Title: Social, economic and environmental effects of closing commercial fisheries to enhance recreational fisheries

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Abstract
Recreational fisheries can play a major role in the sustainability of coastal fish stocks, bringing them into conflict with commercial fisheries. This article reviews the recent designation of commercial fishing free zones, or 'recreational fishing areas' as a solution to the conflict between commercial and recreational fisheries. The goal of recreational fishing areas is to enhance recreational fishing and provide economic opportunities through charter fishing. However, the effectiveness of recreational fishing areas has not been assessed, and in many cases they may have been implemented for political reasons, without thorough assessment of their social, economic and environmental impacts. In Queensland, excluding commercial fishing on its own is unlikely to result in long-term benefits to recreational fisheries, as recreational harvest is a major component of fish harvest for some key species. Recreational fishing areas need to be combined with efforts to enhance stewardship among recreational fishers if they are to be successful in the long-term.

Keywords: Coastal ecosystem, bycatch, catch and release, *Lates calcarifer, Sillago, Pagrus auratus*, property rights.

1. Introduction

The approaches used to manage recreational fisheries are decades old and failing to avoid overexploitation of coastal fish populations (Coleman et al. 2004, Stuart-Smith et al. 2008, Thurstan et al. 2014). Many recreational fisheries are managed with limits on the size of fish caught, daily bag limits, seasonal closures and spatial closures. These 'input' controls give managers only weak control over recreational fishing mortality and cannot halt the fundamental problem of more people fishing more often (Sutinen and Johnston 2003). In contrast to recreational fishery management, the management of commercial fisheries has improved markedly over the last several decades (e.g. Costello et al. 2008, Worm et al. 2009, Mace et al. 2013, Pascoe et al. 2016). The provision of property rights to commercial fishers and co-management where data collection and decision making are shared with fishers have provided a solution to the 'tragedy of the commons' that had plagued resource management for hundreds of years (e.g. Hardin 1968, Costello et al. 2008, Samhouri et al. 2013, Pascoe et al. 2016). Commercial fishery management has thus seen some recent successes with enhanced profits in some regions (ref Aus?) and the recovery of some depleted fish stocks (ref – US west coast).

Recreational and charter fishing (hereafter 'recreational fisheries') play a large role in the sustainability of many coastal fish stocks (Coleman et al. 2004, Ihde et al. 2011), bringing recreational fishers into conflict with commercial fisheries (Sutinen and Johnston 2003). Recently in Australia a political solution to the conflict between commercial and recreational fisheries has been to implement spatial closures of commercial fisheries. In the state of Queensland for instance, closures of commercial net fisheries, including fixed mesh nets, drift nets and seine nets, have been implemented in estuaries popular with recreational fishers (Government 2015). Similar closures are also being implemented in other states (Agriculture 2015) The stated aim of these closures is to benefit recreational fishers with 'more fish, bigger fish' (Spelitis 2105) and also grow local economies by improving opportunities for charter fishing (Ref – qld gov). These spatial closures do not affect all commercial fisheries and are targeted at net fishing which overlaps in target species catch with recreational fishing. However, in Queensland the state government has not published any assessments of whether spatial closures of commercial fisheries will improve recreational fisheries, or assessments of additional environmental and economic impacts. Further, the closures are apparently not integrated within existing spatial zoning plans for the coastal waters of Queensland. It is unlikely that recreational use zones on their own will lead to effective management of coastal resources, because they do not address the problem of open-access within the recreational sector(Sanchirico et al. 2010).

This article is a critique of recently designated and proposed commercial net fisheries closures in Queensland, and asks whether the closures can improve Queensland's recreational fisheries. Additional effects of closures on coastal ecosystems and society are also examined. The broader goal is to ask in general whether zoning for recreational use is an adequate strategy for managing coastal fish stocks. There is a trend towards designation of 'recreational fishing areas' in Australia (Agriculture 2015, Government 2015), so it is important to ask whether they can be an effective management strategy. Here the literature on fisheries closures is assessed to ask whether such closures are a suitable strategy to improve recreational fisheries and what additional effects may be seen by society and ecosystems. It is then suggested that even when recreational fishing areas are appropriate, additional management measures are needed to sustain fish stocks and enhance recreational fisheries. Finally, key questions that should be answered during the assessment of new recreational fishing areas are suggested.

2. Will closing commercial net fisheries enhance recreational fisheries?

The stated goal of commercial net fisheries closures in Queensland is to enhance recreational fisheries by reducing pressure on fish stocks from commercial harvest (ref). In theory, reducing commercial harvest may enhance recreational fisheries in several ways. First, if the fishery is overexploited, population productivity may increase allowing recreational fishers to take more fish. Even if the commercial fishery is managed sustainably, for instance is at it's maximum economic yield, closing commercial fisheries can enhance recreational fisheries. Reducing fishing mortality will increase fish abundance, potentially increasing the encounter rate between fishers and fish. Lower fishing mortality may also increase the number of large fish in the population and large fish are often more desirable target for recreational fishers than smaller fish (ref). Finally, there may be aesthetic benefits to recreational fishing if commercial fisheries, such as large trawl boats are considered unsightly (ref). However, in some regions lack of commercial boats may be alternatively viewed as an aesthetic loss, for instance fishing port areas can be a tourist attraction (ref).

The benefits of closing commercial fisheries are only likely to be realised for recreational fisheries if commercial harvest is large relative to recreational harvest. Numerous studies have suggested that recreational fishing can be a significant pressure on coastal fish stocks (e.g. Coleman et al. 2004, Stuart-Smith et al. 2008, Thurstan et al. 2014). An analysis of Queensland's historic commercial and recreational harvest for some key species in designated and proposed recreational fishing areas indicates that recreational harvest is a significant contributor to harvest mortality for many species (Fig. 1). For instance, the harvested biomasses of whiting (*Sillago spp.*) one recently designated closed areas off of Rockhampton and a proposed closed area in Moreton Bay are similar between commercial netting and recreational sectors. Commercial harvest of Barramundi (*Lates calcarifer*) exceeded recreational harvest by >3 times. In Moreton Bay, recreational harvest of snapper (*Pagrus auratus*) was an order of magnitude higher than commercial harvest. Thus, closing commercial fishing may increase stock biomass, but the management of recreational harvest, particulary for whiting and snapper is an equally important concern.

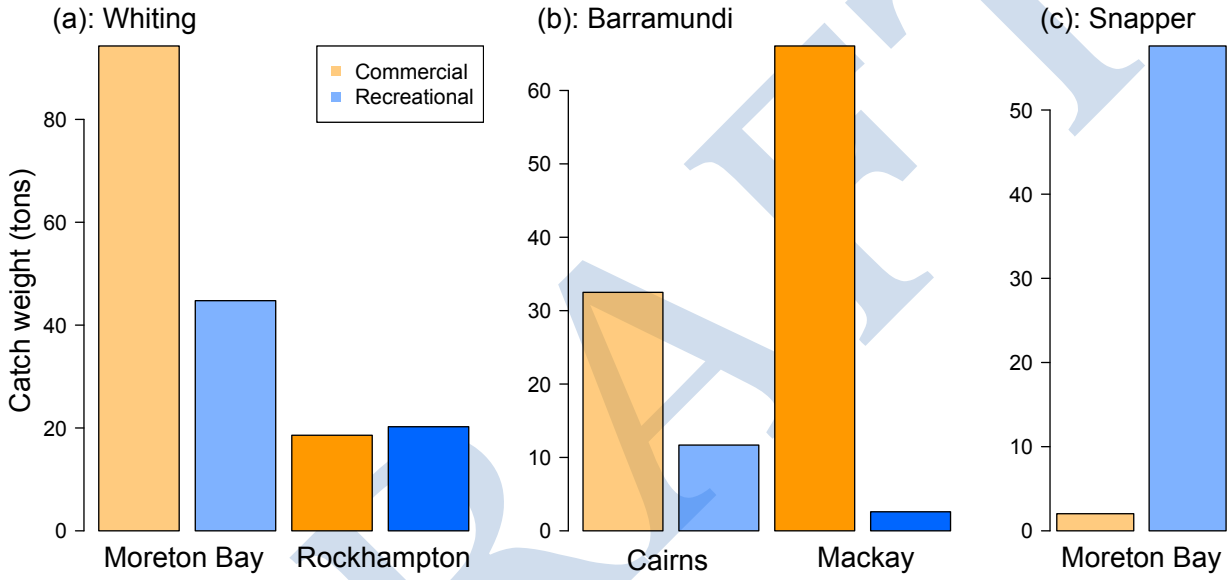

Fig 1. Harvest of (a) whiting (*Sillago spp.*), (b) Barramundi (*Lates calcarifer*) and (c) Snapper [NB: Need to double check catches, very different. Need to account for release mortliaty.](*Pagrus auratus*) by commercial net and recreational fisheries in Queensland for 2010 in areas that have designated or proposed commercial net fisheries closures. Data for commercial harvest are from (State of Queensland 2010) (2010-11 financial year) and recreational harvest from (Taylor et al. 2012). Graphs are for 2010 because data for both sectors was available in this year. Data for recreational harvest were reported as numbers caught, whereas commercial harvest was reported as biomass landed. Therefore, recreational harvest was converted to biomass using the estimates of mean fish weight in (Table 13 of Taylor et al. 2012) and proportion of catch landed in (Table 8 of Taylor et al. 2012).

The analysis reported here is simplistic and uses only publicly available data. A complete analysis to determine the potential benefits of commercial closures to recreational fisheries should be conducted before there implementation, and would include several further studies which are outlined below.

A large proportion of the recreational fishery in Queensland for whiting, barramundi and snapper is catch and release (78.5% of barramundi, 76.2% of snapper and 36% of whiting were released in 2010), suggesting that the impact of the recreational fishery may be able to

support much higher recreational catches and catches of larger individuals. However, catch and release fisheries rely on low mortality rates after release and release mortality varies greatly by species (ref). Many species in Queensland are thought to survive well after release (e.g. XXX, XXX), however recent evidence questions the methods used to estimate fish survival (e.g. Billfish paper). Including mortality from catch and release fishing in the estimates of harvested biomass increases the proportion of the harvest taken by recreational fisheries by … [NB: to do] (Fig 1). Release mortality is therefore a key consideration when deciding if commercial closures will benefit recreational fisheries.

An unknown source of mortality for fish populations in Queensland is by-catch. Commercial operations use nets, whereas recreational fishing primarily use hook and line, although recreational seine netting is also permitted (Government 2016). Commercial net operations likely have higher by-catch of juvenile and undersize fish than recreational fisheries. However, the catch rates of undersize fish in the recreational fisheries are unknown, as is the potential discard mortality. Thus a complete assessment of recreational fisheries closures should consider an assessment of mortality of both sectors across fish stages.

The coastal waters of Queensland already have net fisheries closures that can be used to assess the relative impact of recreational and commercial fishing on some key sport species. For instance, in the Great Barrier Reef Marine Protected Area (GBRMPA) there are no-take green zones and limited use yellow zones, which allow some types of recreational fishing, but exclude net fishing and trawl fishing (Authority). While the GBRMPA's yellow zones are less extensive than Queensland's new recreational fishing areas and cover different habitats, assessment of fish biomass in these zones relative to fished zones could be used to indicate the influence of recreational fishing pressure.

A further reason that recreational fishing areas do not support significantly larger fish populations is that coastal ecosystems are commonly also impacted by development and run-off of pollutants. In Queensland run-off of sediment, nutrients and pesticides from agriculture are a major threat to the habitats and fish populations of the Great Barrier Reef Marine Protected Area (Fabricius et al. 2005, De'ath and Fabricius 2010). The recent development of ports for coal and gas are also an emerging threat (Grech et al. 2013, Grech et al. 2015). In these industrialised bays coastal development may be a major driver of ecosystem health with commercial fishers playing a relatively minor role.

Further, productive recreational fisheries may accelerate depletion, because recreational fishing effort often increases in response to improved fishing (ref). Thus, the benefits of recreational fishing areas may be short-lived.

3. Ecosystem impact of recreational fishing only areas

Closures of commercial fisheries may affect ecosystems beyond just recreationally caught species. Ecological change could feed-back to recreational target species, contributing to either increases or declines in populations. For instance, the commercial Barramundi fishery in Northern Queensland uses nets, which by-catch predatory finfish and sharks. The ecological effects of reducing fishing mortality on predators are unknown in Queensland's coastal ecosystems, however ecological change as a result of commercial closures can have unintended ecological consequences on marine ecosystems (Brown and Trebilco 2014). For instance, by-catch of fin-fish in commercial trawl fisheries for invertebrates may have reduced predation pressure on the invertebrates and enhanced their productivity (Thurstan and Roberts 2010). Such cultivation effects have not been documented in Queensland, however,

the risk of unintended consequences should be considered when making decision to close fisheries.

Recreational fishing areas may contribute toward objectives for ecosystem conservation, although that is not a stated goal for Queensland's latest closures. Many coastal bays are poorly represented in no-take protected areas, which are the typical management tool for ecological conservation (Devillers et al. 2015). Importantly, many of the key migration pathways of estuarine fish from inshore to offshore may be missed in current reserve networks (Englehard *et al.* submitted). Thus, the ecological effects of closing commercial fisheries, but maintaining recreational fisheries, should also be assessed by environmental protection agencies. Recreational fishing areas could form an important part of strategies to representatively protect coastal habitats, but be more politically straightforward to implement than full no-take closures.

Recreational fishing areas may facilitate broader changes in coastal societies that benefit the environment and fisheries in general. For instance, recreational fishing areas can give a greater number of people a vested interest in environmental health (Young et al. 2016). To date in Queensland recreational fishers have generally opposed environmental protection efforts (Pascoe et al. 2014). However, the threats coastal development and agricultural run-off pose to coastal ecosystems may see fisher and conservation perspectives align, although it should be noted that many recreational fishers may be employed in the agriculture and building sectors. Recreational fishers potentially represent a large lobby group with increased power to require ecologically sustainable development.

4. Socio-economic costs and benefits from recreational fishing only areas
a cynical view might hold that the ultimate political aim of commercial closures is to gain votes from recreational fishers, who typically make up a larger proportion of the constituency.

The socio-economic impacts of recreational fishing areas are complex and extend beyond just the fishers themselves. The closures will decrease the profitability of commercial fishing operations, at least in the short-term, and impact upon the livelihoods of commercial fishers. However, the closures may potentially create new economic opportunities in charter fishing and associated tourist industries. There may also be a broader societal impact of the closures by affecting the availability of locally caught seafood in markets. Each of these impacts is examined below.

Recreational fishing areas will come at a cost to the commercial fishing industry and impact upon fishers livelihoods and associated industries, such as seafood processing. In Queensland commercial inshore fishers have been increasingly marginalised by numerous legislative changes to fishery management over the past two decades. These changes include re-zoning of the Great Barrier Reef marine protected area to increase the coverage of no-take areas (ref), creation of the Moreton Bay marine park (Van De Geer et al. 2013), compulsory license buy-backs in some regions and now spatial closures of commercial net fishing. Development of ports in some regions, like Gladstone, may also have caused environmental degradation that has impacted the viability of commercial fisheries (Grech et al. 2013).

The cumulative impact of these legislative changes on commercial fisheries may be greater than the sum of their parts, because a small loss in profits from any one of these changes may put individual fisheries beyond their profit margin. For instance, some analyses that informed the re-zoning of the Great Barrier Reef marine protected area have been criticised for simplistic assumptions about profit losses and fishery stock recovery (ref). The industry

impact of the rezoning may have been greater than expected for some sectors. For instance, Barramundi fishers rely on service barges where they sell catch and replenish supplies for extended trips (ref). A small decrease in profits, even in the short-term, can mean these barge operations are not financially feasible (ref). If the barges stop operation then the fishery must also close over a large area, as was the case in some parts of the Great Barrier Reef marine protected area (ref). Thus, new legislation to reduce commercial fishing opportunities should be assessed in the context of historical legislation.

Recreational fishing areas can improve coastal economies by supporting gear shops and charter fisheries, the economic value of which can exceed the value of commercial fisheries (Pascoe et al. 2014). In Queensland, one objective of the recreational fishing areas is to create a successful charter industry like that seen in other states (e.g. Northern Territory – ref). In such cases, the commercial fishers who have sold-out their licenses can sometimes find renewed employment as charter operators (ref). However, development of a charter industry relies on other services to support tourism and marketing and entrepreneurs who are willing to risk the cost layout of setting up a charter operation (ref). While there are plenty of facilities to support tourism in the locations to date there has been no government investment to facilitate charter businesses or marketing. Such investment is a priority if the closures are going to be matched with increased economic opportunities in charter fisheries.

While enhanced recreational opportunities may benefit people in coastal towns, the reduced availability of locally caught fish in markets may have a broader societal impact. Increasing aquaculture products on markets may be displacing some wild-caught products. This is creating increased competition for local fishers, particularly where they are competing against cheap imported aquaculture, such as for Barrumundi (ref). Further reductions in supply of local fish to markets from fishery closures may worsen competition for local producers and make it harder for consumers to purchase locally produced fish in markets. Thus, while closures of commercial fisheries may benefit local environments, the environmental impact of fish consumption is exported to elsewhere.

5. Management of successful recreational fisheries

Management agencies are not well equipped to limit over-exploitation of fish stocks by recreational fisheries (Sutinen and Johnston 2003, Coleman et al. 2004, Abbott 2014). The large number of participants in recreational fisheries where access can be effectively unlimited risks the tragedy of the commons in areas managed solely for recreational fishing. Current strategies of gear restrictions and limiting fishing seasons have proven inadequate in other regions where participation has increased (ref). Closing commercial fisheries is unlikely to help improve the management of recreational fisheries, particularly if improved fishing sees greater participation in the recreational fishery. If recreational fisheries are poorly managed, Queensland is unlikely to see long-term economic and social benefits from recreational fishing areas.

There is a consensus in the academic literature that the management of recreational fisheries needs to move beyond seasonal closures, size limits and gear limits. A complementary approach to managing recreational fisheries could be to grant individuals or fishing groups property rights (Sutinen and Johnston 2003) and to co-manage fisheries with fishers. However the exact structure of property-rights and co-management for recreational fisheries is still debated in the academic literature (Sanchirico et al. 2010, Abbott 2014). Further, management agencies have been reluctant to consider property rights for recreational

fisheries due to legislative barriers, political implications and administration costs (Ford and Gilmour 2013).

In the case of Queensland, several steps could be taken towards property rights in recreational fisheries and aid in the management of recreational fisheries, without requiring legislating 'strong' property-rights (sensu Sutinen and Johnston 2003).

(1) Recreational catches and the status of key recreational fish stocks should be monitored. Queensland currently has only conducted two recreational fisheries surveys in 2003 and 2009 (refs). These need to be more frequent, particularly for key species like Barramundi. Further, the status of key recreational fisheries should be directly monitored. For instance, numerous approaches for small-scale fisheries are emerging that are cost-effective, such as size-based monitoring from catches (e.g. Hordyk et al. 2015). Such monitoring is unlikely to be met with significant public opposition and only requires greater resources for fishing agencies to monitor catches and stocks.

(2) Recreational catches should be integrated with commercial catches in harvest limits. Full integration has proven difficult in other nations, for instance in New Zealand, legislation that sought to ascribe recreational fishers a portion of the annual total allowable catch failed due to opposition from recreational fishers (Borch 2010). At the very least however, it is important to document if scientifically allowable catches are being exceeded because of overcapacity in the recreational sector, to allow public discussion of the issues.

(3) Plans for future recreational fishing closures should be considered in the context of existing marine and coastal plans. For instance, fishing groups have proposed that Moreton Bay in South-East Queensland also be closed to commercial net fishing (ref). Such a proposal should be assessed against the effectiveness of existing marine park in the Bay that was implemented in 2009. If recreational fishing areas have higher fish biomass, then presumably there is the potential for spill-over of fish into commercially fished areas, allowing greater commercial catch. Further, coastal development is also likely to impact fishery species, however its effects are largely unknown.

(4) Recreational fishing areas should be matched with schemes to educate fishers about fishery science and the need to limit harvest. Recreational fishers may overall have a lower literacy in fishery science and a poorer understanding of system dynamics than commercial fishers. Involvement of commercial fishers in decision making increases buy-in to new regulations and may thus facilitate enforcement and also contributes to educating fishers about fishery science and the need for regulation. Further, commercial fishers spend much of their lives on the water, so have good intuitive understanding of system dynamics. The greater number of participants in recreational fishing and the inconsistent participation for many means that education of recreational fishers is more challenging. Education schemes have been used effectively in the past, for instance with the rezoning of the Great Barrier Reef Marine Protected Area.

(5) One way to better educate recreational fishers is to involve them in management decision making. Co-management, where fishers and managers jointly monitor and make decisions about a fishery has proven a highly successful means to manage fisheries in many contexts (Cinner et al. 2012). Investment in recreational fisheries from government should focus on building co-management initiatives (Sutinen and Johnston 2003). Recreational fishing areas could become focal points for implementing co-management with recreational fishers. The greater number of people precludes the approach used for commercial fisheries with Regional

Assessment Group meetings, except perhaps with members from fishing clubs. Instead, innovative approaches are needed to involve larger numbers of people in decision making. For instance, social media could be used to census fishers on new seasonal closures, at the same time as providing information over why closures may be necessary (ref).

(6) Fishery management agencies should also look for ways to involve recreational fishers more closely in data collection and monitoring. Web-based citizen science initiatives are increasingly being successful at collecting usable data from citizens in Australia, for instance the platforms Redmap for marine range-shifting species have both been used to inform science (Robinson et al. 2015). Proof of concept web-programs for recreational fisheries have also been shown to provide data on areal use that is consistent with standard surveys (Papenfuss et al. 2015).

6. Key questions for recreational fishing areas

The issues raised in this article suggest a number of questions that should be addressed when deciding whether recreational fishing areas are warranted from environmental and social perspectives. Further, plans also need to be made for the management of recreational fishing effort within recreational fishing areas, to ensure the quality of recreational fishing is sustained. The article concludes with recommendations for key questions that should be addressed when proposing new recreational fishing areas

(1) First, it should be assessed whether commercial fisheries are significant contributors to fish mortality relative to recreational fisheries. If recreational fisheries are the major driver of stock dynamics, then the focus should be on improving the management of recreational fisheries. In Queensland, such an assessment could include analysis using existing stock assessment models and recreational fisher surveys. Comparison of fish biomass in across different types of spatial zones (open, restricted and closed) could also inform on the likely effectiveness of recreational fishing areas.

(2) The long-term feasibility of recreational fishing areas should be reviewed. Such a review should include the likely environmental impacts of removing commercial fishing, environmental change from other threat, such as coastal development, and the potential for increased future recreational participation to overexploit fish stocks.

(3) Recreational fishing areas have broader ramifications for society beyond commercial livelihoods as they may also affect fish processing industries and the availability of local fish product in markets. The societal and flow on economic impacts of reducing commercial catch should be evaluated and discussed in public forum.

(4) New recreational fishing areas should be matched with initiatives for the management of recreational fishing effort and efforts to promote marine stewardship among recreational fishers. Such efforts should include education of recreational fishers about sustainable fishing, and joint monitoring and decision making shared by management authorities and recreational fishing groups.

Large-scale closures of commercial fisheries to benefit recreational fisheries signals a shift in the way nations like Australia are exploiting their coastal resources. This shift needs to be accompanied by evaluation and monitoring so that society can avoid making the same mistakes in fishery management that lead to the tragedy of the commons in the past.

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