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Rockfish size and age: The crossroads of spatial protection, central place fisheries and indigenous rights

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ABSTRACT

Indigenous people harvest wild species for food and cultural practice, fundamentally linking biodiversity conservation and indigenous rights. Rockfishes (*Sebastes* spp.) are culturally significant to indigenous people (or First Nations) of coastal British Columbia (BC), Canada, who regulate their harvest under traditional governance structures. First Nations elders, however, have observed a decline in the body sizes and abundance of rockfishes, which coincides with increased exploitation by non-indigenous fishers. Rockfishes are vulnerable to overexploitation because fecundity and offspring quality increase with maternal size or age, yet fisheries truncate size and age structure. During 2006, 2007 and 2013–2015, we worked with the Wuikinuxv, Nuxalk, Heiltsuk and Kitasoo/Xai'Xais First Nations of BC's Central Coast, examining rockfish population characteristics at 282 of their fishing sites. We used hook-and-line gear to collect fishery independent data, and sampled landings from First Nations subsistence fishers. Spatial fishery closures served as experimental treatments. We also applied central place foraging theory to predict declines in size, age and abundance with increasing distance from recreational fishing lodges and other ports. Analyses used linear mixed models and controlled for environmental variables. Our results suggest that spatial closures for commercial and recreational fishers led to greater size and abundance of some, but not all rockfishes, possibly due to interspecific differences in the extent to which closures contain suitable habitat, effects of non-compliance, or other factors. Notably, Yelloweye Rockfish (*Sebastes ruberrimus*), a species key to indigenous diets, were 21% larger inside than outside spatial closures. Possibly reflecting cumulative fishery exploitation, however, old-aged Yelloweye Rockfish were rare. Fishery impacts on size and relative abundance decreased at sites that required longer travel times and greater fuel costs for recreational fishers to exploit, but only for the longest-lived species (size responses) and for long-lived species analysed in aggregate (abundance responses). Measures for protecting indigenous access to rockfishes include evaluation of habitat suitability and compliance within spatial closures, improved understanding of recreational fishery impacts, and treating old-age and large size structures as explicit management objectives. Our study contributes to a global effort to integrate indigenous cultural values with biological conservation.

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1. Introduction

Modern indigenous people embrace new technologies and do not isolate themselves from contemporary culture and economy, yet maintain a tradition of interconnection with wild species. Their gathering of edible and medicinal plants, their hunting and fishing, not only provide physical sustenance but also sustain worldviews that have been rooted in place for many generations. The implication is that over-exploitation and other forms of biodiversity loss threaten cultural diversity (Turner et al., 2000; Poe et al., 2014; Sangha et al., 2015). Some national governments recognize this connection, at least implicitly. Canada's constitution, for instance, grants indigenous fisheries for food, social and ceremonial (FSC) purposes priority access to marine resources (DFO, 2007a). Fulfilling this legal obligation, however, can be difficult to achieve, as indigenous, commercial and recreational fishers often target the same species (e.g. Frid et al., 2016).

Marine protected areas (MPAs) and other forms of spatial fishery closures have broad benefits for biodiversity conservation (Edgar et al., 2014). They are a management tool that can promote the recovery and sustainable use of species important to indigenous people (Zurba et al., 2012; Frid et al., 2016). Most of the world's oceans, however, still are and will likely remain open to fisheries. Thus, it is important to examine not only whether spatial closures are meeting their conservation objectives, but also what factors affect variation in fishery pressure outside closures.

Some fisheries might conform to the foraging model developed by behavioural ecologists to examine decisions made by animals foraging repeatedly from a central place, such as a nest, then returning to provision young. Theory and empirical evidence suggest that these decisions optimize travel costs, such as time and energy, and expected gain at a foraging site (Ydenberg, 2007; Houston, 2011). Fisheries expected to conform to a "central place fishing" model include recreational, artisanal and subsistence fisheries operating from small boats and using ports or other coastal infrastructure to repeatedly start and end fishing trips lasting a single day. The model may be less applicable to most large-scale commercial fisheries, which operate from larger live-aboard vessels that exploit numerous and distant areas before returning to port. When fishers conform to a central place fishing model, the cumulative number of trips to a site might decrease as fuel and time costs of travel increase with distance. Consequently, the impact on fish stocks of central place fishers might weaken with increasing distance from port (Stelzenmuller et al., 2008; Bellquist and Semmens, 2016; Haggarty et al., 2016a).

As a contribution to the global effort to integrate cultural values into ecosystem based management (Poe et al., 2014), we conducted a case study that connects the concepts of spatial protection, central place fishing and indigenous rights to marine resources. We focused on rockfishes (*Sebastes* spp.), which are culturally significant to the four indigenous groups (or First Nations) of British Columbia's (BC) Central Coast (Fig. 1): Heiltsuk, Nuxalk, Kitasoo/Xai'Xais and Wuikinuxv.

Conservation of rockfishes is difficult. Many species have very long lifespans and late maturity (Love et al., 2002). Like other groundfish, female rockfishes produce larvae throughout their lives, and offspring quality and annual fecundity increases with maternal size or age (Love et al., 1990; Berkeley et al., 2004a). These life history traits appear to be adaptations to long-term environmental variability. However the same traits also increase vulnerability to large-scale fisheries, which generally remove the largest and oldest individuals. The loss of females that are large and old – those that contribute the most offspring to the next generation – has been linked to the collapse of many groundfish populations (Berkeley et al., 2004b; Beamish et al., 2006; Hixon et al., 2014).

In recent decades, First Nations elders have observed a decline in the body sizes and abundance of rockfishes at their traditional fishing sites of BC's Central Coast. These declines coincide with a period of rapid expansion of commercial fisheries that began in the late 1970s. The expansion "outpaced management's effort controls" until more conservative fishery restrictions were implemented in the early 2000s (Yamanaka and Logan, 2010). Despite recent reductions in commercial fishery mortality, rockfish recovery may take decades (Berkeley et al., 2004b) and the impact of recreational fisheries is largely unknown. First Nations, therefore, remain concerned about their reduced access to rockfishes in general and to Yelloweye Rockfish (*Sebastes ruberrimus*) in particular. Yelloweye Rockfish are highly prized in traditional diets and recognized by Canada's Species at Risk Act as a species of special conservation concern (DFO, 2015).

The impact of fisheries on rockfish reproductive potential (O'Farrell and Botsford, 2006) is a general problem for which spatial fishery closures may provide partial solutions (Berkeley et al., 2004b; Hixon et al., 2014). Consistent with this notion, the relative abundance and sizes of rockfishes have increased over time inside spatial closures (Keller et al., 2014; Starr et al., 2015). Accordingly, between 2004 and 2007 Fisheries and Oceans Canada (DFO) established a network of Rockfish Conservation Areas (RCAs)—spatial closures aimed to promote rockfish recovery in British Columbia. RCAs exclude commercial and recreational hook-and-line fisheries and bottom trawl fisheries (Yamanaka and Logan, 2010). Indigenous FSC fisheries, which have legal priority (DFO, 2007a) and regulate under traditional governance structures (Trosper, 2003; Lepofsky and Caldwell, 2013), are allowed within RCAs. Central Coast First Nations are working with provincial and federal governments to ensure that RCAs, future MPAs and other forms of fishery management meet their objectives for fisheries sustainability and bio-cultural conservation (Canada-British Columbia, 2014; MaPP, 2015).

To address the conservation concerns of First Nations and inform management decisions, we designed a field study that tested predictions from the hypothesis that spatial variation in fishery pressure affects the average size, age and abundance of rockfishes. To a lesser extent, we also examined Lingcod (*Ophiodon elongatus*), which overlap spatially with rockfishes and are also culturally significant to First Nations. Though much shorter-lived and faster to recover than most rockfishes, Lingcod are also easy to overfish (Berkeley et al., 2004b).

Our first prediction was that average length and age would be greater inside than outside RCAs, which in BC's Central Coast were established in 2004 and 2005. We also predicted that relative abundance, as estimated by catch-per-unit effort (CPUE),