicating whether the respondent was aware that rockfish are long-lived and that older females have healthier offspring, respectively. Model selection was performed as described above.

To evaluate the relationship between anglers' preferences for recovery measures and their fishing practices, preferences *P* were modeled as a function of *FR*, *YF*, and *R*:

$$P = \beta_0 + \beta_{FR} FR_P + \beta_{YF} YF_P + \beta_R R_P \tag{3}$$

Five sets of models were run, each with a different preferred recovery measure as the dependent variable: marine reserves, artificial reefs, hatcheries, derelict gear removal, habitat restoration. Model selection was performed as described above.

To evaluate the relationship between anglers' preferences for recovery measures and their knowledge of rockfish, preferences *P* were modeled as a function of *L* and *H*:

$$P = \beta_0 + \beta_L L_P + \beta_H H_P \tag{4}$$

Five sets of models were run, each with a different recovery preference as the dependent variable (preferences defined above). Model selection was performed as described above.

Finally, to evaluate whether anglers' preferred recovery measures correspond to their perceived threats to rockfish, preferences *P* were modeled as a function of the five threats, habitat loss (*Hab*), pollution (*Pol*), commercial fishing (*Com*), recreational fishing (*Rec*), and predation (*Pred*):

$$P = \beta_0 + \beta_{Hab} Hab_P + \beta_{Pol} Pol_P + \beta_{Com} Com_P + \beta_{Rec} Rec_P + \beta_{Pred} Pred_P \tag{5}$$

Five sets of models were run, each with a different preferred recovery measure as the dependent variable (preferences defined above). Model selection was performed as described above.

3. Results

3.1. Angler response rate and demographics

Of 456 anglers randomly approached at public boat launches and marinas representative of the heaviest use, 443 completed the survey for a response rate of 97%. Respondents were identified as predominantly male (95%, $N=423$) and Caucasian (93%, $N=411$). Respondents had a mean age of 51 years ($SD=12.52$; $Range=23$–78), were Washington State residents for an average of 44 years ($SD=16.61$; $Range=3$–78), had an average of 30 years of fishing experience ($SD=15.85$; $Range=1$–70), and participated in an average of 27 fishing trips per year ($SD=35.04$; $Range=1$–200). Among the respondents, 13% ($N=57$) reported participation one or more angler associations and 0.4% ($N=2$) said they were members of a diving association. Some reported participating in both diving and angling activities (5.3%, $N=23$). The majority of respondents (64%, $N=285$) primarily fished in Central Puget Sound, followed by Whidbey Basin (41%, $N=182$); San Juan Islands (32%, $N=144$); Strait of Juan de Fuca (28%, $N=125$); South Puget Sound (11%, $N=51$); and Hood Canal (7%, $N=32$). Anglers were allowed to select more than one fishing area.

3.2. Angler perceptions of threats to rockfish

Perceptions about threats to rockfish varied among surveyed boat-based anglers. The majority of anglers (49%) stated that commercial fisheries were a threat to rockfish, while pollution and habitat loss followed closely at 34% and 30%, respectively. More than a quarter of anglers surveyed (26%) said derelict fishing gear was a threat and 17% believed that recreational fisheries were a threat. Many anglers also named various other threats to rockfish (60%), ranging from effects commercial fisheries had on the region in the past (33%), overfishing in general (20%), and bycatch (13%). A quarter of surveyed anglers (25%) responded they did not know the threats to rockfish. Percentages add up to more than 100% because anglers were allowed to provide more than one answer.

3.3. Angler preferences for recovery measures

Nearly 49% of surveyed anglers preferred habitat restoration as a recovery measure, 42% preferred marine reserves, 38% preferred artificial reefs, 37% preferred derelict gear removal, and almost 11% preferred hatcheries. About 63% of surveyed anglers indicated they preferred recovery options other than or in addition to those listed in the survey. Of those anglers, 23% of anglers stated they preferred a long-term closure of the rockfish fishery (as WDFW has already done), 20% preferred closure of all gillnetting within Puget Sound waters, 6% preferred education of anglers, and the remaining preferred greater enforcement or pollution reduction (both under 5%). About 17% stated they did not know what options they prefer and most anglers chose more than one recovery measure. Many respondents qualified their choices by stating they would prefer a particular option if certain conditions were met. For example, anglers most often gave conditional responses to their preference for marine reserves and hatcheries, such as choosing a recovery measure if "there was proof it worked." Some also qualified their preference for marine reserves by choosing it as a recovery option if they did not interfere with the salmon fishery. Although these qualified answers were not originally part of the survey, they were noted systematically.

3.4. Perceived threats and preferred recovery measures as related to rockfish knowledge

Over half the respondents (58%) indicated that rockfish are long-lived, while few anglers (13%) understood that older female rockfish produce more and healthier larvae than younger rockfish. Anglers who reported knowledge of rockfish longevity were more likely to perceive rockfish as threatened by habitat loss, commercial and recreational fishing, and predation compared to those who were not aware of this trait.

Knowledge that rockfish are long-lived was an important predictor of all perceived threats to rockfish in regression models ($w_+(j)$=0.975–1.0), except for pollution ($w_+(j)$=0.277; Appendix, Table A1). The odds that fishing and predation were viewed as threats were more than three times greater for anglers who understood that rockfish are long-lived compared to those who did not (Table 1). Anglers who understood the link between maternal age and offspring health were also more likely to perceive recreational fishing and predation as a threat compared to other anglers without that knowledge (Table 1).

Understanding that rockfish are long lived was an important predictor of preference for all rockfish recovery measures ($w_+(j)$= 0.942–1.0) with the exception of hatcheries ($w_+(j)$=0.324; Appendix, Table A2). This relationship was particularly strong for those who preferred marine reserves and derelict gear removal; the odds of preferring marine reserves and derelict gear removal was more than three times greater for anglers who were aware of rockfish longevity than for those anglers who were not (Table 2). Knowledge of the link between maternal age and offspring health was a substantially less important factor explaining management preferences in regression models ($w_+(j)$=0.273–0.598; Appendix, Table A2).

Table 1
Parameter estimates (SE) and odds ratios (95% CI) from the best-fit logistic regression models describing relationships between perceived threats to rockfish and respondents' knowledge of rockfish biology. Models were fitted separately for each perceived threat.

Response	Predictors (best model)	Estimate (SE)	Odds ratio (95% CI)
Habitat loss	Long lived	0.71 (0.23)	2.04 (1.32, 3.20)
Commercial fishing	Long lived	1.17 (0.20)	3.23 (2.18, 4.83)
Pollution	Intercept only	N/A	N/A
Recreational fishing	Long lived	1.30 (0.30)	3.66 (2.09, 6.71)
	Healthy offspring	0.72 (0.30)	2.05 (1.12, 3.71)
Predation	Long lived	1.20 (0.41)	3.32 (1.55, 7.93)
	Healthy offspring	1.12 (0.34)	(1.55, 5.94)

Table 2
Parameter estimates (SE) and odds ratios (95% CI) from the best-fit logistic regression models describing relationships between preferred rockfish recovery measures and respondents' knowledge of rockfish biology. Models were fitted separately for each management measure.

Response	Predictors (best model)	Estimate (SE)	Odds ratio (95% CI)
Marine reserves	Long lived	1.16 (0.21)	3.20 (2.12, 4.89)
Artificial reefs	Long lived	0.62 (0.21)	1.85 (1.24, 2.80)
Hatcheries	Intercept only	N/A	N/A
Derelict gear removal	Long lived	1.11 (0.22)	3.04 (1.98, 4.74)
Habitat restoration	Long lived	0.88 (0.20)	2.41 (1.63, 3.59)

Anglers were also asked about their knowledge of rockfish regulations. Of the anglers who stated they fished for bottom fish (12%), 46% knew the depth regulation, while 88% knew of the no rockfish retention rule. Of the majority of the population surveyed who said they fish for salmon (98%), 20% knew the depth regulation while targeting bottom fish and 64% were aware they could not legally retain rockfish.

Finally, respondents were asked to rate their willingness to take particular actions to recover rockfish, such as using a recompression device to release rockfish, using hook and bait combinations that may result in decreased rockfish bycatch, and learning more about rockfish catch/release methods. On a scale from 1–5 (1=not willing, 5=very willing), most anglers ranked their willingness to learn about rockfish catch/release methods high (mean score=4.27). Anglers were moderately willing to use recompression devices (2.97) and to use prescribed hook and bait combinations (2.60).

Knowledge of rockfish longevity was significantly correlated with willingness to use equipment to recompress and release rockfish (Spearman's rho: R=0.21, $P<0.001$) as well as willingness to learn more about catch avoidance and release methods (Spearman's rho: R=0.26, $P<0.001$). Knowledge about the link between maternal age and offspring health was also significantly correlated with the willingness to proactively use recompression devices (Spearman's rho: R=0.25, $P<0.001$), learn more about catch avoidance and release methods (Spearman's rho: R=0.18, $P<0.001$), and use prescribed terminal tackle (Spearman's rho: R=0.19, $P<0.001$).

Knowledge of the no retention regulation was significantly correlated with a willingness to use a descending device only (Spearman's rho: R=0.24, $P<0.001$). Knowledge of the 120-foot depth restriction while bottom fishing was significantly correlated with willingness to use a decompression device (Spearman's rho: R=0.20, $P<0.001$) and a willingness to learn more about catch avoidance and release methods (Spearman's rho: R=0.24, $P<0.001$).

Anglers who fished for rockfish in the past were most likely to report they would be willing to take all three measures to reduce mortality. There was a significant correlation between having fished for rockfish in the past and each of the proactive conservation actions: willing to use recompression devices (Spearman's rho: R=0.36, $P<0.001$), willing to use prescribed terminal tackle (R=0.24, $P<0.001$), and willing to learn more about catch and release methods (R=0.28, $P<0.001$; Table 3).

3.5. Perceived threats and preferred recovery measures related to fishing practices

Respondents who fished for rockfish in the past (N=188, 41%) stopped fishing for rockfish an average of 4.09 years ago (SD=7.52, $Range$=1–40), about two years before the recreational closure. It is notable that having fished for rockfish did not indicate that fishing

Table 3
Correlations between respondents' fishing practices and willingness to take steps to decrease mortality from incidental catch, as measured by Spearman's rank correlation coefficients.

	Years fishing	Have fished for rockfish
Have fished for rockfish	**0.24***	
Willing to use equipment to sink and release rockfish	0.14	**0.36***
Willing to use prescribed terminal tackle	0.02	**0.24***
Willing to learn more to about catch avoidance and release methods	**0.18***	**0.28***

* Signifies significant correlations at a p-value of less than 0.001.

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trips were to target rockfish only; many anglers stated they had only targeted rockfish at the end of the fishing day when their trip was otherwise unsuccessful. The majority of respondents indicated that they generally target salmon (98%) and crab (52%).

Anglers' perceptions of threats to rockfish were related to their fishing practices, including how many years they had fished, where they fished, and whether they had targeted rockfish in the past. The number of years an angler had fished in Puget Sound ($w_+(j)=0.622$) and whether an individual had fished in the San Juan (SJ) or the Whidbey Basin (Whidbey) areas ($w_+(j)=0.804$ and 0.769, respectively) were important predictors of habitat loss as a perceived threat in regression models (Appendix, Table A3). Number of years fishing ($w_+(j)=0.814$) and whether an angler had fished in Central Puget Sound (CS; $w_+(j)=0.953$) were important predictors of pollution as a perceived threat. Anglers who most frequently fished in CS were twice as likely to identify pollution as a threat than those who did not fish in that region (Table 4). Whether an angler had fished in the SJ basin ($w_+(j)=0.929$) was an important predictor of recreational fishing as a perceived threat. Additionally whether an angler had fished for rockfish ($w_+(j)=0.786$) or fished in SJ basin ($w_+(j)=0.709$; Appendix, Table A3, Table 4) were important predictors of predation as a perceived threat.

Anglers who fished for rockfish in the past were more likely to be supportive of all methods to recovery rockfish ($w_+(j)=0.920$–0.997) than those who did not, with the exception of artificial reefs ($w_+(j)=0.527$; Appendix, Table A4, Table 5). Having fished in CS was an important predictor of preference for habitat restoration ($w_+(j)=0.788$; Appendix, Table A4). Anglers who fished in CS ($w_+(j)=0.789$) and Whidbey Basin ($w_+(j)=0.790$) were more likely to prefer hatcheries compared to those who fished in other regions (Appendix, Table A4, Table 5). Preference for derelict gear removal was related to whether anglers had fished in the SJ ($w_+(j)=0.906$) and Whidbey Basin ($w_+(j)=0.807$; Appendix Table A4, Table 5).

Table 4
Parameter estimates (SE) and odds ratios (95% CI) from the best-fit logistic regression models describing relationships between perceived threats to rockfish and respondents' fishing practices. Models were fitted separately for each perceived threat.

Response	Predictors (best model)	Estimate (SE)	Odds ratio (95% CI)
Habitat loss	Years fishing	0.02 (0.01)	1.02 (1.01, 1.03)
	Whidbey	−0.51 (0.22)	0.60 (0.39, 0.93)
	SJ	0.53 (0.22)	1.71 (1.10, 2.64)
Pollution	Years fishing	0.02 (0.01)	1.02 (1.00, 1.03)
	CS	0.71 (0.22)	2.04 (1.33, 3.19)
Commercial fishing	Years fishing	0.03 (0.01)	1.04 (1.02, 1.05)
	Fished rockfish	0.60 (0.21)	1.82 (1.21, 2.76)
	Whidbey	−0.41 (0.21)	0.67 (0.44, 1.00)
Recreational fishing	SJ	0.62 (0.24)	1.85 (1.15, 2.98)
	JF	0.47 (0.25)	1.60 (0.98, 2.60)
Predation	Fished rockfish	0.72 (0.30)	2.05 (1.14, 3.72)
	SJ	0.65 (0.30)	1.92 (1.07, 3.43)

Table 5
Parameter estimates (SE) and odds ratios (95% CI) from the best-fit logistic regression models describing relationships between preferred rockfish recovery measures and respondents' fishing practices. Models were fitted separately for each recovery measure.

Response	Predictors (best model)	Estimate (SE)	Odds ratio (95% CI)
Marine reserves	Fished rockfish	0.76 (0.20)	2.13 (1.45, 3.13)
Artificial reefs	Years fishing	0.02 (0.01)	1.02 (1.01, 1.03)
Hatcheries	Fished rockfish	0.98 (0.32)	2.66 (1.43, 5.11)
	CS	0.83 (0.39)	2.29 (1.10, 5.25)
	Whidbey	−0.75 (0.37)	0.47 (0.22, 0.94)
Derelict gear removal	Fished rockfish	0.71 (0.21)	2.02 (1.35, 3.05)
	Whidbey	−0.48 (0.21)	0.62 (0.41, 0.94)
	SJ	0.59 (0.22)	1.80 (1.17, 2.77)
Habitat restoration	Fished rockfish	0.65 (0.20)	1.91 (1.31, 2.81)
	CS	0.49 (0.20)	1.64 (1.10, 2.45)

Table 6
Parameter estimates (SE) and odds ratios (95% CI) from the best-fit logistic regression models describing relationships between preferred rockfish recovery measures and respondents' perceptions of threats to rockfish. Models were fitted separately for each recovery measure.

Response	Predictors (best model)	Estimate (SE)	Odds ratio (95% CI)
Marine reserves	Habitat loss	0.66 (0.24)	1.94 (1.21, 3.11)
	Pollution	0.68 (0.23)	1.97 (1.26, 3.08)
	Recreational Fishing	0.71 (0.24)	2.04 (1.27, 3.28)
Artificial reefs	Habitat loss	0.81 (0.26)	2.24 (1.34, 3.75)
	Pollution	0.49 (0.24)	1.63 (1.01, 2.60)
	Commercial fishing	0.91 (0.24)	2.50 (1.56, 4.03)
	Predation	0.95 (0.33)	2.59 (1.37, 5.03)
Hatcheries	Pollution	0.82 (0.31)	2.28 (1.24, 4.19)
Derelict gear removal	Habitat loss	0.55 (0.27)	1.73 (1.02, 2.93)
	Pollution	0.75 (0.25)	2.12 (1.30, 3.47)
	Commercial fishing	1.54 (0.27)	4.65 (2.77, 8.00)
	Recreational fishing	0.64 (0.26)	1.91 (1.14, 3.19)
Habitat restoration	Habitat loss	2.18 (0.32)	8.85 (4.87, 16.89)
	Pollution	0.80 (0.26)	2.22 (1.34, 3.68)
	Commercial fishing	0.80 (0.24)	2.23 (1.40, 3.56)

3.6. *Consistency between perceived threats and preferred recovery measures*

Results generally supported the hypothesis that anglers' preferences for rockfish recovery measures would correspond to perceptions of threats to rockfishes. For instance, anglers who perceived habitat loss as a threat were nearly nine times more likely to prefer habitat restoration than those who did not perceive it as a threat (Table 6; $w_+(j)=1.0$; Appendix, Table A5). The odds of preferring derelict gear removal was five times greater for anglers who perceived commercial fishing as a threat compared to anglers who did not (Table 6); ($w_+(j)=1.0$; Appendix, Table A5). The odds of preferring marine reserves was more than two times greater for anglers that viewed recreational fisheries as a threat compared to those who did not (Table 6); ($w_+(j)=0.944$; Appendix, Table A5).

4. Discussion

This study demonstrates one way to gain representative understanding of a diverse stakeholder group important to endangered species conservation. Specifically, it illustrated that knowledge of rockfish longevity, places where anglers typically fished, and experience fishing for rockfish were important indicators of perceived threats and support for all rockfish recovery measures. In an age of limited resources, this information will help managers make well-informed choices about outreach and education needs as well as conservation actions. In a wider context, this study exhibits the utility of understanding stakeholders for conservation efforts that have as much to do with managing people as managing the species themselves [1,2,47].

4.1. The role of knowledge and cultural relevancy

Rockfish longevity may be a key aspect of rockfish life history for educators and recovery managers to convey to stakeholders. It was an important predictor of support for all recovery measures surveyed, with the exception of hatcheries. Anglers who understood that rockfish are long-lived were also more likely to perceive commercial and recreational fishery removals as a threat to rockfish, consistent with historical evidence about their main causes of decline as well as present day threat analyses [14,15,31]. Educating anglers about rockfish longevity, as well as present threats to rockfish, may be particularly important for long-term support of conservation and recovery measures consistent with angler expectations, as they may have grown accustomed to relatively short management cycles for salmon, their primary target.

Further, anglers who had fished for rockfish in the past had greater knowledge about rockfish longevity than anglers who did not. These anglers were also more willing to take proactive steps to conserve them, along with anglers who knew regulations enacted to protect rockfish. These findings are consistent with other studies that show that valuing, having experience with, and possessing knowledge about a species may increase willingness and support to conserve them [1,3,12]. Anglers who used to fish for rockfish indicated they stopped fishing for rockfish on average just over two years ($SD=7.52$, $Range=1–40$) prior to the moratorium in the rockfish recreational fishery, suggesting they may have been attuned to their decline. A recent study showed that recreational anglers who targeted rockfish in Puget Sound observed declines in rockfish populations as early as the 1960s [48]. However, the majority of surveyed anglers ($N=268$, 58%) in this study reported that they have never fished for rockfish, though it is of note that the survey was conducted during the salmon season. Most anglers surveyed (98%) stated they target salmon (*Oncorhynchus* spp.), which are recognized as culturally and economically important in the Pacific Northwest [49]. As angler have fewer opportunities to interact with listed rockfish, managers may need to educate stakeholders about their current relevance, such as their ecological links to other regionally important species such as salmon. For example, larval rockfish have been documented to provide a significant contribution to the diets of juvenile salmon [50] and may be important to salmon productivity [51].

4.2. The importance of place

Place and experience shaped people's perceptions of threats to rockfish. For example, anglers who most frequently fished in Central Puget Sound were most likely to perceive pollution as a threat to rockfish. This is consistent with scientific evidence that Central Puget Sound exhibits some of the most polluted waters in Puget Sound [52], with the highest levels of persistent bioaccumulative contaminants found in the pelagic foodweb [53].

Preferences for recovery measures were also related to place. Most derelict nets have been removed from the San Juan and Whidbey Basins, [54], and anglers who responded that they most frequently fish in those areas were more likely to prefer derelict fishing gear as a recovery measure than those anglers who fished in other areas. Anglers who preferred habitat restoration for rockfish recovery fish most commonly in Central Puget Sound, which has been under urban and industrial pressure, and has seen over 52% of its shoreline modified as of 2001 [55]. Anglers who preferred hatcheries typically fish in Central Puget Sound and Whidbey Basin, areas that experience the highest volume of anglers [37].

The importance of place points to the potential value of specifying recovery measures for individual basins of Puget Sound, where biologically appropriate. Angler identification with place, in addition to the fact that some anglers who fished for rockfish stopped before the moratorium, also suggests that anglers are attuned to their environment. Therefore, there may be an opportunity for greater use of local ecological knowledge in detecting changes in fish populations e.g. [48].

4.3. Complexity of variables and relationships among them

While this study demonstrates the utility of understanding regional user groups to inform place-based management, it also highlights the complexity of species management and recovery in social–ecological systems. This study explored relationships among knowledge, fishing experience and practices, perceptions, and recovery preferences, but the relationships are not necessarily casual and the genesis of these factors is complex. For instance, this study could not determine if the relationship between fishing primarily in Central Puget Sound and perception of pollution as a threat could be due to interactions with angler peers, local news coverage, or their observations while fishing. There may be several factors at play. Verweij et al. [13] proposed that one's "information environment"—the types, sources, breadth, and depth of specific environmental information stakeholders have access to—could be a significant factor in affecting their perceptions or actions. Indeed, this study demonstrated differences among particular groups of boat-based anglers that may have different information environments. Members of recreational fishing associations responded more frequently than non-members that commercial fisheries were a threat to rockfish (61% and 47%, respectively). Association members also responded more frequently that derelict gear was a threat (40% and 24%, respectively). Angling associations in Puget Sound have been active in derelict gear removal; therefore, their members may be more aware of that threat that non-members. History may also play a role in the present information environment. Many anglers (33%) named past effects of the commercial fishery as a present threat to rockfish and the majority of anglers preferred recovery measures other than or in addition to those listed in the survey, with 20% preferring a closure of all gillnetting within Puget Sound. Indeed, the majority of nets lost and recovered in Puget Sound to date have been gillnets [27].

Despite nearly 200,000 anglers fishing in Puget Sound taking on average dozens of fishing trips annually and scientific data demonstrating that both commercial and recreational fisheries were the primary reasons for the decline of the listed species [14,15], only 17% of the surveyed anglers viewed recreational fisheries as a threat to rockfish. The low percentage may be partially explained by the fact that when asked what they do when they encounter a rockfish, 14% of respondents said they had never caught one. However, a higher proportion reported commercial fisheries as a threat, despite the closure of most commercial fisheries with the threat of rockfish bycatch by WDFW in 2010 [15,31]. The finding that people's perceptions of threats corresponded with preferred recovery measures suggests that educating anglers about how their individual actions or inactions may collectively affect threatened and endangered rockfish will be important for garnering support from stakeholders. The low percentage of respondents identifying recreational fisheries as a threat may also be of note to managers in the context of a recent global study of recreational angler engagement in conservation [56]. Granek et al. [56] reported that when anglers are involved in protecting resources from threats external to recreational fishing, such as habitat destruction or commercial fishing, commitment to conservation is likely to be high. Conversely, in cases where threats are diffuse or related to the recreational fishery itself, there may be greater angler resistance to conservation involvement [56].

4.4. Toward more informed management and collaborative conservation

The high response rate (97%) in this study indicates anglers value being heard and reflects the importance of researchers speaking in person with stakeholders. Though recreational angler organizations in Puget Sound are actively engaged in fisheries policy, they represent a relatively small percentage of anglers (13%); therefore, this study sought to engage and understand the angling population as a whole.

Endangered species recovery demands greater coordination and collaboration with stakeholders [2]. In addition to informing education, outreach, and management, conducting this study prior to developing the recovery plan itself has already resulted in raising the profile of rockfish conservation among some anglers. Preliminary results of this study released in 2012 showed that a small percentage of anglers use descending devices to release rockfish within Puget Sound (3%) [40]; since then, some local angling associations have taken it upon themselves to promote fish descenders among anglers. Sharing preliminary findings regarding anglers' difficulty in accurately identifying rockfish to species (31% correctly identified yelloweye rockfish, 11% identified canary rockfish, and 5% identified bocaccio) [40] also resulted in some angling associations educating anglers in rockfish identification. Accurate identification is imperative because currently managers may have difficulty estimating bycatch mortality of rockfish because released catch is self-reported and anglers often identify rockfish incorrectly [4,40,49]. Additionally, a recent study in Puget Sound suggested that anglers' inability to differentiate between certain rockfish species could lead to the perception that depleted rockfishes are not in need of conservation because anglers do encounter some of the more abundant species [49]. Finally, this education of anglers by anglers may be highly effective; gear intended to decrease bycatch has been shown to be adopted at higher rates when the inventor is a local angler [57].

The challenge is now to continue to engage recreational anglers in rockfish recovery in a meaningful way, especially around diffuse threats such as water quality and recreational fisheries. This and other studies indicate there may be recovery challenges because rockfish are currently of relatively small concern compared to other fishes, such as iconic Pacific salmon [49]. However, this study lays the understanding and foundation needed for future collaborative conservation efforts. Current rockfish data limitations may present an opportunity for research and data collection that draws upon angler knowledge [48,58]. Studies could be conducted cooperatively so that managers, scientists, and anglers have more confidence in the data and analysis [13,58], and anglers could be engaged in monitoring [58] and enforcement as well as conservation advocacy efforts. Cooperative research has been shown not only to inexpensively fill data needs [59], but also engender mutual learning and relationships between participants [60]. Importantly, more actively engaged stakeholders also increase the likelihood of success of endangered species recovery [2]. This study is intended to stimulate further discussion about ways to better elicit, analyze, understand, and incorporate diverse stakeholder perspectives into regulatory and planning processes for endangered species management and conservation.

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Appendix A

Parameter Akaike weights from best-fit models evaluating relationships among recreational anglers' knowledge of rockfish biology, fishing practices, perceptions of threats to rockfish, and preferences for rockfish recovery.

Table A1
Parameter Akaike weights ($w+(j)$) calculated from all candidate logistic regression models describing the relationships between perceived threats to rockfish and respondents' knowledge of rockfish biology. Models were fitted separately for each perceived threat.

	Perceived threats to rockfish				
Predictors	Habitat loss	Pollution	Commercial fishing	Recreational fishing	Predation
Long lived	**0.975***	0.277	**1.000***	**1.000***	**0.983***
Healthy offspring	0.335	0.345	0.265	**0.848***	**0.983***

* Indicates inclusion of predictor in best-fit model(s).

Table A2
Parameter Akaike weights ($w+(j)$) calculated from all candidate logistic regression models describing the relationships between preferred rockfish recovery measures and respondents' knowledge of rockfish biology. Models were fitted separately for each management measure.

	Preferred recovery measures				
Predictors	Marine reserves	Artificial reefs	Hatcheries	Derelict gear removal	Habitat restoration
Long lived	**1.000***	**0.942***	0.324	**1.000***	**1.000***
Healthy offspring	0.290	0.428	0.273	0.598	0.490

* Indicates inclusion of predictor in best-fit model(s).

Table A3
Parameter Akaike weights ($w+(j)$) calculated from all candidate logistic regression models describing the relationships between perceived threats to rockfish and respondents' fishing practices. Models were fitted separately for each perceived threat.

	Perceived threats to rockfish				
Predictors	Habitat loss	Pollution	Commercial fishing	Recreational fishing	Predation
Years fishing	**0.919***	**0.814***	**1.000***	0.327	0.622
Fished rockfish	0.444	0.497	**0.958***	0.328	**0.786***
JF	0.277	0.447	0.428	0.668	0.496
SJ	**0.804***	0.297	0.333	**0.929***	**0.709***
Whidbey	**0.769***	0.449	**0.712***	0.304	0.422
CS	0.357	**0.953***	0.282	0.380	0.304
SS	0.271	0.300	0.267	0.388	0.374
HC	0.373	0.321	0.269	0.270	0.288

* Indicates inclusion of predictor in best-fit model(s).

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Table A4
Parameter Akaike weights ($w+(j)$) calculated from all candidate logistic regression models describing the relationships between preferred rockfish recovery measures and respondents' fishing practices. Models were fitted separately for each management measure.

Predictors	Preferred recovery measures				
	Marine reserves	Artificial reefs	Hatcheries	Derelict gear removal	Habitat restoration
Years fishing	0.276	**0.968***	0.473	0.371	0.625
Fished rockfish	**0.997***	0.527	**0.983***	**0.989***	**0.920***
JF	0.348	0.271	0.305	0.320	0.286
SJ	0.407	0.393	0.274	**0.906***	0.346
Whidbey	0.273	0.373	**0.790***	**0.807***	0.572
CS	0.508	0.427	**0.789***	0.271	**0.788***
SS	0.366	0.282	0.266	0.287	0.637
HC	0.288	0.325	0.270	0.301	0.274

* Indicates inclusion of predictor in best-fit model(s).

Table A5
Parameter Akaike weights ($w+(j)$) calculated from all candidate logistic regression models describing the relationships between preferred rockfish recovery measures and respondents' perceptions of threats to rockfish. Models were fitted separately for each management measure.

Predictors	Preferred recovery measures				
	Marine reserves	Artificial reefs	Hatcheries	Derelict gear removal	Habitat restoration
Habitat loss	**0.864***	**0.978***	0.383	**0.701***	**1.000***
Pollution	**0.979***	**0.938***	**0.861***	**0.980***	**0.994***
Commercial fishing	0.528	**0.998***	0.388	**1.000***	**0.991***
Recreational fishing	**0.944***	0.274	0.423	**0.818***	0.306
Predation	0.301	**0.960***	0.686	0.603	0.264

* Indicates inclusion of predictor in best-fit model(s).

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