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

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Abstract

Recreational fishing mortality can have a major impact on coastal fish populations, bringing recreational fishers into conflict with commercial fisheries. This article reviews exclusion zones for commercial fishing, or 'recreational fishing areas' as a solution to the conflict between commercial and recreational fisheries. Recently designated recreational fishing areas in the state of Queensland, Australia are examined as a case-study. The goal of recreational fishing areas is to enhance recreational fishing and provide economic opportunities through charter fishing. However, recently designated recreational fishing areas in Queensland have not been thoroughly assessed for their social, economic and environmental impacts and they are not integrated within existing management frameworks for fisheries. The designation of recreational fishing areas is thus a shift away from evidence-based management in Queensland's fisheries and has likely occurred solely for political reasons – there are more voters in the recreational fishery than commercial fishery. In Queensland, excluding commercial fishing on its own is unlikely to result in long-term benefits to recreational fisheries because recreational harvest is a major component of fish harvest for some key species and there is no legislated limit to recreational harvest. Current political attention on recreational fishing areas provides an opportunity for fisheries managers, politicians, conservation groups and the public to discuss what is needed to manage sustainable coastal fisheries. In particular, 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, catch and release, *Lates calcarifer, Chrysophrys auratus*, property rights, spatial marine zoning.

1. Introduction

The approaches used to manage recreational fisheries are decades old and failing to avoid overexploitation of coastal fish populations [1-3]. 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 [4]. In contrast to recreational fishery management, the management of commercial fisheries has improved markedly over the last several decades [e.g. 5, 6-8]. 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 [6, 8, e.g. 9, 10]. Commercial fishery management

has thus seen some recent successes with enhanced profits in some regions [e.g 11] and the recovery of some depleted fish stocks [e.g. 12].

Recreational and charter fishing (hereafter 'recreational fisheries') play a large role in influencing the productivity of many coastal fish stocks [1, 13], bringing recreational fishers into conflict with commercial fisheries [4, 14]. 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 and bays popular with recreational fishers [15]. Similar closures are also being implemented in other states [16]. The aim of these closures is to benefit recreational fishers with 'more fish, bigger fish' [17], reduce competition between commercial and recreational fishers for access to fishing sites and also grow local economies by improving opportunities for charter fishing [18]. These spatial closures do not affect all commercial fisheries and are targeted at net fishing, which in some areas overlaps in target species with recreational fishing and in other areas is viewed as impinging on recreational users accessing fishing sites. However, in Queensland the state government did not published any assessments of whether planned spatial closures of commercial fisheries would improve recreational harvest or access, or assessments of additional environmental and economic impacts. Further, the closures are 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 [19].

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 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 [15, 16], 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 goal of commercial net fisheries closures in Queensland is to enhance recreational fisheries by reducing pressure on fish stocks from commercial harvest [18]. 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. Finally, there may be access and aesthetic benefits to recreational fishing if commercial fisheries are closed. For instance, recreational and commercial fishers may compete for the same boat ramps, or recreational fishers may view the bycatch of commercial

net fisheries as wasteful. 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.

Closing a commercial fishery is only likely to increase recreational harvest if commercial harvest is large relative to recreational harvest, however recreational fishing can be a significant pressure on coastal fish stocks [e.g. 1, 2, 3]. In Queensland stock assessments for Tailor found that recreational harvest is ~10 times commercial harvest and there is concern that the current rate of harvest mortality will result in recruitment overfishing [20]. Further an assessment of recreational fishing pressure in 2010 found that across the state of Queensland, recreational harvest exceeded commercial harvest for some key recreational species, including Tailor and Snapper (*Chrysophrys auratus* formerly *Pagrus auratus*), but not for other species including Barramundi (*Lates calcarifer*) and Whiting (*Sillago spp.*) [21].

An analysis of Queensland's commercial and recreational harvest focussing on regions with designated and proposed recreational fishing areas indicates that recreational harvest is a significant contributor to mortality for some popular recreational species (Fig. 1, data from [22]). For instance, the harvested biomasses of Whiting (*Sillago spp.*) in recently designated closed areas off of Rockhampton and a proposed closed area in Moreton Bay are similar between commercial netting and recreational sectors. In Mackay commercial harvest of Barramundi (*Lates calcarifer*) exceeds recreational harvest, but around Cairns recreational catch (including released fish) was almost 3 times commercial harvest by net fisheries. In Moreton Bay, recreational harvest of Snapper (*Chrysophrys auratus*) was an order of magnitude higher than commercial harvest in nets. In Moreton Bay recreational catch of Tailor was similar between commercial and recreational fisheries, but most recreationally caught Tailor were released. Thus, closing commercial fishing may increase stock biomass, but the management of recreational harvest is an equally important concern.

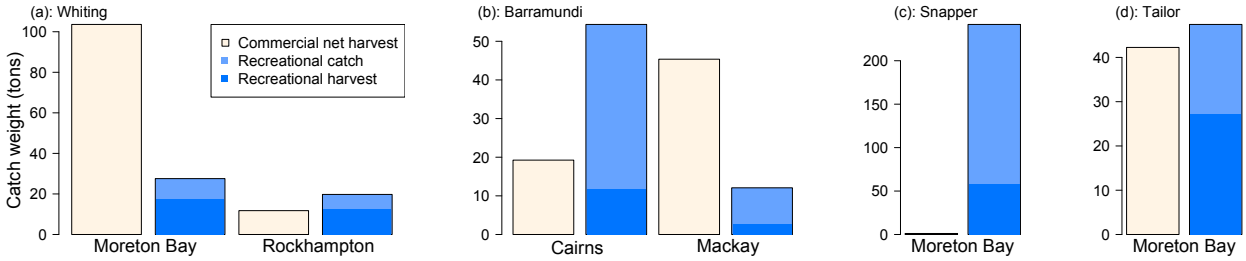

Fig 1. Harvest of (a) Whiting (Sillago spp.), (b) Barramundi (Lates calcarifer), (c) Snapper (Chrysophrys auratus) and (d) Tailor (Pomatomus saltatrix) by commercial net and recreational fisheries in Queensland for 2010 in areas that have designated or proposed commercial net fisheries closures. Data for commercial harvest are from [22] (2010-11 financial year) and recreational harvest from [21]. Graphs are for 2010 using zones from [21] 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 catch was converted to biomass using the estimates of mean fish weight from Taylor, Webley and McInnes [21]. Recreational catch was estimated by multiplying harvest by proportion retained Taylor, Webley and McInnes [21].

3. Steps that should be taken for a complete assessment of recreational fishing areas

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 their implementation, and should include several further considerations, which are outlined below.

(1) The effectiveness of recreational fishery areas will depend on catch and release mortality. 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 43% of Tailor and 36% of Whiting were released in 2010 [21]), suggesting that an exclusive recreational fishery may be able to support much higher catch rates than a mixed commercial and recreational fishery. However, catch and release fisheries rely on low mortality rates after release and release mortality varies greatly by species [23, 24]. For instance, for Snapper it is 30% whereas for Tailor release mortality is 8%. Including mortality from catch and release fishing in the estimates of harvested biomass could increase the proportion of harvest in the recreational sector considerably for sensitive species. Release mortality is therefore a key consideration when deciding if commercial closures will benefit recreational fisheries.

(2) By-catch mortality in the recreational and commercial fisheries needs to be accounted for across life-stages. By-catch is an unknown source of mortality for fish populations in Queensland. Commercial operations use nets, whereas recreational fishing primarily use hook and line, although recreational seine netting is also permitted [25]. 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.

(3) Existing net closures could be used to assess the likely long-term effectiveness of new closures. 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 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 [26]. Assessment of fish biomass on protected reefs relative to fished zones could be used to indicate the influence of recreational fishing pressure.

(4) The susceptibility of recreational fishing areas to other human threats should be assessed. In particular, the coastal ecosystems most popular for recreational fishing (and thus most likely to be designated as recreational fishing zones) are typically in close proximity to human settlement and industry. For instance, in Queensland run-off of sediment, nutrients and pesticides from agriculture are known to be a major threat to the habitats and fish populations of the Great Barrier Reef Marine Protected Area [27-29]. The recent development of ports for coal and gas are also an emerging threat to estuaries, bays and reef ecosystems [29-31]. In these industrialised bays coastal development may be a major driver of fish populations with commercial fishers playing a relatively minor role, thus closing commercial fisheries may not improve recreational fishing.

(5) Whether fish stocks can sustain current and future levels of recreational fishing effort should be assessed. Participation in recreational fishing is increasing in many nations [e.g. 14], and participation may further increase if fishing improves, eventually negating short-term increases in fish populations. In Queensland, recreational fishing participation may have declined slightly between 2000 and 2014 [21, 32]. However the phone surveys used to

196 estimate participation in the recreational fishery may be biased by the switch to mobile
197 technology in that time [21, 33]. Regular surveys or licensing are required to keep track of
198 recreational fishing effort. Alternative methods to phone surveys, such as surveys at fishing
199 stores [33] or surveys that exploit social networks [34] could also provide a more complete
200 assessment of recreational fishing effort.
201
202 **4. Ecosystem impact of recreational fishing only areas**
203
204 Closures of commercial fisheries may affect ecosystems beyond just recreationally caught
205 species. Ecological change could feed-back to recreational target species, contributing to
206 either increases or declines in populations. For instance, the commercial Barramundi fishery
207 in Northern Queensland uses nets, which by-catch predatory finfish and sharks. The
208 ecological effects of reducing fishing mortality on predators are unknown in Queensland's
209 coastal ecosystems, however ecological change as a result of commercial closures can have
210 unintended ecological consequences on marine ecosystems [35]. For instance, by-catch of fin-
211 fish in commercial trawl fisheries for invertebrates may have reduced predation pressure on
212 the invertebrates and enhanced their productivity [36]. Trophic cascade effects from fisheries
213 closures may be weak for Queensland's coral reef fisheries [37], however, the risk of
214 unintended consequences should be considered when making decision to close inshore
215 fisheries.
216
217 Recreational fishing areas may contribute toward objectives for ecosystem conservation,
218 although that is not a stated goal for Queensland's latest closures. Many coastal bays are
219 poorly represented in no-take protected areas, which are the typical management tool for
220 ecological conservation [38]. Importantly, many of the key migration pathways of estuarine
221 fish from inshore to offshore may be missed in current reserve networks [39]. Thus,
222 assessment of the ecological effects of closing commercial fisheries, but maintaining
223 recreational fisheries, should also be of interest to environmental protection agencies.
224 Recreational fishing areas could form an important part of strategies to representatively
225 protect coastal habitats, but be more politically straightforward to implement than full no-
226 take closures.
227
228 Recreational fishing areas may facilitate broader changes in coastal societies that benefit the
229 environment and fisheries in general. For instance, recreational fishing areas can give a
230 greater number of people a vested interest in environmental health [40]. To date in
231 Queensland recreational fishers have generally opposed new no-take reserves [41]. However,
232 the threats coastal development and agricultural run-off pose to coastal ecosystems may see
233 fisher and conservation perspectives align. Recreational fishers potentially represent a large
234 lobby group with increased power to lobby for ecologically sustainable development.
235
236 **5. Socio-economic costs and benefits from recreational fishing only areas**
237
238 The socio-economic impacts of recreational fishing areas are complex and extend beyond just
239 the fishers themselves. The closures will decrease the profitability of commercial fishing
240 operations, at least in the short-term, and impact upon the livelihoods of commercial fishers.
241 However, the closures may potentially create new economic opportunities in charter fishing
242 and associated tourist industries. There may also be a broader societal impact of the closures
243 by affecting the availability of locally caught seafood in markets. Each of these impacts is
244 examined below.
245

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 [42], creation of the Moreton Bay marine park [43], compulsory license buy-backs in some regions [44] 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 [29, 31].

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 [45]. The industry impact of the rezoning may have been greater than expected for some sectors [but see also 46]. For instance, declining catches combined with buy-backs may cause closures of fish producers [44], so fishers lose the market for the remaining catch they take.

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 [41]. In Queensland, one objective of the recreational fishing areas is to create a successful charter industry. In such cases, the commercial fishers who have sold-out their licenses may find renewed employment as charter operators. 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. 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 [47, 48]. This is creating increased competition for local fishers, particularly where they are competing against cheap imported aquaculture, such as for Barramundi. 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.

6. Management of successful recreational fisheries

Management agencies are not well equipped to limit over-exploitation of fish stocks by recreational fisheries [1, 4, 49]. 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 for managing recreational fisheries in other regions where participation has increased [1, 14]. Further, closing areas to commercial fishing is an implicit decision to apportion a greater share of the catch to recreational fishing and may erode total allowable catch limits. Closing commercial fisheries is thus unlikely to help improve the management of recreational fisheries, particularly if improved fishing sees greater

297 participation in the recreational fishery. If recreational fisheries are poorly managed,
298 Queensland is unlikely to see long-term economic and social benefits from recreational fishing
299 areas.
300
301 There is a consensus in the academic literature that the management of recreational fisheries
302 needs to move beyond seasonal closures, size limits and gear limits. A complementary
303 approach to managing recreational fisheries could be to grant individuals or fishing groups
304 property rights [4] and to co-manage fisheries with fishers. However the exact structure of
305 property-rights and co-management for recreational fisheries is still debated in the academic
306 literature [19, 49]. Further, management agencies have been reluctant to consider property
307 rights for recreational fisheries due to legislative barriers, political implications and
308 administration costs [50]. Recreational fishers are also likely to strongly oppose increased
309 management efforts which they see as impinging on their right to 'get away from it all' [14].
310
311 In the case of Queensland, several steps could be taken towards property rights in
312 recreational fisheries and aid in the management of recreational fisheries, without requiring
313 legislating 'strong' property-rights [sensu 4].
314
315 (1) Recreational catches and the status of key recreational fish stocks should be monitored.
316 Queensland's most recent recreational fisheries surveys were in 2000, 2010 and 2014 [21,
317 32]. Closing commercial fisheries will increase the relative influence of recreational fishing
318 mortality on fish populations. Because recreational fishing mortality is commonly unknown
319 this will increase uncertainty in stock status. Surveys of recreational fisheries need to be more
320 frequent. Further, the status of key recreational fisheries should be directly monitored. For
321 instance, numerous approaches for small-scale fisheries are emerging that are cost-effective,
322 such as size-based monitoring from catches [e.g. 51]. Such monitoring is unlikely to be met
323 with significant public opposition and only requires greater resources for fishing agencies to
324 monitor catches and stocks.
325
326 (2) Recreational catches should be integrated with commercial catches in harvest limits. Full
327 integration has proven difficult in other nations, for instance in New Zealand, legislation that
328 sought to ascribe recreational fishers a portion of the annual total allowable catch failed due
329 to opposition from recreational fishers [14]. At the very least however, it is important to
330 document if scientifically allowable catches are being exceeded because of overcapacity in the
331 recreational sector, to allow public discussion of the issues.
332
333 (3) Plans for future recreational fishing closures should be considered in the context of
334 existing marine and coastal plans. For instance, fishing groups have proposed that Moreton
335 Bay in South-East Queensland also be closed to commercial net fishing [52]. Such a proposal
336 should be assessed against the effectiveness of existing marine park in the Bay that was
337 implemented in 2009 [43]. If recreational fishing areas have higher fish biomass, then
338 presumably there is the potential for spill-over of fish into commercially fished areas,
339 allowing greater commercial catch. Further, coastal development is also likely to impact
340 fishery species, however its effects are largely unknown.
341
342 (4) Recreational fishing areas should be matched with schemes to educate fishers about
343 fishery science and the need to limit harvest. Recreational fishers may overall have a lower
344 literacy in fishery science and a poorer understanding of system dynamics than commercial
345 fishers [14]. Involvement of fishers in decision making increases buy-in to new regulations
346 and may thus facilitate enforcement and also contributes to educating fishers about fishery
347 science and the need for regulation. For instance, recreational fishers often underestimate the

cumulative impacts of recreational fishing on fish stocks [53]. The greater number of participants in recreational fishing, combined with many participants being only occasional fishers, means that education of recreational fishers is more challenging. However, public consultation and education was effective in the rezoning of the Great Barrier Reef Marine Park [42], so similar efforts could be applied to educate fishers about the new recreational fishing areas.

(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 [54]. Investment in recreational fisheries from government should focus on building co-management initiatives [4]. 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. Survey methods that exploit social networks, like chain-referral methods, could be an effective way to both contact recreational fishers for consultation and to distribute surveys for monitoring [34].

(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 platform Redmap for marine range-shifting species has been used to inform science [55]. Proof of concept web-programs for recreational fisheries have also been shown to provide data on areal use that is consistent with standard surveys [56].

6. Recommendations for the assessment and implementation of 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 that fishing quality is sustained. The article concludes with recommendations for key questions that should be addressed when proposing new recreational fishing areas

(1) 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 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 threats, 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 quantitatively evaluated so that discussions in the public forum can be based on evidence.

(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 led to the tragedy of the commons in the past.

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