Assessment of novel gear designs to reduce interactions between species of conservation interest and commercial fishing nets

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Acknowledgments

In developing this project significant consultation took place initially with Mr John Page of the Moreton Bay Seafood Industry Association (MBSIA). John, like many commercial fishers, is conscientious about conservation and is continually looking to identify and develop fishing techniques and gears that promote a safe, efficient and ethical fishery. Consultation also occurred with the Queensland Seafood Industry Association (Winston Harris, Eric Perez, and Scott Wiseman), Queensland fisheries and conservation management agencies (Mark Lightowler, Queensland Department of Employment, Economic Development (DEEDI); Rachel Pears, Great Barrier Reef Marine Park Authority (GBRMPA); and Jim Higgs, Department of Natural Resources and Mines (DNRM)), and expert scientists (Ian Halliday, DEEDI and Colin Simpfendorfer, JCU). Initial discussions were also held with Michael Tudman (Manager, Bycatch Reduction Program, AFMA) about possible project benefits to the ongoing concern of Australian sea lion incidental capture (mortality) in nets of the Southern and Eastern Scalefish and Shark fishery. We are also grateful to the fishers, managers and conservation groups who took time to participate in the project workshops, and to the fishers for their honesty and hospitality and who agreed to be interviewed as part of the project.

Executive Summary

This project tested modified gillnets designed by commercial net fishers in the Queensland East Coast Inshore Finfish Fishery (ECIFF) to try and identify gears that would mitigate and/or improve interactions between fishing nets and Species of Conservation Interest (SOCI). The study also documents previously unrecognised initiatives by pro-active commercial net fishers that reflect a conservation-minded approach to their fishing practices, which is the opposite of what is perceived publicly.

Between 2011 and 2014, scientists from James Cook University and the Queensland Department of Agriculture and Fisheries teamed with commercial fishers representing the Queensland Seafood Industry Association and the Moreton Bay Seafood Industry Association to conduct field trials of various modified net designs under normal fishery conditions. Trials were conducted in Moreton Bay (southern part of the fishery) and Bowling Green Bay (northern) and tested different net designs developed by fishers to improve the nature of interactions between net fishing gear and SOCI.

Background

There is a regulatory mandate for governments and communities to help conserve SOCI and to manage threats. An increase in dugong mortalities on the Queensland east coast during 2009 and 2010, and increased media coverage of these, resulted in increased concern of their population status and on the impacts that net fishing may be having. Simultaneously, some commercial fishers had been experimenting with alternative net designs to mitigate negative interactions with dugong and other SOCI. This provided the opportunity to combine the scientific and fishery expertise to comprehensively test these designs to ultimately help conservation efforts.

Objectives

The project set out to develop a close working partnership between scientists and commercial fishers to collaboratively identify and develop modified net designs appropriate to the different fishery operations found along the coastline, which might decrease the likelihood of SOCI net entanglement. We then wanted to test the performance of these nets in improving the nature of SOCI interactions, but also to ensure that the fishery performance (catch rates of target species, bycatch and discards; value of the catch) of each design was not compromised compared to standard nets used in the fishery. Subsequent to the field trials being conducted, commercial fishers urged the project to ascertain the range of bycatch mitigation strategies adopted independently by industry through surveys. Therefore, we also conducted fisher interviews to identify and document the range of voluntary initiatives that fishers had been adopting to improve fishery interactions with SOCI, so as to potentially identify strategies that could be effective for other fishers to adopt and/or that further research may explore.

Methodology

Field trials were conducted under normal fishing conditions and practices with local commercial fishers in Moreton Bay in southern Queensland and in Bowling Green Bay near Townsville in northern Queensland. A scientific observer was present on each trip to record relevant data for the different net designs. In Moreton Bay a single 800-m general purpose net was used with four 100-m panels of the standard net used locally (control) alternating with four 100 m panels of one of the modified net designs, the breakaway panel (BAP) net. This net uses lighter twine attaching net panels to head and foot ropes to allow large animals to ‘break’ through short sections of the net.

In Bowling Green Bay, we used three separate nets of 120 m length, each of a different design. The three designs were: 1) the low-profile (LPN) net which is anchored at each end from the head rope and designed to allow large animals to push *under* the net. This is the standard net used locally and therefore was treated as the control; 2) the BAP net; and 3) the Push-over net (PON) which is anchored at each end from the foot rope and designed to allow large animals to push *over* the net. Data were recorded for each net and analysed to compare SOCI interactions as well as metrics of fishing performance.

We also conducted interviews with selected fishers in the ECIFF to establish what voluntary changes they had adopted over the years in attempts to mitigate interactions with SOCI while fishing. In doing so we were also able to identify fisher perceptions about SOCI generally and how they relate to other local issues. Results from the interviews should not be seen as representative of the fishery but rather a snapshot of the range of views expressed by Queensland net fishers about the issue SOCI, and examples of fisher initiatives to attempt to minimise interactions with SOCI during their day-to-day fishing operations.

Key findings

The project was able to prove that the concept of the BAP does work, however there were insufficient confirmed interactions with SOCI during the trials to adequately test that any of the modified net designs improve the nature of interactions with SOCI. Despite this, in the north we were able to show that the PON performed poorly compared to all other nets, and that the BAP net had similar catch rates of target species and a similar value of the catch compared to the local standard net (LPN). The BAP however did have higher catch rates of non-marketable species. In the south, the BAP had similar fishery performance to the local standard net when comparing all metrics.

From the fisher interviews, it was established that some commercial fishers have gone to great efforts to adapt their fishing practices to mitigate and improve the nature of any interactions with SOCI. Many fishers have manipulated their gear in a number of ways to achieve this by using shorter nets, tauter nets and lighter gear. However, most have adopted behavioural changes, mostly in where and when they go fishing to avoid SOCI. Consistent with previous reports and data, fishers also perceive that the risk level of interacting with SOCI, although variable among regions and depending on the species is generally very low. However, poor fishing behaviour is likely to increase this risk.

Therefore, it is fisher behavioural changes that are likely to be more effective in reducing interactions between fishing gear and SOCI, and certain gear changes are likely to help increase the likelihood of a positive outcome when an interaction does occur. Changes in behaviour, and not gear changes, are likely to have the greatest positive impact in addressing the issue of SOCI interactions with net fishing gear.

Implications

The project demonstrates the willingness and motivation of commercial net fishers in the ECIFF to strive to continually improve their fishing practices to be as ecologically friendly as possible, and will hopefully help to better educate non-commercial fishers of these efforts.

Experimental research to try and identify methods for mitigating fishery interactions with rare and/or threatened species can be challenging. More effective approaches are likely to be simple ones through the use of fisher developed Codes of Conduct and prolonged fisher education. For the ECIFF a regional approach would work best given the diversity of coastline and fishery operations, and needs fisher involvement and preferably leadership to engender stewardship.

Recommendations

Further development is required to further address issues around SOCI interactions with commercial fishing nets in the ECIFF:

- Better reporting and data for of SOCI interactions.

- Review of SOCI-related fishery regulations to ensure their effectiveness.
- Development of a Code of Conduct framework to extend to regional areas of the fishery.
- Better education and mentoring of commercial fishers on improved fishing practices (e.g. Great Barrier Reef Marine Park Authority's Reef Guardian Fisher Program).
- Better education of recreational fishers on the positive initiatives of commercial fishers in striving for best practice.
- Research to better understand fisher attitudes and perceptions of SOCI.

Keywords

SOCI, conservation species, net fishing, species interactions, modified net designs, fisher initiatives, fisher interviews, dugong, turtles.

Introduction

The unintended mortality of bycatch species in commercial fishing gears is a serious issue in many fisheries around the globe, particularly for species of conservation concern. Many coastal cetaceans and sirenians are naturally rare, and exposure to fishing may be high due to overlapping habitat preferences of the species and fishing areas. Due to the general low productivity of cetaceans and sirenians, even the occasional mortalities in fisheries may threaten populations (Read, 2008). For example, exposure to fishing has seen dugong (*Dugong dugong)* extirpated from most of its natural range with only a few relic populations remaining (Marsh et al., 2002). Similarly rare coastal dolphin species such as the Australian snubfin (*Orcaella brevirostris*) remain only in small regional populations and thus may be similarly vulnerable to local population extirpations.

In the absence of a demonstrable solution for minimising interactions between fishers and marine megafauna, management solutions are likely to resort to spatial or temporal closures. Indeed there are many global examples of the closure of productive fishing grounds in order to conserve marine megafauna. However, closures may have secondary impacts such as displacement of fishing effort to other areas, and reductions in catches resulting in impacts to social and economic benefits as well as food security. Rather than spatial or temporal closures, modifying fishing gear may be successful in avoiding unnecessary interactions with marine megafauna, while maintaining access to fishing grounds.

Bycatch mitigation strategies have been researched extensively in fisheries worldwide, historically with a focus on trawl and seine nets. Much of the past research on gillnets has been species-specific and focused on seabird bycatch (e.g. Werner et al, 2006), or turtle and cetacean species through the use of pingers (see review by Dawson et al, 2013). However bycatch mitigation in gillnets has received more attention in recent years (Uhlmann and Broadhurst, 2015), particularly in the context of multi-species fisheries.

Bycatch mitigation strategies examined for gillnet fisheries have included time-area closures, individual bycatch limits, gear modifications and buy-outs with varying effectiveness depending on many factors particular to the fishery in question (Senko et al, 2014). In their review of bycatch mitigation strategies for turtles, Gilman et al (2009) concluded that some of the most promising gear modifications for gillnets include: increasing gear visibility (but not to target species); reducing the vertical height of nets; increasing tie-down length or eliminating them; incorporating shark-shaped silhouettes; and modifying float configurations. Maldonado-Diaz et al (2011) demonstrated that bouy removal on gillnets reduced bycatch of loggerhead turtles due to the reduced effective vertical fishing height. Another potential gear modification is to increase the tension in the gillnet by using larger floats on the head rope, and increasing the weight in the leadline. Thorpe and Frierson (2009) trialled this modified gillnet design to assess the effectiveness in mitigating shark bycatch in two US coastal gillnet fisheries; Spanish mackerel (*Scomberomorus maculatus*) and the spot (*Leiostomus xanthurus*), and found that bycatch was reduced across several shark species regardless of their mode of entanglement. There are a range of other bycatch mitigation methods that can be deployed in gillnet fisheries including changes in twine size and material (Jensen 1995; Hovgard, 1996; Trippel et al., 2003; Gray et al., 2005), mesh size (Hamley, 1975) or net length (Rudstam et al., 1984; Acosta, 1994). Despite this, the efficacy and suitability of particular strategies will depend on the characteristics of the particular fishery.

One of the key bycatch species known to be taken in tropical and sub-tropical gillnet fisheries, for which very little mitigation work has been carried out, are the dugong (*Dugong dugon*) and manatees (*Trichechus* spp.) (but see Hodgson et al., 2007). They also represent a species group of global concern from a conservation perspective. Bycatch data for sirenians are extremely scarce and consist of observed catches and observations of animals with markings or gear attached suggesting they have come into contact with gillnets, however almost all of these are anecdotal only (Hodgson et al., 2007; Reeves et al, 2013).

Species of Conservation Interest (SOCI) refers to species classified as at-risk to some extent by a number of processes, and gillnets are regarded as one of these threats. In Queensland, these species include turtles (principally Family Cheloniidae), dugong, inshore dolphins (*Sousa chinensis* and *Orcaella heinsohni*), whales, sawfish (Family Pristidae) and some large sharks. Within Australia, the dugong is listed as 'vulnerable' under Queensland's *Nature Conservation (Wildlife) Regulation 2006*. The dugong is also listed as a 'protected species' under the *Great Barrier Reef Marine Park Regulations 1983*. The three most common marine turtle species on the GBRMP, loggerhead (*Caretta caretta*), green (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*), are listed as 'endangered', 'vulnerable' and 'vulnerable' respectively under the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act 1999)*. The two inshore dolphin species found along the GBRMP coastline are both listed as 'near threatened' under Queensland's *Nature Conservation (Wildlife) Regulation 2006* while the humpback whale (*Megaptera novaeangliae*) is listed as 'vulnerable'. All of these species are protected in Australia under the *EPBC Act 1999*.

In northern Australia, particularly in the Great Barrier Reef Marine Park (GBRMP) - a World Heritage Area, there are significant efforts to minimise impacts on the environment and on all species, especially on SOCI. In particular the Great Barrier Reef Marine Park Authority has developed a *Reef Guardian* program in partnership with commercial fishers to recognise and promote sustainable fishing practices (http://www.gbrmpa.gov.au/our-partners/reef-guardians/reef-guardian-fishers). The East Coast Inshore Finfish Fishery (ECIFF) includes a commercial gillnet sector that operates along the eastern Queensland coastline and is known to interact with SOCI, however information on the extent and nature of these interactions is scant.

Given their conservation status, and also that the fishery operates within a World Heritage Area, the development and testing of strategies for net fisheries that may minimise interactions between fishery gear and SOCI is a high research priority of the Great Barrier Reef Marine Park Authority, Fisheries Queensland and conservation groups such as the World Wildlife Fund. This project addresses some of these high priorities and also addresses one of the high priority research areas specified for inshore fisheries by the Queensland Fisheries Research Advisory Board for 2010. Effective mitigation using modified gear will minimise the need for urgent government intervention as seen in the Boyne River recently (http://www.cabinet.qld.gov.au/MMS/StatementDisplaySingle.aspx?id=74570).

Solutions for reducing fishery-related interactions and mortalities of SOCI requires an understanding of how and why the fishery interact with SOCI. Management of dugong interactions in the Qld ECIFF has been based on reducing total interactions rather than the nature of the interactions (e.g. improving the fate of an animal once an interaction has occurred). Previously, this has largely been achieved by implementing closed areas (e.g. 'Dugong Protection Areas' and the recently proposed 'Net Free

Zones') but other approaches could be considered, especially as fishers have indicated closed areas have excluded significant and highly productive areas to commercial fishing which has impacted the viability of some businesses. This has provided fishers with the motivation to explore alternative approaches to improving or minimising dugong and other SOCI interactions. Fishery-specific solutions are required, and the solutions are often best informed by the fishers themselves (Uhlmann and Broadhurst, 2015).

In the ECIFF fishers have developed innovative gillnet designs and fishing techniques based on their own experiences to reduce the likelihood of interactions with SOCI. However, these innovations are not documented and not well known outside the industry. From the wider perspective of government and conservation, rigorous testing of these designs and techniques are lacking meaning promoting such innovations as responsible practices is not possible. The motivation behind this project was largely driven by one such commercial fisher who operates commercial gillnets in Moreton Bay, southeast Queensland, an area with a large local population of dugong. Therefore this project was developed in direct consultation with net fisher Mr John Page of the Moreton Bay Seafood Industry Association (MBSIA), following preliminary trials of a modified gillnet design, and in response to perennial concern about incidental gillnet capture/entanglement of species of conservation interest (SOCI), such as dugong, dolphin and turtle. Although a similar concept has been used for many years to some extent in fisheries in the U.S. to mitigate whale entanglement in gillnet and lobster trap buoy lines, Mr Page independently conceived and self-trialled the main gear modification used during this study; referred to as the "breakaway panel" (BAP) (McPhee and Stone, 2008). This project follows on from these preliminary trials and addresses the FRDC strategic challenge #1 to "maintain and improve the management and use of aquatic natural resources to ensure their sustainability".

The weak link regulations (also sometimes referred to as "breakaway" nets) used in some U.S. gillnet fisheries were introduced for several Atlantic fisheries in 1997 following a number of interactions and mortalities with whales (Johnson et al., 2005; Werner et al., 2006). These were introduced as part of the Atlantic Large Whale Take Reduction Plan (ALWTRP) under Regulations of the U.S. Federal Register (NOAA, 1997). The U.S. breakaway design, although similar in concept, applies to gillnet and lobster trap fisheries and revolves around having a weak link in either the trap and net buoy lines and in float ropes between net panels. These weak links may include swivels, plastic weak links, lighter breaking strength rope sections, hog rings or rope simply stapled to a buoy stick (NOAA, 1997). At the time of implementation these measures were not tested for their effectiveness in the field however the regulations provided for such testing to be conducted. The specifications for weak links in these fisheries were revised in 2002 and 2007 and included for lobster traps: regulating for reductions in the breaking strength of weak links in buoy lines and, for gillnets: maximum breaking strength of weak links in gillnets, an increase in the number of weak links per gillnet, and greater specificity in where weak links need to be placed in gillnet panels, (NOAA, 2007; http://www.greateratlantic.fisheries.noaa.gov/protected/whaletrp/docs/Outreach%20Guides%20Updated%20May%202015/northeast_gillnet_2015.pdf). These changes were made following whale mitigation fishing gear research and consultation between government and industry (Salvador and Kenney, 2002).

The operational characteristics of U.S. Atlantic gillnet fisheries compared to the ECIFF are very different. In the U.S. gillnets are bottom set in deeper water using anchors and floats requiring very long float lines due to the depth and resulting in vertical tautness in the nets. The major bycatch concerns are large whales that get entangled in surface floats and float lines (Johnson et al., 2005; Werner et al., 2006). In the ECIFF, the nearshore fishery component we based our modified net trials in, are also bottom set and anchored gillnets, however the water depth is generally only 1-3 m and nets are not vertically taut thereby creating a ‘belly’ in the net when set (Harry et al., 2011; White et al., 2013). This design is optimal for catching key target species however allows large non-target animals to become entangled in the net without easily breaking free, potentially causing harm or death to the animal as it tries to free itself. This requires the fisher to interact with the animal to cut it free creating an unnecessary hazard to the fisher and the vessel. This also reduces the efficiency and profitability of the fishing gear due to damaged nets and time taken away from fishing. The BAP net works by having ‘collapsible’ panels that allows very large animals to push through rather than becoming entangled. The panels can be re-tied relatively easily therefore potentially minimising any impact on fishing efficiency.

This design was tested during preliminary trials in Moreton Bay during 2007/08 and 2009/10 in research conducted by the MBSIA with funding from DAFF, the GBRMPA, DEEDI and WWF, and resulted in no change in target species catch rates, while showing promise in reducing interactions with SOCI (McPhee and Stone, 2008). This study provided some evidence of the designs effectiveness however was based on only a limited number of net sets. A more comprehensive test of the design was therefore required before decisions could be made about promoting the design as possible preferred practice for use in inshore net fisheries in minimising negative interactions with SOCI.

In this report, we document field trials to test modified net designs, including the ‘breakaway panel’ described above. This was conducted under normal fishing conditions in the Queensland ECIFF in different regions where operational characteristics and target species differ. Although not part of the original proposed project, late in the project at the request of fishers we also conducted surveys of fishers to understand their perceptions of the risk of SOCI interactions along the coastline and document the different gears and behaviours that fishers have adopted over time to reduce negative interactions with SOCI.

Objectives

1. Identify alternate net designs and fisheries to which they may apply through an expert panel/workshop.
2. Assess the effectiveness of alternate net designs to minimise (negative) interactions with species of conservation interest.
3. Determine the impact of alternate net designs on "normal" fishery operation metrics for the Queensland east coast (e.g. target species catch rates, net maintenance).
4. Identify voluntary gear and behavior changes fishers have made in their fishing practices to reduce the likelihood and nature of interactions with SOCI[1].

[1] The original fourth objective was to extend the outcomes of net trials to fishers and potentially promote a particular gear modification to be adopted by the net fishery. This objective was changed in the latter part of the project at the request of commercial fishers.

Methods

The East Coast Inshore Finfish Fishery (ECIFF)

The targeted fishery for this research is known as the East Coast Inshore Finfish Fishery (ECIFF) and occurs off the east coast of Queensland, Australia between Cape York (10.5^0 S) and the southern state border (28.2^0 S)(Figure 1). Much of the fishery occurs within the boundaries of the Great Barrier Reef World Heritage Area (GBRWHA) that extends from Cape York (10.5^0 S) to Bundaberg (24.5^0 S). Operating within a WHA means the ECIFF is particularly well scrutinized regarding ecological impacts.

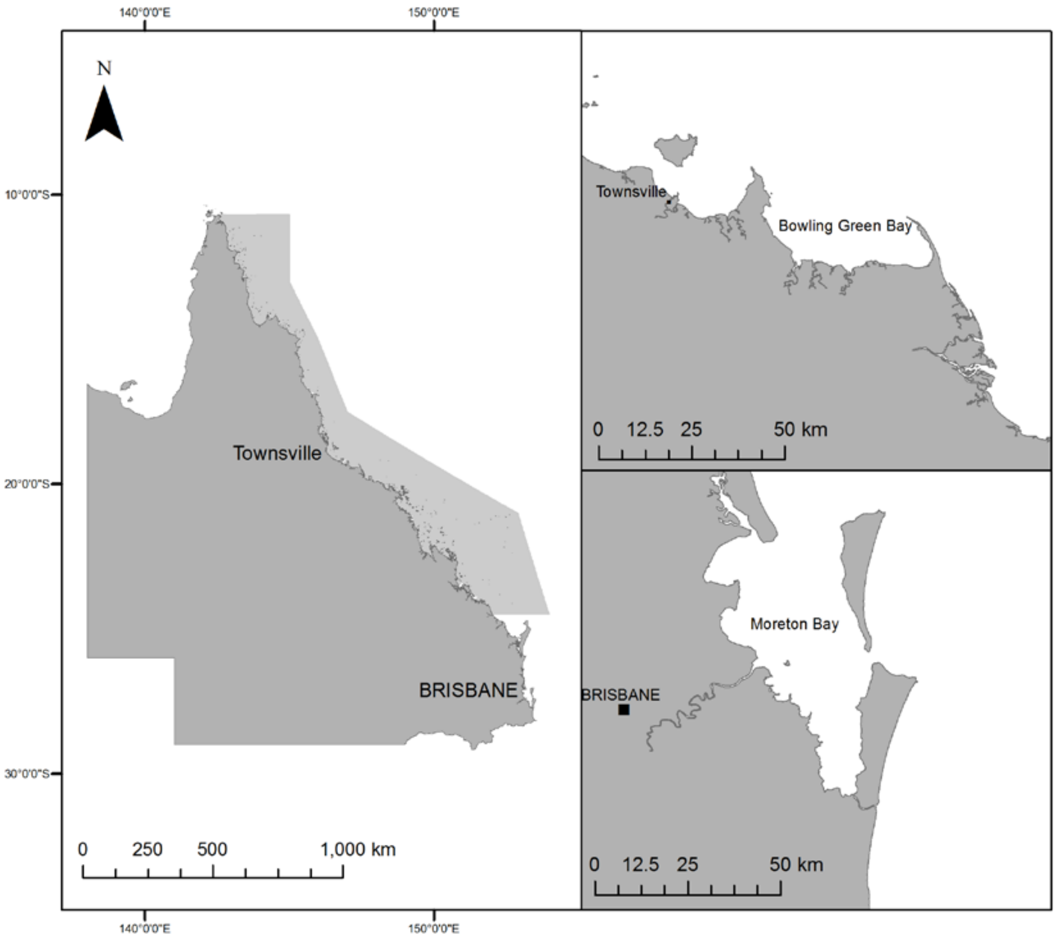

Figure 1. Map showing the different regions where field trials were conducted to test the modified net designs. The left panel shows the regions (Townsville and Brisbane) within the state of Queensland with the shaded area indicating the Great Barrier Reef Marine Park. The right panels show each region in more detail with Bowling Green Bay near Townsville in the upper panel, and Moreton Bay near Brisbane in the lower panel.

Species of Conservation Interest and the ECIFF

The commercial fishing sector of the ECIFF is largely a mesh net fishery though some seine and hauling netting also occur. The set net component of the fishery has for a long time been implicated in continuing deaths of Species of Conservation Interest (SOCI), and most notably dugong. Fishing locations favoured by commercial net fishers often overlay the favoured shallow coastal habitats of dugong (Grech et al., 2008). Although fishers are legally required to record and report interactions with SOCI, it is likely that very few fishers do. Over the last two decades a number of management changes to mitigate the deaths of dugong in the ECIFF have curtailed access and/or fishing methods of commercial net fishers.

A recent spate of dugong deaths in Bowling Green Bay to the southeast of Townsville was one of the catalysts for this research. A further catalyst for this research is the development by some proactive fishers of gill net designs believed to minimise capture or entanglement of dugong should dugong interact with the net. Fishers have adopted this approach because oftentimes dugong can be difficult to sight and visually monitor, precluding a mitigation action such as moving fishing gear when an animal is sighted. Further and as previously stated, favoured dugong habitat often overlays favoured fishing locations. This means that the while dugong mortalities may be effectively mitigated by prohibiting gill nets from high density dugong habitats, this would likely have substantial impacts on catch rates and catches of fishers and impact the availability of local seafood. A more amenable mitigation strategy would be to explore the use of nets that did not result in dugong mortality if interactions occurred.

Gill nets used in the ECIFFF

Although fishers use a variety of different gill net styles, all are generally the traditional construction made by hanging a panel of monofilament netting between a weighted foot rope and a floated head rope. Mesh nets can be quite variable in length, depth, mesh size and ply strength/breaking strain. Commonly though, gill nets are usually passively fished by anchoring both ends of the net to maintain a position that targeted fish are likely to swim through. The standard net is typically buoyed along the head rope so that the head rope maintains position at the surface of the water (Figure 2). The foot rope is generally weighted with a lead cored rope that provides sufficient weight to stretch and hold the net vertically within the water column. Depending on the depth of the net and the depth of the water fished, the standard net may be held vertically taut in the water column (when net depth is equal to water depth) or the standard net may be loosely folded within the water column (when net depth exceeds water depth).

Most fishing in nearshore waters by ECIFF fishers sees gill nets set in waters shallower than the depth of the net. This method of fishing means that the gill nets lose some of their selective characteristics and catch fish by both “meshing” and “entangling” fish. Meshed fish are caught by becoming wedged within a single mesh of the net. Mesh may lodge around the gill, head, shoulder or dorsal area depending on the shape of the fish and the size of the mesh. Entangled fish are caught when they become entrapped by the wall of net and often by numerous meshes, though none of the meshes singularly captures the fish as meshed fish may be. These are important points as the science behind gill net selectivity is complex (Hamley, 1975). Gill nets can be constructed and fished to be very selective in the species and size of fish caught. Highly selective gill nets are taut both horizontally and vertically in the water column. When a gill net is not stretched taut both horizontally and vertically in the water column, the panel of mesh can adopt less selective entangling characteristics (White et al., 2013). In the case of the multi-species ECIFF, fishers deliberately construct and fish with gill nets that have both selective meshing and less-selective entangling characteristics. The less selective entangling characteristics are particularly important for very large specimens of target species like barramundi (*Lates calcarifer*) with large individuals too big to be captured by wedging in mesh nets.

Mesh gill nets can be quite selective in the type and size of fish they retain if the individual meshes are stretched tautly both vertically and horizontally (Hamley, 1975). Mesh nets that are taut vertically are generally achieved by setting the net in water deeper than the net depth where the weight of the foot rope and floatation of the head rope stretch the panel of net and thus meshes vertically. Without vertical tautness, a mesh net panel will have a belly and loose layers of net and this type of net loses its selective characteristics and becomes more of an entangling device than a selective device. Similarly, if mesh nets are not stretched horizontally loose layers may occur thereby negating the selective characteristics of a tautly set net.

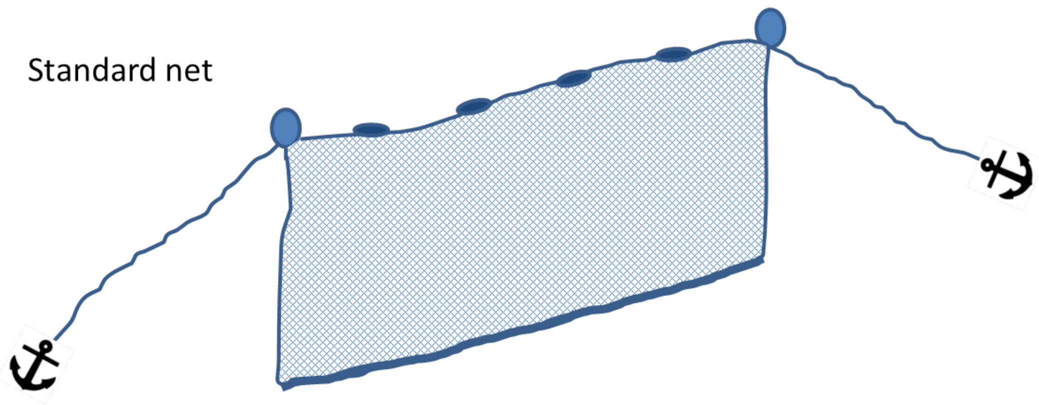

Figure 2. A stylised representation of a ‘standard net’ as used in the ECIFF (see text for description).

The ECIFF targets a diversity of species from small species such as whiting (Sillaginidae) and garfish (Hemiramphidae), through to large barramundi, mackerels (Scombridae) and sharks (Halliday et al., 2002). Accordingly, gill net construction is diverse and in the ECIFF there exists a large range and variable nature of mesh net components and mesh net construction characteristics (Table 1). The variability in gill net characteristics means that the term “standard gill net” is quite plastic and encompasses a diverse array of gill net types. This knowledge is important and needs to be carefully considered in research testing new gill net designs, particularly where those new designs may be quite prescriptive. Generally however, the sector of the ECIFF that most often encounter SOCI are those targeting barramundi and shark and would use higher breaking strain mesh. It is important to acknowledge that most fishers have individual methods and techniques of constructing gill nets developed over a period of time to suit their personal circumstance of fishing. While the outcome of this project may be to encourage the use of different gill net designs, such an outcome needs to be mindful of the diverse preferences in gill net types and fishing methods that occur throughout the ECIFF.

Table 1. The standard components of mesh nets used in the ECIFF, and the range of different construction characteristics.

Head rope	Generally a polyethylene or polypropylene rope 6 – 12 mm in diameter. These ropes are buoyant in seawater and aid floatation. Occasionally a “cored” head rope may be used were buoyant floatation is incorporated in the individual rope strands.
Foot rope	Similar as above though lead weights are spaced along the rope to sink the base of the net. Some cored lead ropes are used, and lead is woven into the strands of these ropes more evenly distributing weight along the net base.
Mesh size	The size of mesh used varies from 12 – 215 mm.
Mesh ply	Mesh ply is a nominal rating of the breaking strain of monofilament line used to construct the net. These measures are untested, and the diameter of similarly rated monofilament nets can vary considerably between different net manufacturers. Generally breaking strain correlates with line diameter.
Hanging twine	May be natural or synthetic twine, and have twisted or braided construction. Measured colloquially as “ply”. Similar to the monofilament mesh ply above, twine varies considerably between different manufacturers.
Hanging ratio	The hanging ratio measures how tightly the net is stretched along the head and foot rope. Generally ranges between 50 and 66%.
Hung net depth	Mesh nets may be quite shallow (1 – 1.5 m fishing depth) to very deep (9 – 10 m fishing depth) depending on area of use and species targeted.

Untestable and uncontrollable characteristics of nets

It is important to note that there are a number of unmeasurable characters of gill nets that are likely to impact entangling characteristics. Some fishers advocate building in greater “looseness” to improve catch rates. Mesh net panels can be loosely or tightly attached to head and foot ropes varying the length of twine used between tie-off points. Short lengths of twine between tie-offs will hold the mesh panel close and snug to head and foot ropes, while longer lengths of twine will allow the mesh panel to hang lower and more loosely from the head and foot ropes. The distance between tie-off points can also be varied and will impact net tautness.

Another common unmeasurable characteristic is net static or “proudness”. A net that is heavily weighted on the foot rope and frequently buoyed on the head rope will sit vertically proud and strong in the water column. A net that is lightly weighed and infrequently buoyed on the head rope may also sit vertically in the water column, though will be more prone to waft and wander with moving water. The latter type of net is more likely to collapse and entangle fish than the former. Tide and wave generated water movement can also affect a nets position and thus tautness in the water column.

The individualism of fishers and the variable nature and characteristics of net products greatly limits the ability of this project to test very prescriptive net types as there are simply too many variables. Therefore, testing the more general operating characteristics of typical net types in a sub-set of regions of the fishery is more likely to result in widespread adoption of alternative net designs by fishers in the event that a clear benefit is demonstrated.

Workshopping the issue

To inform the field trials, a workshop was held to discuss different types of net modifications. While the project motivation was the potential of the BAP demonstrated in earlier but inconclusive testing (McPhee and Stone, 2008), core project staff and consulted fishers acknowledged that other ECIFF fishers may have similar proactive ideas for reducing entanglement risk.

The workshop brought together several key ECIFF net fishers and industry representatives, together with fisheries and conservation managers, and research scientists. The workshop recognised the diversity of fishing that occurs in the ECIFF (e.g. Harry et al., 2011), and the recent spate of dugong incidents in north Queensland and agreed that, to capture some of the variability in net fishing operations, a southern and northern regional approach was appropriate. The BAP was designed for ‘general purpose’ (GP) mesh net fishing, a specialised fishery using a single continuous net of up to 800 m in length and predominantly conducted south of the Great Barrier Reef Marine Park. Fishing activities are limited by the regulation that describes permitted gear and use under the N1 fishery symbol (Fishery Regulation 2008; https://www.business.qld.gov.au/industry/fisheries/commercial-fishing/licences-and-fees/commercial-fishing-licences/fisheries-symbols).

Further north in the waters of the GBRMP, net fishers are governed by a different set of netting regulations and target very different species of fish. Fishing activities of fisheries are limited by the regulation that describes permitted gear and use under the N2 fishery symbol (Fishery Regulation 2008; https://www.business.qld.gov.au/industry/fisheries/commercial-fishing/licences-and-fees/commercial-fishing-licences/fisheries-symbols). The workshop participants agreed that the nearshore fishery sub-sector of the ECIFF (Harry et al., 2011) within the GBRMP should be the focus of the northern field trials. The nearshore sub-sector of the ECIFF is most often implicated in dugong captures, entanglements and subsequent deaths. Fishers in this fishery are permitted to use 3 individual nets with each net limited to maximum length of 120 m.

Permitting the activities of the field trials was discussed at length, including the deliberate targeting of dugong. That is, to truly assess the effectiveness of net modifications in reducing entanglement risk of dugong, interactions with dugong are required. The clear advice of the key management and conservation agencies present at the workshop (GBRMPA, QDAF and WWF) was that purposefully increasing the likelihood of dugong entanglement in fishing nets would be publicly unpalatable and politically sensitive and therefore obtaining a research permit that would allow this was extremely likely to be unsuccessful. Further, the time period for considering such an application would likely be extremely lengthy.

In light of this limitation, the workshop agreed that the field trials would best proceed using a fishery dependent approach employing skilled fishers with considerable local knowledge to fish in areas dugong frequent and take the chance that dugong interactions may occur in the absence of deliberate targeting. Commercial fishers were confident that interactions with dugong would occur during the trials by taking this approach.

Practical and logistical limitations of net modifications:

In identifying potential net modifications for trials, fishers also had to consider the practicalities of the different designs when in use. For example, modifications need to be robust enough not to require continual maintenance and be suitable for retrofitting to current gear. Furthermore, modifications that are effective for one species may not work for others (e.g. whale breakaway lines used in U.S. fisheries would be ineffective for dugong as their mode of entanglement differs).

To develop a breakaway panel, we needed to employ a method to attach the head rope to the net where the lower limit of force required to detach the panel from the head rope was less than the force required to break meshes in the body of the net. It also needed to be strong enough so that when target species, such as large fish and small sharks, were meshed in the net the breakaway net panel ‘weak point’ was not broken. The twine attaching the net panel to the head rope also needed to be long lasting. Therefore, the identification of suitable net types for testing during the project was far from a simple process.

Field tested nets

The workshop agreed that in this study we test the efficiency of three different net types in reducing negative interactions with SOCI. The three net types are variant designs and the intellectual property of proactive fishers working towards a solution that doesn’t require space/time closures or impede economic efficiency of their businesses. Since interactions with net fishing gear is always a possibility and we were interested in identifying gears that when interacted with by SOCI, resulted in the animal swimming away in a healthy state, we defined a *negative interaction* as one where the animal became entangled in the net. In each region monofilament mesh material was used and each net in the north was constructed using 50 ply (approximately 50 kg breaking strain) while in the south 80 ply (approximately 80 kg breaking strain) was used. The mesh size used for all the nets used in both regions was 165 mm (standard for each area of operation). Nets in the north were 16 meshes deep and a 0.5 hanging ratio, while in the south they were also 16 meshes deep but with a hanging ratio of 0.66. This was again standard for each region and all net configurations and specifications were standardised throughout the trials.

Modified net designs

1. <u>Low-profile net</u>. The low-profile net (LPN) was designed by innovative fishers following a spate of dugong deaths in Bowling Green Bay, northern Queensland and is now the ‘standard’ net used in this region. The nets are anchored from either end of the float rope in a static position. A limitation is placed on the depth of the net that maintains tautness and reduces belly in the net to

allow an interacting dugong to readily push under the net and escape (Figure 3a). A continuous lead cored foot rope also helps to maintain tautness in this net. Foot ropes are commonly made from a nylon rope with lead weights crimped on at standard distances (often 0.5 – 1.0 m). This foot rope design can lead to slack loops of foot rope that can entangle contacting dugong. Although this net is modified compared to nets used anywhere else in the fishery, as the standard net for the region it was used as the control for the northern trials in BGB.

2. Push-over net. The push-over net (PON) works on the same principles as the LPN, though this net is anchored from either end of the foot rope (Figure 3b). There is no belly in this net as water movement (tidal and/or wave generated) holds the net panel flat between the anchored foot rope and freely floating head rope. A dugong interacting with the PON should be able to push over the top of the net.

3. Break-away panel. The break-away panel (BAP) net was designed by John Page and is simply the inclusion of a sacrificial twine in the net construction that breaks when a large animal pushes against the belly of the net. The net was comprised of a number of individual panels, which were each approximately 5 m in length, and once the sacrificial twine is broken, the panel of mesh netting falls away from the float rope allowing passage of the animal through the hole created in the net (Figure 3c). Standard mesh net construction includes the use of a hanging twine that stitches a panel of mesh netting to a head or float rope as well as the bottom lead rope (Figure 2). The hanging twine is termed a tablin. The BAP includes an additional twine, a lighter and more easily broken twine (sacrificial twine) that sews the mesh net panel to the stronger tablins.

Proof-of-concept

Recognizing that *in situ* encounters with SOCI can be rare, the study first tested for proof-of-concept under controlled conditions with an on-land evaluation of one of the net designs – the BAP. This testing trialed different strength of sacrificial hanging twine by measuring the force required to break the weak link (e.g. Salvador & Kenney, 2002). This would test whether the concept design actually worked as intended and would also help inform the appropriate strength of sacrificial twine to be used during the field trials. Three different strength polyethylene twisted twines (6, 9 and 12 ply with approximate tensile strengths of 15, 21 and 25 kgs respectively) were tested. A calibrated force gauge (REED SD-6100) measured the force required (kilograms of force) for the sacrificial twine to be broken. A short 5-metre panel of net was stretched taut horizontally and vertically between two steel poles. A spherical 300-mm float was used as a surrogate blunt-headed marine animal simulated as impacting the gill net perpendicularly to both the vertical and horizontal planes. A rope passed through a mesh in the vertical centre of the net was used to pull the polyethylene float against the net until the sacrificial twine broke (Figure 4). Recognizing that some netting applications may require the sacrificial twine to break more easily, we introduced a simple overhand knot to create a weak point in the 9 ply twine tests only and tested the force required. For each combination of ply strength and presence or absence of weakening knot, 10 replicate measures of force (kilograms) were obtained.

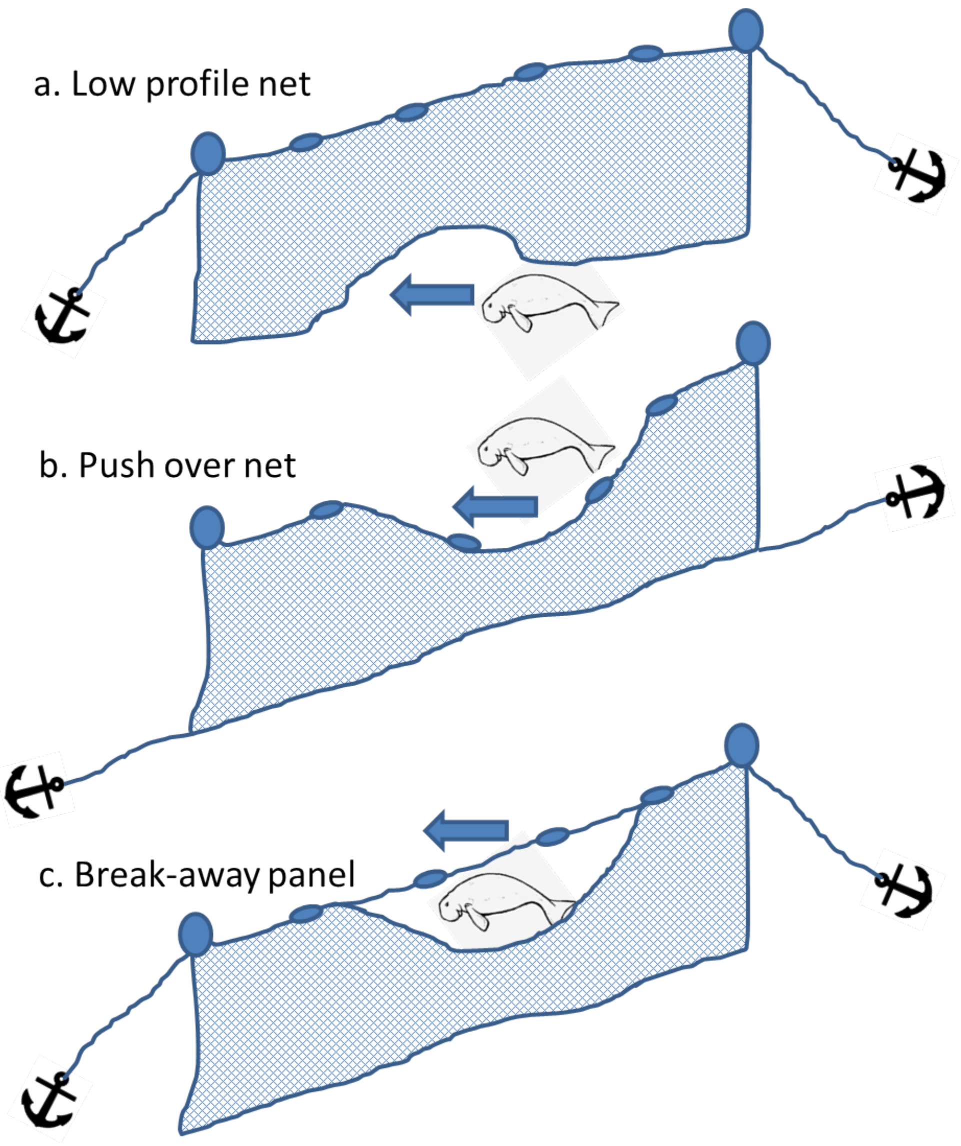

Figure 3. Stylised representations of the 3 variant net types trialled by the project and demonstrating the theoretical working of the net that allows dugong passage rather than entanglement. The nets include the a. low profile net, b. push-over net, and c. breakaway panel net (see text for technical descriptions).

Field trials

Modified net fishing gears were tested in two coastal embayments on the east coast of Queensland Australia. The fishery-dependent testing meant that nets were tested simultaneously. Field testing locations, Bowling Green Bay (BGB) in tropical north Queened and sub-tropical Moreton Bay (MB) (Figure 1), were chosen because of their known high densities of dugong as well as the co-existence of important commercial net fisheries. In each region the configurations of the nets used was constrained by the state fishery regulations, which therefore dictated the experimental designs.

In BGB commercial net fishers target barramundi in shallow coastal waters (generally 0.5 – 1.5 metre depth). The fished waters have abundant seagrasses and are important for feeding dugong. In BGB, licensed commercial fishers are permitted by regulation to set 3 individual LPN nets within a 1 nautical mile (1.85 km) stretch of coastline. Each net must be no longer than 120 m with a stretched mesh size of a 100 – 215 mm. The net must be weighted down with continuous lead core rope (6-8 mm in diameter) along the full length of the net and the depth of the net must not be more than 16 meshes. Each net is set in a fixed location using an anchor at each end to prevent movement. The nets fish passively by being set in locations that fish are likely to move through. Fishers actively monitor the nets to remove captured fishes as soon as possible to maintain product quality, and to monitor any SOCI interactions.

In sub-tropical MB, commercial net fishers target a number of small carcharhinid species as well as teleosts in shallow waters, often in seagrass habitat. Fishers in MB are licensed by regulations to use a different type of net that is termed a general purpose (GP) net. The GP net can be up to 800 m in length and can only be used in one continuous length of net.

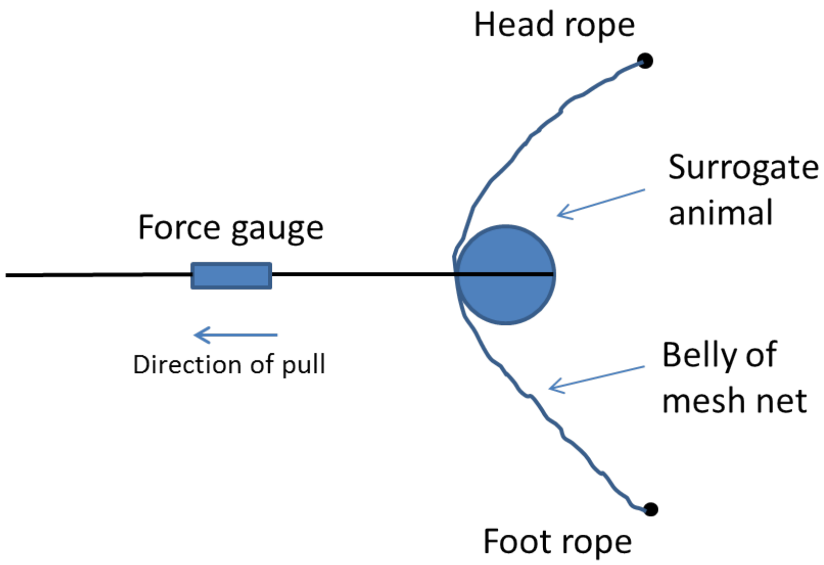

Figure 4. Diagram of the proof-of-concept evaluation design used for the BAP net. The force required to break the sacrificial twine attaching the net to the float and lead rope was measured using a force gauge while pulling a surrogate animal (large float) against the net.

For trials in BGB, we worked with two local fishers with extensive local experience (40+ years in combination). To be able to trial the three chosen net designs and to conform to state fishing regulations, the fishers were asked to fish with 1 LPN (control), 1 PON and 1 BAP. This meant that each net could not be replicated during each trial. Each net was randomly assigned to fishing locations chosen by fishers to avoid introducing perceived bias that some net designs were likely to be less efficient. The three nets were set in shallow coastal water (0.5 – 0.0 m) and moved across an extensive intertidal sand flat (approximately 1 km in width) to follow the tidal margin as the tide ebbed or flooded. This is standard fishing practice as the tidal margin is the most productive margin for fishing. It is also anecdotally important for dugong feeding.

In MB, the fishery dependent field trial also worked with two local fishers with extensive local experience (50+ years in combination). One of these fishers was John Page who designed BAP net being trialled. The single net allowed by state regulation in MB meant that, although we used replicate panels of the two nets being tested, the replicates were not able to be tested independently. This resulted in a pseudo-replicated sampling design, which was unfortunately unavoidable. For the field sampling we constructed a single 600 m GP net that had panels of 100 m of BAP net alternating with 100 m of standard construction (control) net used locally (i.e. 100m control/100mBAP/100m control/100m BAP/100m control/100m BAP). The GP net was similarly used as a passive fishing gear set in a static position using anchors at either end.

In each region fishing occurred during daylight hours only. Each time a net was set and subsequently retrieved back into the boat was considered a net set sample. Consistent with local fishing operations, each day's fishing in BGB consisted of multiple sets of each net while in MB each day's fishing consisted of a single net set. A scientific observer accompanied the fisher on each trip and for each replicate set they recorded information on: net type, location, depth, time fishing, species captured, fork length and fate (kept/marketed or released), as well as noting any interactions with SOCI. We also recorded any damage to nets, what caused it, whether it was fixed on site and how long it took to fix.

Data analysis

The experimental design used in both the north and south regions during this study were dictated by the state regulations. Also, there were other sensitivities (discussed earlier) that precluded special permit conditions that would allow us to work outside the regulations. This resulted in issues of non-independence (in the southern trials) and pseudo-replication in the sampling designs used (Hurlbert, 1984). This also precluded the use of Generalised Linear Mixed Models as the preferred data analysis approach, which would've allowed the inclusion of random effects to better explain sources of variation and minimise the probability of Type I errors (Bolker et al., 2008; Zar, 1984).

Therefore, comparisons of the fishing performance and effectiveness in reducing negative SOCI interactions among the different net designs were done in each region separately using analysis of variance or t-tests. Where necessary data were log transformed to meet the assumption of normality (Zar, 1984). For the catch rate analyses we standardised catch rate for each replicate sample (net set) to units of numbers of fish captured/100 m net/hour fished (# fish/100m/hr). This assumes a linear relationship between soak time and catches, which given the relatively short soak times is likely to be valid. Catch rate was aggregated to daily level for the analyses, despite likely issues with pseudoreplication, because one-days fishing is the functional unit at which fishers operate. With the inability to use GLMM's for data analyses we adopted the more conservative significance level for tests of $p = 0.01$.

To fully understand the effect of each different net modification we analysed catch rate against several different catch classifications: SOCI catch; total finfish catch; retained (or marketable) catch; discarded (unmarketable or regulated) catch; and catch value. Catch value was determined for each set and net design combinations by multiplying the weight of each retained species by the market value of that species and data were standardised as the catch value ($) per net hour fished. We also compared metrics of net damage and approximate down time resulting for each net type.

Fisher interviews

During the course of the project it became clear that there were several changes (fishing gear and behavioural) that fishers had made to their operations over the years in trying to optimise their businesses as well as trying to be as environmentally friendly as possible, particularly with regard to SOCI interactions. This was noted at the project workshop held in Townsville in August 2014 after the field trials were conducted, where fishers present lamented the fact that despite pro-active and positive changes made voluntarily in their industry, they were not documented and therefore fishers gained no credit for their efforts. At this meeting fishers urged that the project document fisher initiatives in the Queensland ECIFF particularly given the historical and continuing poor perception of the fishing industry, particularly net fishing, despite their environmental credentials.

Subsequently, with the assistance of a social scientist with the relevant expertise, the project team developed a standardised set of survey questions for fishers (Appendix 4). Ethics for these surveys was covered under JCU ethics permit H5711. The aim of this survey was to learn about fishers' perceptions of SOCI, the risk the ECIFF posed to SOCI species, and any changes in their fishing operations that they had identified and/or adopted that would improve interactions with SOCI. To achieve this the survey was broken into four key sections:

- Fisher business background;
- Perceptions about the risk (likelihood of local encounter) to SOCI;
- Changes made to fishing operations to reduce the likelihood of interactions with SOCI; (behavioural and gear modifications); and
- Perceptions about other fishery issues and the relative importance of SOCI

The intent of the survey process was not to attempt to interview all participants in the fishery, rather to survey a sub-sample of fishers known to be conscientious and professional with their practices and therefore more likely (or known in some cases) to be useful sources of information about changes in fishing practices in relation to SOCI that we wanted to document. For the purpose of the survey we focused questions around four different SOCI species/species groups: dugong, turtles, dolphins and whales. We attempted to survey fishers that covered the full geographical range in which the fishery operates so as to be able to capture if there were regional differences in any modifications and reasons for these. We also structured questions so that we could differentiate the perceived level of risk for each species group in different habitats where fishing occurs: estuarine, foreshore (<2 m depth) and offshore (>2 m depth). This is also important since different species are targeted and different gears and methods are used depending on the habitat area (Harry et al, 2011). These interviews were conducted in person with fishers during February, 2015.

Results

Proof-of-concept

We were able to prove that the concept design worked as intended, however, that elastic properties of the nets, particularly in water, made it very difficult to get consistent and reliable data on the force required to break the sacrificial twine. Nevertheless, the results still informed the choice of breaking strength for twine that was used in the field trials. In the dry tests of 9, 12 and 15 ply polyethylene twine we found that with all breaking strains used the force required to break the sacrificial twine was very high, however the strongest ply (15) required what was considered to be excessive force and was sometimes not able to be broken. The force required to break the sacrificial twine in the dry tests was significantly influenced by ply strength ($F = 169.5$, df = 2, 54, $p < 0.001$) and the inclusion of a weakening overhand knot ($F = 40.6$, df = 1, 54, $p < 0.001$). Mean force required to break the sacrificial twine increased incrementally from 10.6 to 15.8 to 19.3 N for 9, 12 and 15 ply polyethylene respectively (Figure 5). The inclusion of a weakening overhand knot using the 9 ply sacrificial twine decreased the force required to break the twine by about 15% from 16.5 to 14.0 N (Figure 6). Based on these simulated tests, and the advice of the fishers assisting in these tests, we used 12 ply breaking strength for the sacrificial twine to tie on individual net panels during the field trials.

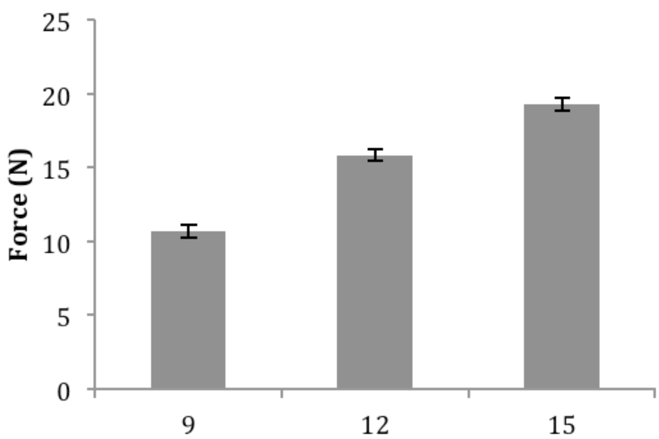

Figure 5. Force (Newton) required to break the different strength (9, 12 and 15 ply) polyethylene twine to be used as the sacrificial breaking point in the breakaway (BAP) net design during proof-of-concept tests. Error bars are SE.

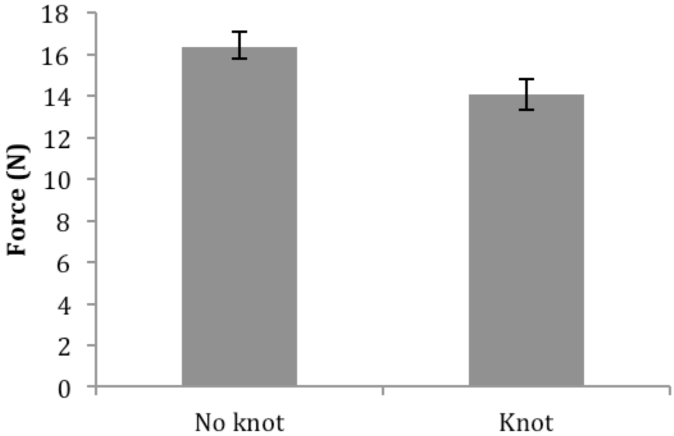

Figure 6. Proof-of-concept tests to compare whether placing a knot on the 9 ply sacrificial twine altered the strength of the twine by causing a weak point. Error bars are SE.

Field tests

The first year of the project coincided with two significant weather events that directly impacted the areas where field trials were to be conducted. These events displaced local dugong populations causing delays in field trials, and also compromised the likelihood of obtaining SOCI interaction data, particularly with dugong. The first event occurred during January 2011 and was extremely high rainfall and record-breaking flooding in southeast Queensland, including the Brisbane River that flows directly into Moreton Bay. The second was Category 5 Tropical Cyclone Yasi that occurred in February 2011 and crossed the coast near Mission Beach in north Queensland, impacting a wide area including where our northern field trials were to occur.

Bowling Green Bay

In BGB a total of 80 net deployments totaling 175 hours fishing were completed; 28 deployments for 62 hours of fishing with the LPN (control) net, 24 shots for 57 hours of fishing with the PON, and 28 shots for 56 hours of fishing with the BAP net.

SOCI interactions

No dugong or dolphin interactions occurred, however interactions with other SOCI were recorded. The LPN captured two narrow sawfish (*Anoxypristis cuspidata*) and one green turtle (*Chelonia mydas*); the PON captured one hawksbill turtle (*Eretmochelys imbricata*), and the BAP captured one narrow sawfish (*Anoxypristis cuspidata*) and one green turtle (*Chelonia mydas*). For each net, these captures represented 2.2, 0.9 and 1.1% of total catch by number of individuals. It is important to remember that the net modifications used during this study were principally designed for improving interactions with larger animals such as dugong and dolphin and were not anticipated to improve outcomes for other SOCI. Neither of the two SOCI interactions[2] in the BAP caused a break in the

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[2] All SOCI that interacted with nets during the trials were released alive and in a healthy condition.

sacrificial twine, as was expected for animals other than dugong or dolphins. There were 12 breaks in the sacrificial twine recorded during the trials however what caused these on each occasion is not known. There were insufficient SOCI interactions to conduct statistical analyses among the different nets (Figure 7a).

Catch rates

In BGB, the mean total CPUE was lower in the PON net compared to the BAP and LPN nets however the difference was not significant using the conservative significance level (ANOVA result $F_{2,77}$ = 3.58, P = 0.03; Figure 7c). All nets had greater catch rates of marketable species than what was discarded. The BAP net had greater discard catch rates than both the LPN and PON nets however this was also not significant (ANOVA result $F_{2,77}$ = 4.19, P=0.02; Figure 7e). There was also no difference in the CPUE for retained catch among the three net types (ANOVA result $F_{2,77}$= 2.47; P=0.09; Figure 7g). Although there was no statistical significant difference in the landed catch value among the three net types (ANOVA result $F_{2,77}$ = 3.417, P=0.038; Figure 7i), the catch value from the PON net was considerably lower than the other net types which from a business perspective of a fisher may be considered a significant factor.

Moreton Bay

A total of 18 net shots or 52 hours fishing were done in the southern trials.

SOCI interactions

No dugong interactions occurred in MB, and the only SOCI to interact with the net during the field trials were turtles. In some instances they were identified as green turtles but in others the species couldn't be identified, therefore we report them here grouped as "turtles". There were insufficient interactions to conduct statistical analyses among the different nets (Figure 7b), and none of these interactions produced sufficient force to break the sacrificial twine in the BAP and cause the panel to break away as intended for very large animals.

Catch rates

In the southern trails no significant differences in CPUE for total catch, discarded catch or retained catch were recorded (t-tests P>0.05; Figure 7d, f, h). Similarly, there was no impact on catch value between the two different net designs (t-test P>0.05; Figure 7j).

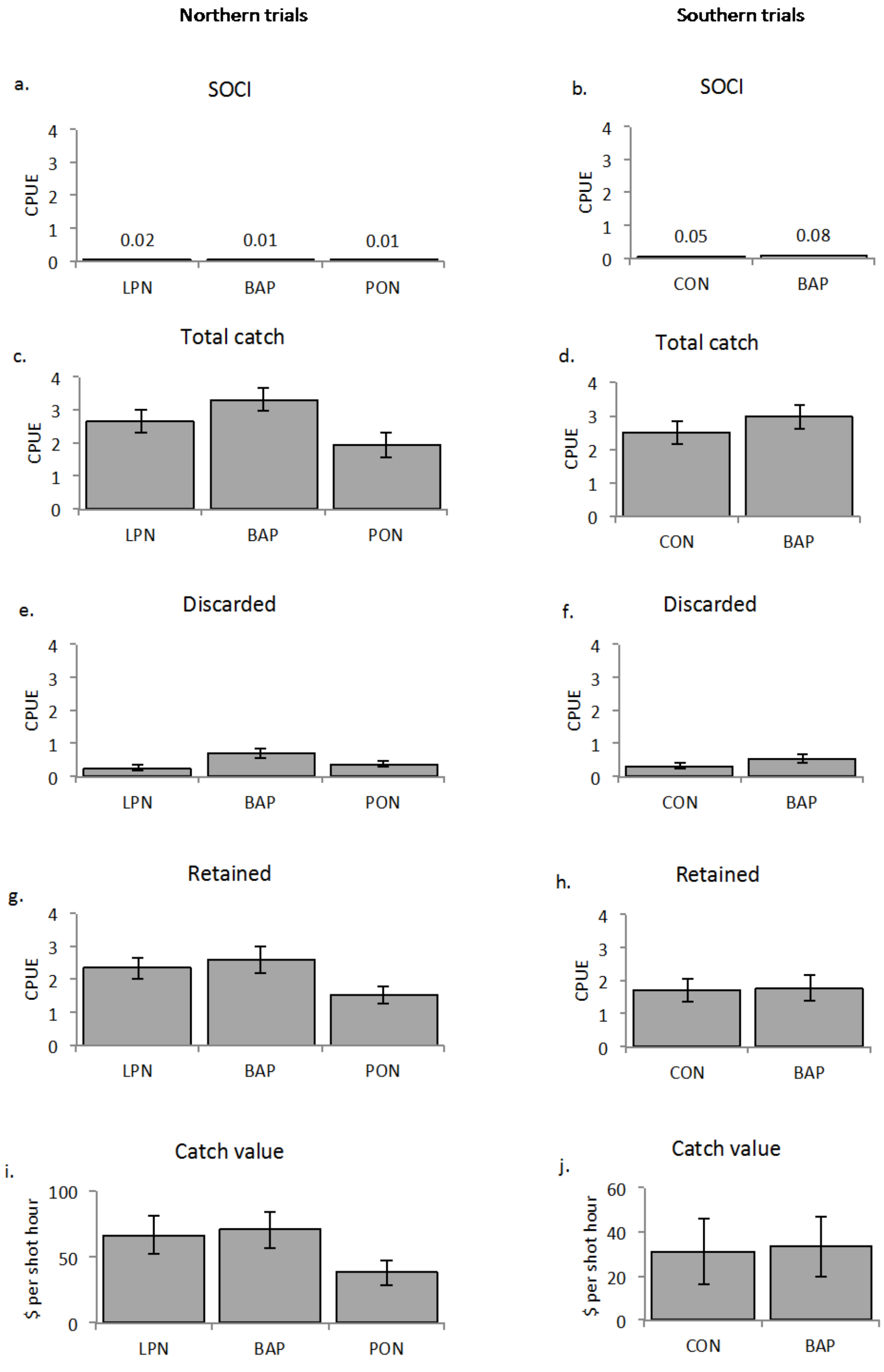

Figure 7. Catch rate data (# fish/100m/hr) from the field trials for the different net designs in each of the northern (Bowling Green Bay; left column figures a, c, e and g) and southern (Moreton Bay; right column figures b, d, f and h) regions. Catch rate data are shown for: Conservation species (SOCI), total catch, discarded catch and retained catch. Also included is the value ($) of the catch (per hour) for each net design in each region. Where data analyses were possible significant differences are indicated in the respective plots where non-significant groupings are assigned the same letter. CON = control net (standard net in MB and LPN in BGB); BAP = breakaway panel net; PON = Push-over net. Error bars are SE.

Net damage

In the BGB trials, a total of 12 breaks were recorded in the BAP net with a breakage occurring on average once every two net deployments (Table 2). Due to the nature of the environment fished (shallow surf zones), repairing breakages in unstable vessels was not possible. Breakages were repaired outside of fishing hours.

In contrast, the calmer waters of MB allow for breakages to be repaired while fishing. A similar rate of breakage was recorded in both the BAP and CON nets in MB, again at the rate of about one breakage every two net deployments (Table 2). The time to repair breakages in the BAP net was on average approximately four minutes longer compared with breakages in the CON net (42 % more time).

Table 2. Summary of the damage to the different net types recorded during field trials. n.a. = not applicable.

Region	Net design	No. of breaks	Break rate (per deployment)	Average time to mend (min)	SE (mend time)
North	BAP	12	0.43	n.a.	n.a.
South	BAP	9	0.50	13.06	0.81
South	CON	8	0.44	9.13	1.59

Fisher interviews

A total of 12 interviews were conducted with Queensland ECIFFF net fishers along the coast ranging from Moreton Bay in the south to Cairns in the north. All interviews were targeted at fishers likely to or known to adopt innovative best practice measures in their fishing to minimise contact with SOCI. Interviewees were owner-operator commercial fishers with experience in the fishery ranging from 6–46 years (median: 31.5 years). Almost all fishers often travelled in excess of 100 km from their homeport when fishing and in the previous year those interviewed fished an average of 171.3 days (median: 171) (one fisher had an unusually low number of fishing days).

Risk of interacting with SOCI

The level of perceived risk for each of the SOCI assessed (dugong, turtle, dolphin, or whale), where risk is the *likelihood of an encounter in the particular area*, was generally very low for all species in all locations but variable depending on the species, the region and the habitat. On a scale of 1–10 where 1 = “No likelihood” and 10 = “Very high likelihood”, the overall average level of perceived likelihood for each species group was: Turtle = 3.74, Dugong = 2.35, Whales = 1.93 and Dolphins = 1.91. Whales are only encountered in offshore areas and the perceived level of likelihood of encountering whales was greatest in the Cairns (9) and Mooloolooba (7) regions (Figure 8). Overall, the likelihood of an interaction with turtles was perceived to be greater than or approximately that for other SOCI species in all habitats, particularly in foreshore and offshore habitats (Figure 8). The perceived likelihood of encountering turtles was greatest in Moreton Bay (Mean=8.5; n=2), and moderately high on foreshores in the Ayr region (Mean=6.5; n=2). The perceived likelihood of encountering dugong was lowest in estuarine habitats and was very low in all areas, while dolphin were, on balance, the least likely to be encountered.

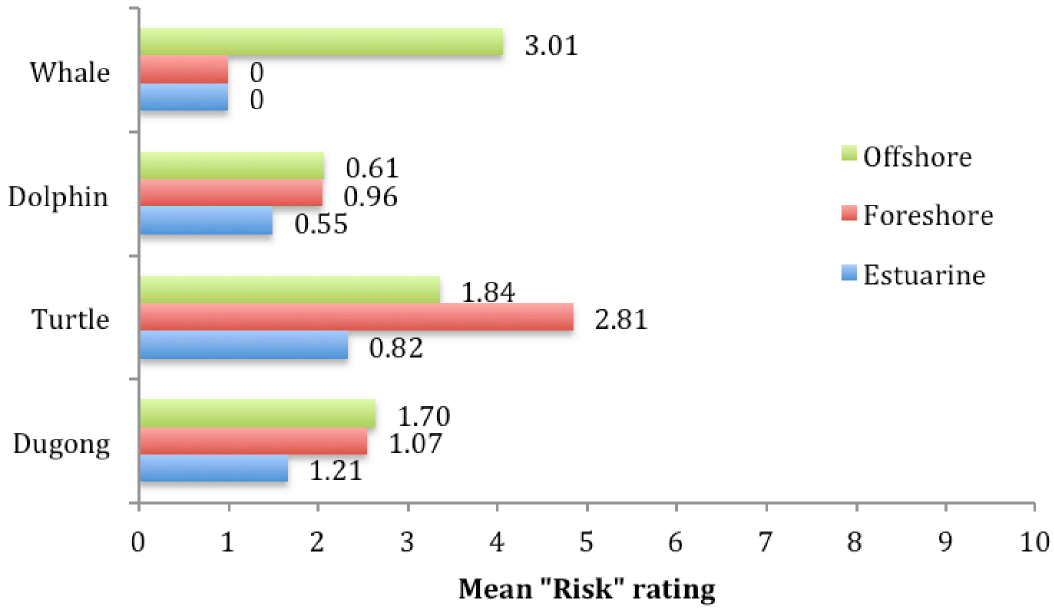

Figure 8. Mean perceived likelihood (risk), scored from 1 (no risk) to 10 (very high risk), that fishers would encounter whales, dolphins, turtles or dugongs in particular habitats: offshore (> 2m depth), foreshore (< 2m), and estuarine. Number labels for each bar represent the standard deviation of scores (effectively representing regional variation).

Voluntary behavioural changes

All fishers were acutely aware of the potential for SOCI interactions with gillnets and all the fishers interviewed had made voluntary behavioural changes in their fishing operations over time to minimise the likelihood that they will interact with SOCI while fishing. From the 12 interviewees, each fisher had made between 1 and 4 different behavioural changes in how they go about their fishing (see Appendix 5). We coded these different changes into common types and came up with 4 different behavioural change groupings: *time and place* – changes made based on where and when they go fishing; *vigilance* – increased vigilance while fishing; *setting of gear* – how gear are set; and *other*. Most of the behavioural changes fishers identified were based on *time and place* in an effort to avoid interactions with SOCI, although not all fishers used these types of strategies. Example quotes from fishers on this type of change were: "I only fish around low tide and the water is too shallow for dugongs and turtles", and "If whales are in the area I won't set at night". Of the changes made to how fishers set their gear (*setting of gear*), almost all changes were shorter sets (Figure 9), with fishers stating that this reduced interactions with SOCI and, if there was an interaction, increased the likelihood of a positive outcome. They also stated that shorter sets improved the product quality. In the '*other*' category, changes included "Tell others where and when SOCI are sighted" and "negotiated a net-free area where dugong are known to move".

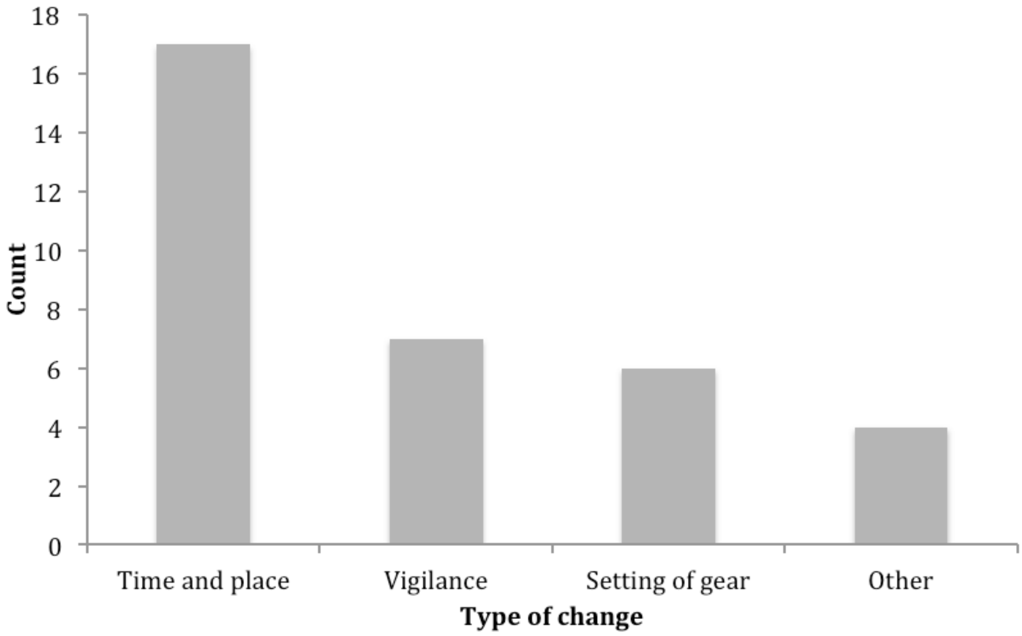

Figure 9. Types of **behavioural** changes being adopted by net fishers to minimise and/or avoid interactions with SOCI in the ECIFF.

Voluntary gear changes

In almost all cases, the fishers interviewed had made voluntary changes to their fishing gear to reduce the likelihood that they will interact with SOCI while fishing. From the 12 interviewees, only one had not made any gear changes and those that did had made between one and four different gear changes over time (see Appendix 5). We coded these different changes into common types and came up with eight different gear change groupings: *breaking strain* – fishers use lighter mesh or twine to connect net to ropes; *BRDs* – bycatch reduction devices of some type used, e.g. escape panels, which are gaps in between net panels; *Hanging ratio* – how tightly the net is stretched between the head and foot rope; *Net depth* – height of the net; *Net length*; *Operational* – changes to the type of gears used other than nets; *Pingers*; and *Selectivity* – changes in mesh size.

Most of the gear changes adopted revolved around configurations (*Net length*, *Breaking strain*, *Hanging ratio*, *BRDs* and *Selectivity*) of the nets themselves (20 of the 28 changes mentioned). The most common types of gear changes were fishers generally using lighter breaking strain gear to allow large animals to break through if encountered, shallower nets to allow SOCI to swim over or below the net and to avoid loosely hung nets in shallow water, and hanging nets tauter which is thought to reduce the likelihood of entanglement by large animals (Figure 10). Some fishers use shorter nets to minimise SOCI interactions and some have used pingers in the past although primarily for dolphins. In terms of operational changes some fishers have added net reels, which increases fishing efficiency, but also apparently allows greater capacity to effectively deal with a SOCI interaction. One fisher changed the layout of his vessel to better deal with large animals safely and effectively, particularly large sharks.

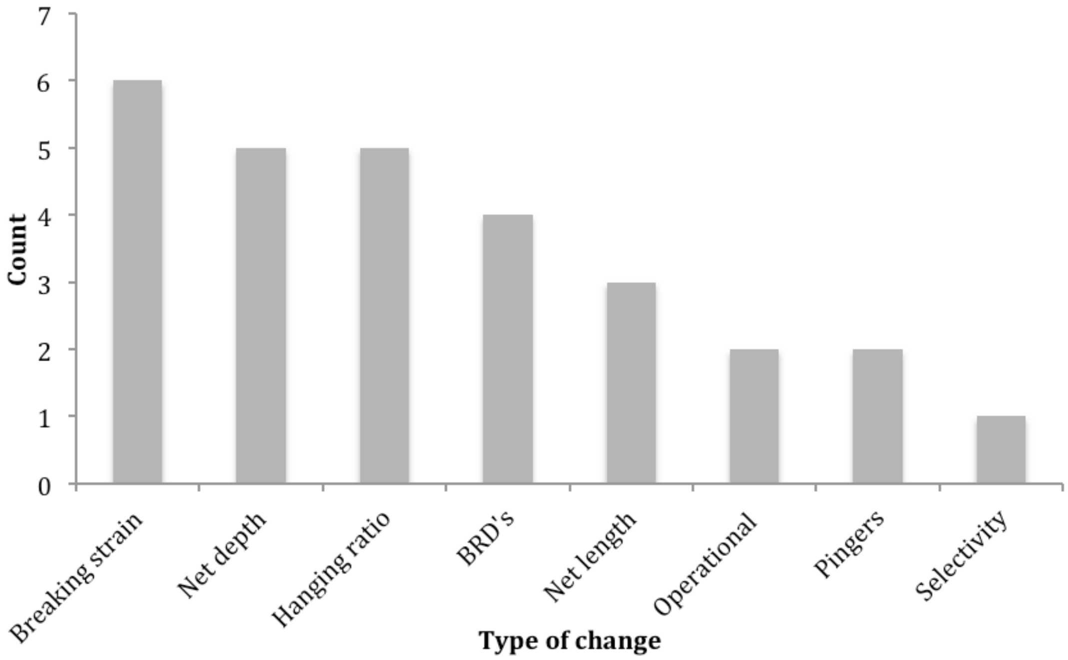

Figure 10. Types of **gear** changes being adopted by net fishers to minimise and/or avoid interactions with SOCI in the ECIFF.

Reasons for changes

Regardless of the type of changes made to their fishing operations, we also asked fishers what had motivated them to make the respective changes. Almost all changes were to avoid and/or reduce interactions with SOCI species and, where identified, included a number of factors: environmental concerns; poor perception of industry resulting from SOCI deaths; and damage to nets resulting in decreased profitability (reduced catch rates, time to mend the net, etc.). For many gear changes fishers identified that the change was more likely to result in a positive outcome from any interaction with SOCI (e.g. less likely to get entangled). In some cases fishers also identified that changes resulted in less bycatch and better quality product.

Fishers also identified, in many cases, the particular SOCI for which changes were made. Although several mentioned that changes made were for SOCI generally, most fishers made gear or behavioural changes to avoid and/or reduce interactions with dugong (Figure 11). Where changes were made due to turtles they were mostly gear-based and for whales they were mostly behavioural (Figure 11).

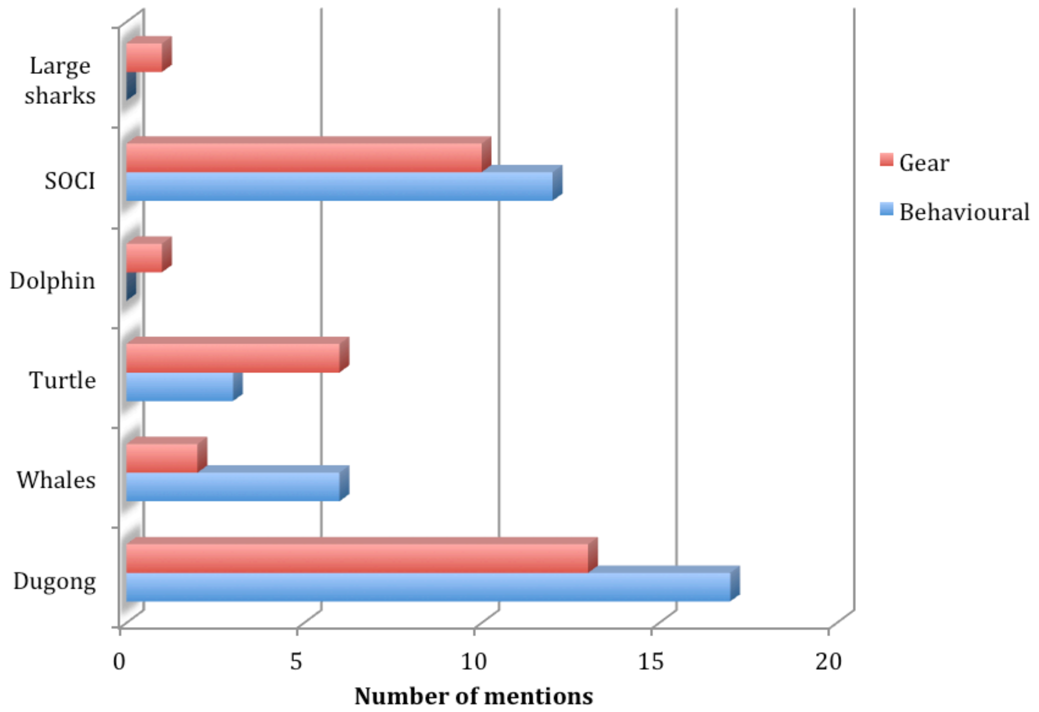

Figure 11. Number of times different SOCI species/species groups were mentioned as reasons why changes were made to fishing operations (behavioural and gear-based).

Other fishery issues

When asked what they thought was the most pressing issue in their area facing the net fishery, fishers gave several responses that we have coded into eight different groupings. The most common issue identified related to continued access to traditional fishing grounds (33%), however this was linked to several other issues including: the impact changes in access has on current fishers (displacement, resource user conflict; 24%), and the processes that lead to these (and other) government decisions affecting the fishery (politics, misinformation; 29%) (Figure 12). Further, fishers thought that, compared to the issues they identified, the issue of SOCI interactions with the ECIFF was negligible to very low (Mean=1.63; Range=1 - 2.5).

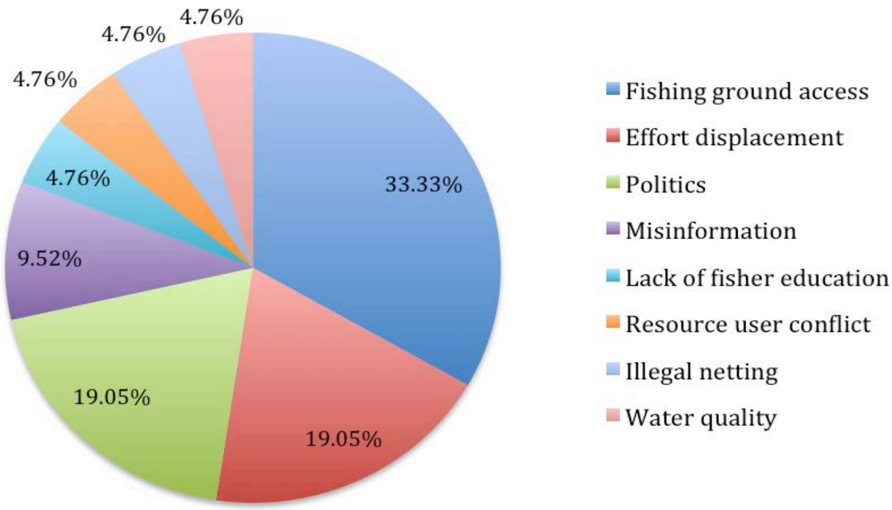

Figure 12. Issues identified by fishers as 'the most pressing issue facing the ECIFF', grouped into categories and expressed as a percentage of the total number of issues identified.

Discussion

This project took on the challenging but important task of attempting to identify net designs that would improve interactions between net fishing gear and Species of Conservation Interest (SOCI) in the Queensland inshore net fishery (ECIFF). This involved a process to first identify potential alternative net designs appropriate to the fishery, to develop an experimental design for trialling the effectiveness of the alternative nets within the constraints of local regulations and permit conditions, and finally testing the performance of the nets in the field. For a true test of the effectiveness of the different nets in improving the nature of interactions with SOCI, and potentially also reducing interactions with SOCI overall, we needed data on actual interactions with SOCI. Although SOCI includes many species such as turtles, dolphins, sawfish and whales, we were especially interested in obtaining data on dugong interactions with nets since this project was largely motivated by an increase in reported dugong mortalities along the Queensland coast in 2009 and 2010. Ultimately, interactions with SOCI species across the entire field-testing period were insufficient to compare catch rates among the different gears. Therefore, despite being able to provide evidence for one of the net designs that the intended concept does work in practice (from artificial testing), and despite 'observing' in the field large but unidentified animals hitting the nets with positive outcomes (no entanglements), it was not possible to obtain enough verifiable field data to robustly determine the effectiveness of the modified net designs for promotion as 'preferred practice' or not.

Alternative net designs

The project was initially motivated by the need to trial a particular net design, called a breakaway panel (BAP). Mr John Page, who has had extensive experience fishing within the dugong rich waters of Moreton Bay, was unaware of a similar concept used in U.S. Atlantic net and trap fisheries when he conceived the BAP net idea. John designed the BAP to allow large animals to 'push' through the net rather than become entangled. The BAP incorporates a "breakaway" or sacrificial twine (which attaches the net panel to the head and lead ropes) that breaks when sufficient force is applied to the belly of a monofilament net. When the sacrificial twine breaks, the body of the mesh net falls away or can be easily pushed out of the way by the impacting animal. A similar "weak link" system has been used in gillnet and trap fisheries in the U.S since the 1990's however provides for weak breaking points in float ropes attached to bottom set gillnets and lobster traps (Johnson et al., 2005; NOAA, 1997). This is to mitigate the issue of whales interacting with and becoming entangled with surface gear of bottom set fishing equipment.

The BAP concept was first tested in a preliminary study to show that the concept actually works and collect data on catch rates to determine any effects on fishing performance of the net (McPhee and Stone, 2008). Despite showing positive results, the scope of this study was limited by the capacity for adequate replication in the field and no SOCI interactions occurred. We extended the initial study to attempt to obtain data on whether the outcomes from interactions with SOCI were improved with the BAP net design. We also included a number of other modified net designs engineered by similarly proactive and solution thinking fishers. These included a low profile net (LPN) designed by Neil Green (a long-term gill net fisher from northern Queensland) and a push-over net (PON) designed by ANON. The LPN was designed on the premise that a net with a drastically reduced height and evenly weighted lead-cored foot rope allows interacting animals to simply push under and swim free. The PON operates on a similar principle of reduced height and low profile, though the foot rope is more securely anchored to the bottom and interacting animals are presumed to simply push over the top of the net. The project therefore tested the fishing performance as well as the SOCI interactions with each of these alternative net designs.

Proof-of-concept – breakaway panel

By conducting simulated interactions between large animals and the BAP net in a controlled setting on land (and in-water), we were able to prove that the concept for which the net was designed does work. Although similar tests have been carried out for U.S. fisheries some years ago to test the concept of weak points in float ropes (Salvador and Kenney, 2002), it was very important that the different concept of weak points in how net panels are connected to head and foot ropes, was independently tested in the local context. These tests also helped to inform what twine strength should be used for the sacrificial twine to tie the net to the head and foot rope. Without measures of the force that large animals such as dugong exert on nets, it was not possible to quantitatively determine the optimal strength twine for use during the field trials. Rather, by conducting these tests alongside commercial net fishers and drawing on their practical experience, we were able to choose a twine strength presumed to be optimal. Choosing the right twine strength was important to ensure that large target animals (e.g. small sharks and large barramundi) would not inadvertently break the panels, nor that large SOCI were unable to break through as intended. Closely working with fishers was useful given the outcomes of the proof-of-concept trials since they clearly demonstrated that the elasticity in the nets, and their components, adds up, particularly in the water, explaining the significant force required to break the sacrificial twine in some instances.

Using locally relevant gear

The ECIFF is a diverse fishery covering a very large coastline, different target and non-target species, and variations in gears and methods used. Like all fisheries it has its own characteristics and peculiarities. In carrying out testing of modified net designs we wanted to ensure that this variation was captured to some extent so that, if possible, a single net design may potentially be promoted for the whole fishery. During an initial project workshop with numerous fishers present it was determined that the spatial diversity and complexity of the fishery meant that developed gear designs and approaches needed to be similar to current regional practice for maximum uptake potential. They also needed to be within government fishing regulation requirements. This is consistent with the overall approach advocated by Uhlmann and Broadhurst (2015). With this in mind we decided to separately apply the BAP concept to local gear in both the northern and southern regions of the study. In each region the standard net used locally was included as the ‘control’ net, and in the north we also trialled a second modified net design termed the “Push-over net” (PON). In the north the control net was actually a local modification, called the “Low-profile net” (LPN), on the standard net used in other regions of north Queensland.

Experimental design issues

A separate but major limitation imposed on the field trials was the state and local fishery regulations and strict permit conditions. Although these meant that fishing trials were conducted in a manner consistent with usual fishing practices, state fishing regulations meant that the replication of modified net designs in the north, and true independence of net replicates in the south, were not possible. Also, permit conditions did not allow the usual practice of night-time fishing and restricted setting nets in the vicinity of observed SOCI. These issues constrained the experimental design used in the net trials and further demonstrate the challenges in conducting SOCI mitigation gear research. An ideal experiment would have involved the deployment of multiple nets of each type on any given fishing day. This solves issues of pseudoreplicaiton but still does not truly solve independence as fishing alters the availability of fish. The fishery regulations prevented us from implementing such an experimental design, however was not a reason not to conduct the trials given the project objectives. This is a common issue facing researchers working on applied research, despite which useful research outcomes have still been achieved (Davies and Gray, 2015). However, given the results we obtained (i.e. non-significance) more complex analyses would not have altered our conclusions.

Interactions with SOCI

There were no confirmed interactions with dugong and very few SOCI interactions overall; in the north there were three turtle and three sawfish (*Anoxypristis cuspidata*) interactions while in the south there were six turtle interactions. All of these animals were released alive. The lack of data on SOCI interactions prevented any analyses to determine the effectiveness of modified net designs in improving the outcomes of interactions with respective SOCI. Although this was always going to be a significant challenge for the project, the unfortunate timing of two significant weather events heavily impacted on the capacity for interactions with SOCI, in particular dugong. The first event occurred during January 2011 and was extremely high rainfall and record-breaking flooding of the Brisbane River that flows directly into Moreton Bay. The second was Category 5 Tropical Cyclone Yasi that occurred in February 2011 and crossed the coast near Mission Beach in north Queensland, impacting a wide area including our northern field trial location. Each of these events caused significant die-off of seagrass meadows (Rasheed et al, 2014) resulting in displaced dugong populations. Also, a significantly higher than usual mortality of dugong was reported in the year following these weather events with many reported to have died from ill health (Meager and Limpus, 2012b). This impact was long lasting and continued throughout the field trial period (2012–14) resulting in no dugong interactions and very few sightings.

Fishery performance of nets

In the northern trials, where barramundi (*Lates calcarifer*) and blue threadfin (*Eleutheronema tetradactylum*) are the two predominant target species, although not statistically significant, the worst performing net design in this study was the push-over net (PON). Lower catch rates of total catch and retained (marketable) catch in the PON net resulted in a lower value of the catch and, although not statistically significant, from a fishers perspective is an important result as it translates to a financial loss to their business. For the breakaway panel net (BAP) and the low-profile net (LPN; control net) the total catch rates and catch rates of retained and discarded catch (marketable: target and non-target species) were similar.

In the southern trials, there was no difference in total catch rates, discard catch rates, retained species catch rates, and catch value between the BAP and control nets. The result for the southern trial was expected given that a preliminary study had similar results, but also the fact that the BAP has been used commercially for some time in Moreton Bay by the fisher who designed it (JP) and is unlikely to have done this if their were negative consequences in fishing performance. However, we have demonstrated that when fishing in a different region with different habitat and different target species, the fishing efficiency of a net incorporating the BAP concept is at least as good as other nets used locally.

It is important to note that further extensive testing of alternative net designs and their impact on SOCI may continue to be stifled by low populations of dugong and thus the rarity of interaction events. Under such conditions, and the absence of empirical evidence we were able to provide here, we suggest that the innovative and proactive developments taken by fishers in modifying net design or fishing behaviours are encouraged and supported. However, while many fishers strive to be stewards of the environments in which they fish and will accordingly often be open minded about trialling and adopting new gears and techniques, the impact of such changes on the profitability of their businesses must also be considered. Where a gear or technique negatively impacts profitability, encouraging uptake may be self-defeating as more days fishing will be required to maintain income, and more days fishing increases the risk of interaction(s). We would suggest a rigorous cost-benefit analysis for any recommended gear changes as mandatory.

The data also demonstrates the effectiveness of net fishing operations in Queensland at catching target species and marketable non-target species with higher catch rates compared to non-marketable (discard) species. The selective characteristics of gillnets (Hamley, 1975) are well documented and this result is consistent with previous studies (see Halliday et al, 2002), which also showed low levels of bycatch across Queensland's diverse net fisheries.

From data collected during the southern trials, there were a similar number of breakages reported in the two net designs, but the estimated time to mend each break was greater in the BAP net. In the final project workshop, with five commercial net fishers present, there was much discussion about the performance of the different net designs and the applicability of each novel net to different fisheries and target species. There was universal agreement that breakages in the BAP net need to be repaired at sea otherwise continued fishing after a breakage will be at a lower catching efficiency because of the break. There was similar universal agreement that repairing breaks in the BAP at sea would not be practical in some sectors of the fishery, and thus not practical in those fisheries. Accordingly, we explored other novel net designs namely the LPN and POS net. Both these nets are built to a strength standard such that breakages are rare, and thus catching efficiency is not compromised. However, as previously noted the profitability of these nets may preclude their automatic use, if it is lower. Despite positive results in the fishing performance of both the BAP and LPN, the lack of SOCI interaction data makes it impossible to justify the promotion of these designs as the "preferred practice" over gear currently used. This does not mean that fishers can't voluntarily adopt the use of legally modified net designs especially given that the theoretical concept has merit. It is also important to note that in addition to modifying fishing gears, changes in fisher behavior and how a fisher uses a net are also strong determinants of risk to SOCI.

Fisher interviews

The interviews were an amendment to the original proposed project and its objectives and were conducted *in lieu* of the original 4th objective at the request of fishers. The objective of the interviews was primarily to document voluntary changes made by fishers to their fishery operations to reduce the likelihood of interacting with SOCI. However, we were also able to collect other information of relevance and interest to the issue of SOCI interactions with the Queensland ECIFF. It should be noted that, due to the primary objective, results from the surveys should not be seen as representative of the fishery but rather a snapshot of the range of views expressed by pro-active Queensland net fishers about the SOCI issue, and examples of fisher initiatives to attempt to minimise interactions with SOCI during their day-to-day fishing operations.

Responses from fishers about the perceived risk, or likelihood of encountering the respective SOCI, was highly variable but generally stated a very low risk. This is not surprising given documented and anecdotal information regarding variability in local population abundance of the various species. Of the species groups included in the surveys (turtles, dolphins, dugongs, whales), turtles were the most likely to be encountered regardless of habitat while whales were exclusively found in offshore (> 2m depth) waters. Overall, the likelihood of encountering any of these SOCI was lowest in estuarine habitats. These are not surprising results at all but it is important to note the level of regional variability in these overall patterns.

When considering overall risk, it is important to note that the interviews did not ask for fishers' views about the potential *consequences* (e.g. environmental, public perceptions of the fishery, safety and efficiency of fishing operations, damage to gear) of interactions with SOCI. For example, the environmental consequences of an interaction would vary depending on the species and factors such as its conservation status, cumulative impacts and the level of human-induced mortality the population can withstand from all sources. Such information would need to be considered in a full risk assessment and could be supplemented by information obtained from other sources.

The perceptions of the level of risk for different SOCI documented here are consistent with reported mortalities of dugongs and turtles attributed to netting, acknowledging that many deaths go unreported (from all sources) (Meager and Limpus, 2012a). In terms of reported deaths of dugong caused by netting, Meager and Limpus (2012b) reported that, despite a significant increase in dugong mortality during 2011, netting was confirmed as the cause of death for only 2 dugong out of 240 confirmed mortalities and was similar to previous years (Ave: ~3.25 mortalities 1996-2011). Turtle mortalities confirmed to be caused by fishing nets made up ~1.2 % of the total number of turtle deaths in Queensland during 2011 (Meager and Limpus, 2012a). Alarmingly, indigenous hunting was reported to account for 57 dugong mortalities in 2011. This is much higher than reported in other years and Meager and Limpus (2012b) attributed the latter result to improved reporting in that one year. Despite the low perceived risk of interacting with SOCI, fishers, managers and conservationists agree that one death of any SOCI from anthropogenic causes is too many.

The relatively low level of dugong mortality caused by netting is consistent with the low level of risk of an encounter perceived by fishers in the ECIFF interviewed during this study, notwithstanding that there is likely to be low levels of reported SOCI interactions by net fishers most likely out of fear of inflaming poor public perception and/or prosecution but also concern that they will lose fishing grounds (Anon, 2014). Since prior to the introduction of Dugong Protection Areas (DPAs) in Queensland nearly twenty years ago this level of perceived risk (i.e. likelihood of an encounter) has not changed (Sterling et al, 1997). As was noted by fishers during the course of this project, there will always be a chance that SOCI will interact with fishing gear once it is put in the water, however, the likelihood is generally very low but can be influenced by fisher behaviour.

All the fishers interviewed had made at least one voluntary change to their fishing behaviour over time in an attempt to reduce the likelihood of an interaction with SOCI. There were ultimately three major types of behavioural change being: i. changes in where and when to go fishing (time and place), e.g. certain locations, certain tides, certain times of the year, etc., or combinations of these; ii.

increased vigilance in watching their nets while they were in the water; and iii. shorter deployments. By far the most common type of behavioural change was appropriate spatio-temporal fishing effort (time and place). This type of behaviour can only come about by experience or by being taught by others, but is ultimately a choice the fisher makes. Although fishers also choose where and when to go fishing to maximise catch rates, there is also a huge incentive to avoid SOCI interactions. The reasons, many cited by fishers in the interviews, are many and include: i. the poor image an interaction creates for the fishing industry, ii. reduced catch rates of target species, iii. reduced quality of retained catches, iv. damage to nets, v. safety concerns in having to deal with a very large animal entangled in the net, and vi. fishers don't want to cause mortalities of SOCI. Although not captured during these interviews, during project workshops fishers highlighted that it was more likely to be poor choices of fishing locations/times that caused SOCI interactions with fishing nets that resulted in death or injury. Some of these types of behaviour included setting nets overnight when being able to observe potential SOCI and deal with them is compromised, using deep nets in shallow water, thereby creating "loose" nets more likely to cause entanglement[3], and low levels of vigilance while fishing.

Most interviewees had also made voluntary gear changes to reduce the likelihood of SOCI interactions that mostly involved changes in configurations of the nets themselves. The most common types of gear changes were fishers using lighter breaking strain gear to allow large animals to break through the net, shallower nets to allow SOCI to swim over or below the net and to avoid loosely hung nets in shallow water, and hanging nets tauter which is thought to reduce the likelihood of entanglement by large animals. Some fishers also use shorter nets to minimise SOCI interactions. Two fishers noted that current regulations in two different regions actually cause an increase in the likelihood of their fishing gear interacting with SOCI. In one region the boundary of a no-fishing zone placed adjacent to a headland forces the fisher to place his nets in a zone frequented by whales during their seasonal migration. In another region, the local regulations prohibit nets from being anchored on both ends of the net. The regulation in this area specifies an anchor may only be used on one end of the net, and accordingly the net hangs loosely in the water column. Nets need to be taut within the water column to minimise entangling large SOCI and the area in question is prone to high use by whales during seasonal migrations.

Although there has been research on the use of pingers (Dawson, 1991; Mackay and Knuckey, 2013) and some on operational characteristics (e.g. Lopez Barrera et al., 2012), most of the research conducted to date to mitigate SOCI interactions with gillnets have focused on gear modifications (e.g. Thorpe and Frierson, 2009; Gilman et al, 2009). Most of these studies have examined many of the types of strategies adopted by fishers in the ECIFF. Indeed, these same strategies are those that were identified prior to the establishment of DPAs as being the most likely to mitigate dugong entanglement in nets: taut nets, reduced breaking strain of net and tie-down material, taut head and foot ropes, shorter nets and shorter sets, and net attendance (increased vigilance (Sterling et al, 1997). Other strategies have been tested such as time/area closures and industry buy-outs (Senko et al, 2013), however such studies are limited. Importantly, all of these mitigation studies have found that different

[3] An offshore component in the northern ECIFF targets shark and grey mackerel in deeper (10-20 m) water using appropriately deeper nets. 'Lazy' operators have been known to illegally use deeper offshore nets in very shallow foreshore areas.

strategies only work for different species and no single strategy is 100% effective at mitigating all bycatch (Uhlmann and Broadhurst, 2015).

Net fishing and SOCI – current practice in the ECIFF

As described above some fishers in the ECIFF have voluntarily adopted different gears and behaviours - some for many years - to minimise the likelihood that an interaction will occur, or improve the outcome of any interaction between their fishing gear and SOCI. Apart from those strategies documented during the interviews, it is worth highlighting two key management initiatives in Queensland that are directly targeted at managing interactions between SOCI (in both cases dugong) and the ECIFF.

In 1998, a system of Dugong Protection Areas (DPAs) were declared in legislation under the *Fisheries Act 1994* and the *Queensland Nature Conservation Act 1992*. Two types of protection areas were established with Zone A DPAs having quite stringent controls prohibiting most types of commercial mesh netting, while Zone B DPAs allow commercial mesh netting though some changes to net dimension and fished methods are enforced. These DPAs are located in areas where dugong populations are highest. Spatial closures are also used elsewhere in helping mitigate fishery interactions with SOCI. To reduce harbour porpoise mortality in the U.S., NOAA use a combination of spatio-temporal fishery closures and gear modifications as part of their Harbour Porpoise Take Reduction Plan (HPTRP) in the northwest Atlantic gillnet fishery. The plan determines where, when and how commercial gillnet fishing gear can be set. (http://www.greateratlantic.fisheries.noaa.gov/protected/porptrp/qsum.html).

The second Queensland initiative occurred in 2011 whereby, as a result of a spate of dugong deaths in the Bowling Green Bay (BGB) area, a Special Management Area (SMA) was negotiated between local fishers and fisheries managers (http://www.gbrmpa.gov.au/managing-the-reef/how-the-reefs-managed/fisheries-in-the-marine-park/east-coast-inshore-finfish/commercial-netting-changes-in-bowling-green-bay-species-conservation-dugong-protection-special-management-area; accessed March 28, 2016). Local fishers had for some time modified their fishing to avoid the local dugong population and the dugong deaths were reportedly caused by non-local fishers. The fishing community of BGB initiated the steps to reduce dugong entanglement and possible subsequent death, by proposing changes to net configurations in the BGB area. Within the SMA there is an area where no netting is permitted and another area where netting is allowed but under specific regulations: limits on the lengths of nets (120 m length), maximum proximity of nets to each other, nets may be no more than 16 meshes in depth, and they must use a lead core rope (as opposed to lead weights attached to ropes) to ensure the net is evenly sitting on the bottom. As a fisher-led initiative, this is partially captured in the fisher interviews.

Pingers have been trialled to some extent in Queensland and used by some fishers, however their efficacy has been variable (Dawson et al., 2013; Hodgson et al., 2007). Numerous studies have demonstrated the positive benefit of pingers for reducing small cetacean (mostly dolphins) bycatch in gillnets however their effectiveness depends on using the appropriate frequency and spacing and is variable among different species. They have also been trialled on dugong in Queensland. Using 4 and 10 kHz pingers Hodgson et al (2007) found no effect on the movement and feeding behaviour of dugong in Moreton Bay. Contrary to this, McPherson et al (2004) used 2.9 kHz pingers and observed repeated “cautious avoidance responses” by dugong, however this was only based on verbal reports from volunteer fishermen.

Net fishing and SOCI – future practice

Non-fishing related threats to SOCI are many and varied and include water quality and run-off issues, extreme weather events, climate change, coastal development, traditional hunting, boat strikes and illegal fishing (DEEDI, 2011). Threats and their levels will also vary depending on the region and the species. To address the issue in perspective we should ensure there is focus on efforts to address high-level threats. For the most at-risk species, these efforts need to try to reduce all sources of human-induced threats. Therefore, the greatest positive impact on SOCI populations needs to begin with region-specific risk-based approaches. For the commercial net fishery in Queensland there are positive approaches that can be done to minimise threats to SOCI, and even if the likelihood of interactions may be low, these approaches should be promoted in partnership with industry. Given the vast area and diversity in fisher methods and practices in the ECIFF, research attempting to discover and apply “best practice” gear modifications that can effectively and adequately mitigate net interactions with all SOCI is likely to be costly and inefficient.

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In the ECIFF, fishers have been adopting different strategies in their fishing operations over time as they learn from their experience or others. From both a business and conservation point of view fishers are motivated to avoid interactions with SOCI and many have demonstrated this willingness with their own initiatives such as the BAP net trialled during this study. The example in Bowling Green Bay deals with a local situation using smart and simple strategies driven by industry and is proving to be very effective. Recently in Gladstone Harbour significant issues of fish kills and marine animal health conditions arose associated with large-scale industry development. There were also several SOCI deaths locally and the region was identified as a dugong mortality ‘hot spot’ (Meager and Limpus, 2012a). This resulted in the development of a Gladstone Code of Best Conduct for net fishing with gear and behavioural strategy recommendations not dissimilar to those documented in this report, being used by some fishers along the entire coastline. The Queensland Governments’ fishery management agency released a guide for commercial fishers to also promote netting practices that would reduce the likelihood of an interaction or an entanglement with SOCI (DEEDI, 2011). These are great initiatives, and when developed appropriately, are more likely to have the greatest uptake and therefore the greatest positive effect. The issue often is having an adequate approach for extending such outputs that ensures effective uptake.

Locally relevant Codes of Conduct (CoC) are most likely to be an effective self-management tool for east coast net fishers in minimising the likelihood of interactions between SOCI and fishing nets. These have been promoted and initiated to some extent in the past however, generally efforts fail to commit adequate resources to ongoing promotion, monitoring and review, thereby making them appear as temporary measures at best. With a history of regulatory change in the fishery, and complex rules already in place, mandatory change is less likely to be effective, especially if it is in place to address an issue that fishers already perceive as ‘low risk’. Further, the perceived lack of consultation with net fishers in recent introductions of Net Free Zones along the Queensland east coast (Queensland Parliament, 2015) has strained industry trust in government. To be effective a CoC needs to be driven by industry members, involve extensive consultation with all relevant fishers, and involve other key stakeholders such as Fisheries Queensland and GBRMPA. And it requires stewardship. When rules, even voluntary ones, are made without including stakeholders such a process is less likely to foster ownership and stewardship behaviours and the rules are more likely to be broken. A transparent and inclusive process is likely to engender greater ownership and effectiveness in the management. Importantly, it will also require a comprehensive communication strategy and an ongoing process to prolong promotion and for monitoring its effectiveness.

Despite this study not able to demonstrate a net design that can be promoted as best practice, there are several gear changes that fishers are using in different regions of the ECIFF that they believe are effective in reducing SOCI interactions. There are also many behavioural strategies being used by individuals that they believe are appropriate and effective in their respective regions. Behavioural changes are perhaps the simplest and most effective changes other fishers could make, if they were more aware of them. This is consistent with suggestions of Uhlmann and Broadhurst (2015) based on a review of bycatch mitigation research and found that, on average, operational and/or post-handling techniques can reduce bycatch discard mortality ~40% more than changes to gear configurations. Extending these strategies to the wider fishing industry membership would not only demonstrate the pro-active and creative initiatives that others are developing, often in isolation, but also would make all fishers aware of the simple things they can try in their fishing operations to reduce SOCI interactions. It may also improve the image of the fishing industry, especially given that some of the key issues identified related to a poor perception of the net fishery. However, in addressing this there also needs to be education of fishers about poor fishing practices that may increase the likelihood of SOCI interactions.

Finally, the Great Barrier Reef Marine Park Authority Reef Guardian Program is a potential alternative approach to local Codes of Conduct. This program also fosters and encourages better stewardship practices by net fishers and provides important acknowledgement of fishers meeting stewardship criteria. Although this program appears to be successful, it is still in relatively early stages and with increased resourcing and interest could prove to be a cost-effective approach to better educate fishers about best practice while also fostering greater trust and respect between management and industry, and greater public awareness of industry practices. There is even the potential for formal recognition through accreditation schemes that could increase industry recognition, improve product marketability and provide incentive for other fishers. The benefits of these types of initiatives to SOCI are likely to be significant and should be recognised and promoted more widely.

Conclusion

There are several key conclusions to be drawn from this study:

- Although we could prove that the concept of one of the net designs trialled here, the breakaway panel net, does work and thus could theoretically reduce entanglement of SOCI in fishing nets, the project did not provide empirical evidence. Similarly the two other net designs tested, the low-profile and push-over nets, may also be very effective in reducing the entanglement of SOCI, yet in the absence of empirical evidence the project outcomes can not promote any particular net design for preferential use.

- The perceived likelihood of an interaction of any SOCI with fishing nets in the ECIFF is very low. Likelihood varies regionally and among the different habitats and fisheries (estuary, foreshore, offshore). However, poor fishing practices are likely to increase this likelihood across all regions and fisheries, and hence increase the risk of mortalities to SOCI species.

- Many fishers in the ECIFF have taken the initiative in reducing interactions with SOCI and for many years fishers have voluntarily adapted their fishing practices to minimise the chance of interacting with SOCI. The voluntary adaptions include changes to both gear and fishing behaviour. Importantly, individual fishers perceive likelihood of interacting with SOCI to be different among the different fisheries and gears that they use, and adopt gear and/or behavioural changes as judged necessary. Clearly, individual fisher knowledge, experience and desire to do the right thing play a pivotal role in the risk commercial mesh nets present to SOCI.

- Behavioural changes rather than gear changes are likely to be more effective in reducing interactions between fishing gear and SOCI. While certain gear changes are likely to help increase the likelihood of a positive outcome when an interaction does occur, even highly modified commercial mesh nets may still entangle SOCI when fished inappropriately. Clearly changes in fisher behaviour may also be required to reduce the risk commercial mesh nets pose to SOCI. From a holistic perspective, interactions with net fishing gear in the ECIFF are likely to be a relatively low source of overall annual mortality, and the consequence of this will vary depending on the species concerned. However, under-reporting from all threat sources of SOCI is almost certain and the extent that fishers under-report SOCI interactions (as well as other threats) is unknown but likely to be significant.

Implications

- Experimental research to identify methods for mitigating fishery interactions with rare and/or threatened species can be challenging. A characteristic of many SOCI is low abundance and rare sightings. Thus attempts to test fishing net characteristics relating to SOCI interactions can be frustrating and unrewarding, as this project experienced. In the absence of empirical demonstration that some mesh net designs may reduce entanglement risk for SOCI, changes to fisher behaviour may be more effective. Many regional fisheries have CoC or Environmental Management Systems developed by proactive fishers demonstrating strong stewardship values for the ecosystems in which they fish. In addition, the Great Barrier Reef Marine Park Authority has a Reef Guardian Program that similarly fosters and encourages better stewardship practices by net fishers. The benefits of these types of initiatives to SOCI are likely to be significant and should be recognised and promoted more widely.

- The project demonstrated the willingness and motivation of many commercial net fishers in the ECIFF to strive to continually improve their fishing practices to be as ecologically friendly as possible, and will hopefully help to better educate non-commercial fishers of these efforts.

- An important industry accolade has been awarded to one of the project co-investigators for his leadership and stewardship values demonstrated in resolving a dispute of fishing access to an important dugong habitat following a number of likely net-caused deaths of dugong in 2011 in Bowling Green Bay (http://www.gbrmpa.gov.au/managing-the-reef/how-the-reefs-managed/fisheries-in-the-marine-park/east-coast-inshore-finfish/commercial-netting-changes-in-bowling-green-bay-species-conservation-dugong-protection-special-management-area). Fishing access was maintained after the development of a low-risk net and a prohibition on certain net types. This development has had significant implications for local fishers by maintaining access to an important and productive fishery ground. The presentation of the industry accolade has important implications by further demonstrating to the broader community the stewardship values held by commercial fishers.

- An important implication of this research is that demonstrable benefits of industry (and individual fisher) stewardship actions and activities may not always be obvious. The recent declaration of the Queensland Labour Party Sustainable Fishing Policy incorporates the declaration of three net free zones (NFZs) along the Queensland east coast. While the primary goal of these NFZs is promotion of recreational and charter fishing opportunities, a secondary goal is to reduce the risk posed to SOCI by commercial mesh netting. In the absence of demonstrable benefits to SOCI by fisher gear innovation and adaptive fishing behaviours, the cost to commercial mesh net fishing can be as extreme as loss of fishing ground access. The flow-on loss of sustainable seafood production should also not be understated. The clear implication is that innovation and stewardship demonstrated by fishers may not yet be sufficient to maintain access to some fishing grounds (see future development).

Recommendations

Further development

- **Reporting and data for SOCI Interactions.** There is considerable distrust of the data collected on interactions between SOCI and fishing gears by the compulsory SOCI logbook. Future research needs to explore why fishers are distrustful of recording interactions in the SOCI logbook, and what changes are needed to improve reporting including both fisher-dependent and fisher-independent options.

- **Review SOCI specific fishing regulations to ensure their effectiveness.** Since 1998 many changes have occurred in the ECIFF. Most notably, fishing effort in the offshore component of the fishery has increased in some areas and become more mechanised. These changes in fishing gear and fisher behaviour are likely to have changed the risk certain nets and fishing behaviours pose to dugong and SOCI more broadly. In some instances changes in fishing gear and fisher behaviour may have lessened risk, while in others risk may be heightened. The risk of SOCI capture in commercial mesh nets should be reviewed as a matter of priority, and should consider risks to key at-risk species including dugong and inshore dolphins. In the absence of contemporary evidence, much of the community still perceive net fishing to be indiscriminate.

- **Develop a Code of Conduct framework.** A framework for the development of a CoC, developed in conjunction with fishers, will better enable regionally relevant Codes to be implemented. Given the regional variability in how the fishery operates and the SOCI species likely to be encountered, a CoC would need to be regional. Providing a simple and easy tool to develop these will reduce costs and increase the likelihood that it will actually happen. Further, it is critical that any framework incorporates ongoing promotion, monitoring and review processes.

- **Educate and mentor fishers**. Although many fishers are well informed and aware of SOCI in the areas that they fish, there are also many that are not likely to be well informed; particularly new entrants. Championing responsible fishing and stewardship may be the strategy most likely to minimise SOCI interactions and improve the outcomes of unavoidable interactions when they occur. The Great Barrier Reef Marine Park Authority Reef Guardian Program has been successful even though still in a relatively early stage and this program should be continued with greater resourcing as a cost-effective and inclusive approach to improve the industry not just in relation to SOCI but more holistically.

- **Research into fishery attitudes towards SOCI.** This project provides a snapshot of the perceptions of SOCI from a small group of commercial net fishers. Research into attitudes towards SOCI more widely throughout the ECIFF, whether fishers are willing to adopt change, and explore ways to best encourage the types of changes some fishers have already adopted, may help fast-track fishery-wide reductions in SOCI interactions.

- **Project extension.** Commercial fishing has a generally poor public image based on fishing practices like netting despite positive and proactive efforts by industry members as identified in this study. Further extension of the outcomes of this project to the broader public may help improve the image of commercial net fishing, and with proper education, can help ensure future debates around commercial net fishing in Queensland are balanced and informed.

Extension and Adoption

Through involvement of individual fishers, the Queensland Seafood Industry Association and the Moreton Bay Seafood Industry Association, input has been continuous throughout the project from industry and ongoing progress and outcomes have been shared. A close association with the Great Barrier Reef Marine Park Authority has been maintained throughout the project also with 2-way dialogue at all times.

Project coverage

Media release, March 2012

Fishing industry leads charge to reduce net bycatch

Queensland fishermen are behind a new research project to reduce the risk of tangling species such as dugongs and turtles in their nets.

Project leader Mr David Welch said that the main aim of the project was to identify net designs that decrease the likelihood of species of conservation concern getting caught, while improving safety and maintaining the fishing efficiency for target species such as barramundi.

"The idea behind this research came directly from fishers who have been modifying their fishing gears to reduce the risk of tangling dugong and turtles," Mr Welch, who is from the James Cook University's Centre for Sustainable Tropical Fisheries and Aquaculture, said.

"Preliminary trials tell us that different net types can significantly reduce the chance of entanglement of large bycatch species. As part of the project we will design and trial a few options to find the best outcome," he said.

The project is being headed by James Cook University's Centre for Sustainable Tropical Fisheries and Aquaculture and funded by the Fisheries Research and Development Corporation (FRDC) on behalf of the Australian Government.

Conservation and management groups are increasingly concerned about the status of large marine life such as dugong, marine turtles and dolphins.

Although interactions between these animals and fishing gear is very low, the fishing industry want to do all they can to continuously improve their practices and gear to achieve this.

The research will be conducted this year in the inshore waters around Townsville and in Moreton Bay.

"The initiative and innovation shown by fishermen in designing alternate nets for use in this important research demonstrates their commitment to world's best fishing practices, and for this the industry should be commended," said Queensland fisheries manager Mr Mark Lightowler.

The project is a partnership of fisheries scientists from JCU and the Queensland Department of Employment, Economic Development and Innovation, commercial fishers from the Moreton Bay

Seafood Industry Association and Queensland Seafood Industry Association, as well as fisheries managers from Fisheries Queensland, GBRMPA and DERM.

Contact: David Welch, 0414 897 490, david.welch@jcu.edu.au
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Numerous print and radio media reported on the above media release.

See also: http://world.edu/fishing-industry-leads-charge-to-reduce-net-bycatch/

ENVIRONMENT VIEWS

Inshore fishing industry behind new dugong-friendly net research

Researchers and fishers are working together on a new net design intended to further reduce any risk of interaction with species of conservation interest, as David Welch reports.

INCREASINGLY, conservation and management agencies working with the seafood industry have put the spotlight on species of conservation interest (SOCI), such as dugong and dolphins. This has meant increasing scrutiny and pressure on the inshore net fisheries to further reduce any interactions with SOCI animals.

A new research project is showing great innovation and initiative by Queensland's inshore net fishers, with the trialling of modified net designs that may mean fewer net interactions with large animals such as dugong.

SOCI animals are under pressure from a whole range of impacts, including climate, environmental degradation, boat strike, hunting and commercial net fishing. Although data from annual reporting of incidental captures and deaths already show that interactions of animals like dugong with fishing gear are very low, commercial fishers are committed to achieving the best outcome possible for any interaction.

Further, there is constant pressure on fishers to promote and demonstrate best practices. The development of a net design that achieves this, while at the same time maintaining catch rates of target species, would demonstrate world's best practice for the industry.

Moreton Bay net fisherman John Page using the prototype "dugong-friendly" net.

One of the changes made to the standard gill net is the way the netting is hung.

Moreton Bay net fisher John Page has devised a modified net design with this in mind and has trialled a prototype version that has shown great promise. Further, the trials indicated that the modified nets may improve overall fishing efficiency by reducing net damage and associated costs.

This has led to a full-scale research project recently funded by the Fisheries Research & Development Corporation (FRDC) on behalf of the Australian Government, and is being managed by James Cook University's Centre for Sustainable Tropical Fisheries & Aquaculture.

The main aim of the project is to identify net designs that decrease the likelihood of species of conservation concern getting caught, while improving safety and maintaining the fishing efficiency for target species such as barramundi.

Preliminary trials suggest that different net types can significantly reduce the chance of entanglement of large bycatch species. As part of the project, we will design and trial a few options to find the best outcome. The research will be conducted this year in the inshore waters around Townsville and in Moreton Bay under "normal" commercial net fishing operations and by commercial fishers.

The inshore net fishery operates very differently in south eastern Queensland compared with the north of the State, so the project is trialling net designs that are as practical and relevant to local fishing operations as possible.

If we can identify a net design that not only reduces entanglement of SOCI animals in commercial nets but also maintains or improves fishing efficiency, then ultimately we would work with fishers to promote their use throughout Queensland.

This project concept originally came from the fishing industry, which is evidence of their commitment to best practise and taking on a stewardship role toward achieving safe and sustainable fisheries in Queensland. What is even more remarkable is that no similar research has been conducted elsewhere in the world.

The project members working together on the project include fishers from the Moreton Bay Seafood Industry Association and Queensland Seafood

Project materials developed

The key end-users for the outcomes from this project are the Queensland net fishers, relevant management agencies (GBRMPA and Queensland fisheries management) and scientists (various institutions). These groups, along with recreational fishers, are the target audience for a project information flyer.

Appendices

Appendix 1 – Staff

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Appendix 2 – Intellectual Property

No patentable or marketable products or processes have arisen from this research. All results will be published in scientific and non-technical literature. The raw data from fisher interviews and the net trials (land and on-water) remains the intellectual property of James Cook University and the respective fishers interviewed, whichever is applicable. Intellectual property accruing from analysis and interpretation of raw data vests jointly with JCU, QSIA, and the Principal Investigator.

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Appendix 4 – Fisher survey questions

Reducing SOCI interactions in the ECIFF

Commercial Fisher Surveys

Date:	**Time:**	**Interviewer:**	**ID:**

A bit about your fishing business:

First, we just need a few details about how and where you operate

1) Are you a:
   ☐ licence owner – operator

   ☐ licence owner but non-operator

   ☐ operator using someone else's licence

   ☐ Other __________

2) a) Where is your HOME PORT? ____

   b) How long have you been operating there? ______ years OR since ______ *(what year)*

   c) Do you fish from any other ports?
   ☐ No
   ☐ Yes: Which ports? ____

   d) How far do you operate from your primary home port?

   ☐ very local to home port (i.e. <50km)
   ☐ close to my home port (50-100km)

   ☐ I roam quite some distance from my home port (>100km)

3) Approximately how many DAYS did you fish in the ECIFF in the previous 12 months?

   ____

4) How much of your ECIFF effort is spent in:

   a) estuarine/river areas: _____ %

b) foreshore areas (<2m deep): _____ %

c) offshore areas (>2m deep): _____ %

How you feel about SOCI risk

Before we learn about your fishing practices in relation to SOCI, we'd like to know YOUR opinion about the RISK of any commercial fisher interacting with SOCI in your fishing area. Even though you may have made some changes to the way you fish, we're trying to get an idea of the risk to SOCI from the whole fishery in your area, before any modifications you or others might have made in reaction to that risk.

*Note, when we say '**SOCI**' we refer to dugong, turtles, dolphins, and whales.*

*When we say '**interaction with SOCI**' we mean any species of SOCI that may come into contact with fishing gear, whether it is entangled or not, and released alive or not.*

5) a) In your confidential opinion, on a scale of 1-10, where 1 = NO risk, and 10 = VERY HIGH risk, how much risk is there of interacting with the following SOCI species in the commercial net fishery in each of the net fishing habitat types in your fishing area, if you're using standard fishing practices and gear:

Scale: No risk ⟶ *VH Risk*

1 2 3 4 5 6 7 8 9 10

Habitat \ Species	Dugong	Turtles	Dolphins	Whales
i) estuarine/river areas?				
ii) foreshore areas (<2m deep)?				
iii) offshore areas (>2m deep)?				

b) For those with high risk (score >5), can you please explain WHY there is high risk? *(specify species)*:

____

____

Reducing SOCI interactions

Now, remembering the definitions above, we'd like to learn from you if you have found ways to reduce interactions with SOCI.

6) Have you implemented any VOLUNTARY changes to your fishing in an attempt to reduce SOCI interactions?
   ☐ Yes *– Go to next q*
   ☐ No *– Go to Q10)*

7) *(For those who said they HAVE made changes):* Were these changes:
   ☐ Behavioural (e.g. changed fishing area / times etc) *– to Q8)*
   ☐ Gear changes/ modifications *– to Q0*
   ☐ Both *– to Q8) then Q0*

8) a) Can you please explain any BEHAVIOURAL changes you've made? (*Please state what species these changes relate to. You may describe >1 change for >1 species*):

____

____

____

b) WHEN did you make these changes? ________________________________

c) WHY did you make these changes?

____

____

d) Did you come up with these changes *(tick one)*:
   ☐ by yourself, based on your own ideas?
   ☐ together with other fishers?
   ☐ because someone passed this knowledge on to you?

e) How effective do you think these changes are in reducing SOCI interactions in your fishing area (on a scale of 1-10)?

Not at all effective ⟶ *Complete success!*

1 2 3 4 5 6 7 8 9 10

f) Have you recommended these changes to other fishers in your area?

   ☐ No I haven't: Why not? ____

   ____

   ☐ Yes I have:

   g) Have other fishers adopted these changes?

☐ No - *to next Q*

☐ Yes:

i. How many others that you know of? ______

ii. Where? *(may tick >1)*

☐ In my fishing area

☐ Elsewhere: ____

iii. Do other fishers seem happy with this change?

☐ No

☐ Yes

iv. Explain why they <u>do or don't</u> seem happy with the change (what feedback have you heard?) ____

____

9) *(For those who made gear changes):* a) Can you please explain any voluntary GEAR changes you've made? (*Please state <u>what species</u> these changes relate to. You may describe >1 change for >1 species*):

____

____

Please draw here if appropriate

b) WHEN did you make these changes? ______________________________

c) WHY did you make these changes?

____

____

d) Did you come up with these changes *(tick one)*:

☐ by yourself, based on your own ideas?

☐ together with other fishers?

☐ because someone passed this knowledge on to you?

e) How <u>effective</u> do you think these changes are in reducing SOCI interactions in your fishing area (on a scale of 1-10)?

Not at all effective ⟶ *Complete success!*

1 2 3 4 5 6 7 8 9 10

f) Have you <u>recommended</u> these changes to other fishers in your area?

☐ No I haven't: Why not? ____

____

☐ Yes I have:

g) Have other adopted these changes?

☐ No - *to next Q*
☐ Yes:

i. How many others that you know of? ______
ii. Where? *(may tick >1)*
☐ In my fishing area
☐ Elsewhere: ____

iii. Do other fishers seem happy with this change?
☐ No

☐ Yes

iv. Explain why they <u>do or don't</u> seem happy with the change (what feedback have you heard?) ____

____

____

10) *(For those who said they have <u>not</u> made changes):* Why not?

☐ No need to in this region

☐ I want to, but there are barriers that stop me
☐ Other

Please explain ANY of these options here: ______________________________

____

____

11) a) Do you have any ideas for minimising / avoiding SOCI interactions that you have not yet been able to implement?

☐ No *– Go to Q 12)*

☐ Yes

b) Please explain:

____

____

c) Why haven't you implemented these ideas?

____

____

Other issues

While we have been focussed on SOCI specifically in this survey, we know that there are other issues affecting the ECIFF that may be of more concern to fishers. We'd like to know what issues fishers are currently MOST worried about. This may be SOCI catch, or may be something else entirely! Please answer honestly – there are no right or wrong answers of course.

12) a) In your opinion, what do you think is the most pressing issue currently facing commercial net fishers in the area where you fish?

____

____

b) *If this is different to the issues surrounding SOCI interactions:* How do you think the issue of SOCI interactions in the ECIFF compares to the issue(s) you just outlined, on a scale of 1-10, where 1 = SOCI interaction is the least pressing issue in your area, and 10 = SOCI interaction is equal to the other most pressing issue(s) in my area

SOCI → *SOCI*

= non-issue *= biggest issue*

1 2 3 4 5 6 7 8 9 10

Many thanks for your time and information. We will document everything we find along the coast and get back to you soon. Everything will of course be treated with confidentiality and respect.

If there are other fishers you think we should speak to, please let us know – it is hard for researchers to get contact details for fishers, so any help with that would be greatly appreciated.

Name: ____________________________________ Ph: _________________________

Name: ____________________________________ Ph: _________________________

Name: ____________________________________ Ph: _________________________

Appendix 5 – Survey responses

5.1 Behavioural changes

Behavioural changes	Why	Grouping
Set nets in a direction that avoids known pathways of movement (whales & dugongs)	to avoid interactions with whales and dugongs	Setting of gear
Increased vigilance while fishing (constant awareness)	Passed on by father; don't want to put self into a situation that may jeopardise their fishery (avoid SOCI)	Vigilance
If whales are in the area, no night fishing	Passed on by grandfather who used the same techniques 50 years ago (to avoid whales)	Time and place
Increased vigilance	To avoid dugong interactions.	Vigilance
Constant vigilance on nets - always checking while set	To avoid dugong interactions.	Vigilance
No fishing in Dugong A and B zones	(avoid dugong)	Time and place
Won't fish in known high density dugong areas	To avoid dugong interactions.	Time and place
Reduced night time fishing	Less SOCI interactions because you can see them better and they can see the gear better	Time and place
Work in daylight hours only (and even then keep a vigilant watch)	To avoid whale interactions	Time and place
Won't fish until tide has dropped enough for dugong to move away	To reduce interactions with SOCI	Time and place
Avoids afternoon tides in certain locations	To avoid dugong interactions with nets	Time and place
If they come across dugong on a location they avoid that area for a while (days-months)	Targeted fishing reduces bycatch and more bycatch attracts SOCI; dugong damage to a net reduces catch rates, and costs time and money	Time and place

Behavioural changes	Why	Grouping
Tell others where and when SOCI species are sighted (bush telegraph)	(Avoid SOCI)	Other
After Brisbane floods there were more dugong than usual in the area and acting erratically (stressed, unpredictable) so avoided areas where seen	Passed on by grandfather who used the same techniques 50 years ago (avoid dugong)	Time and place
Shorter sets	To avoid dugong interactions.	Setting of gear
Fishes around low tide so very shallow water which avoids dugong and turtle	(avoids dugong and turtle)	Time and place
Constant vigilance	To avoid dugong and whale interactions.	Vigilance
Shorter net sets	Less SOCI interactions and fish in better condition	Setting of gear
Only use 1 hour shots	To avoid turtle deaths	Setting of gear
If dugong are sighted in the area they make a noise to scare them away (eg. bang oar on the side of the boat)	To reduce interactions with SOCI	Other
If dugongs are present he waits for them to move off otherwise he goes elsewhere	To avoid dugong interactions with nets	Time and place
Shoot nets at low tide (targeting tailor); also avoids dugong which move off flats at low tide	Targeted fishing reduces bycatch and more bycatch attracts SOCI; dugong damage to a net reduces catch rates, and costs time and money	Time and place
If SOCI (particularly dugong) are sighted slowly move boat to be between animal and nets; hook float line on net to the boat ready to pull along the net to retrieve animal (if necessary)	(Avoid SOCI, particularly dugong)	Other
Any areas where high numbers of SOCI are avoided	Passed on by grandfather who used the same techniques 50 years ago (avoid SOCI)	Time and place
Fish last of tide drop and first of tide run-in	To avoid dugong interactions.	Time and place

Behavioural changes	Why	Grouping
Shorter sets to minimise turtle and dugong interaction	(minimise turtle and dugong interaction)	Setting of gear
Before setting for mackerel, look and listen for whales (don't set if they are present)	To avoid whale interactions.	Time and place
Always watching for SOCI	To reduce interactions with SOCI	Vigilance
Generally avoid high density dugong areas	To avoid dugong interactions with nets	Time and place
Shorter sets: due to high sharks numbers eating fish out of nets (also SOCI interactions are less likley and shorter stes mean they can be addressed quicker)	(reduce SOCI interactions)	Setting of gear
Negotiated a net free area in a blue zone 'corridor' where dugoing known to move	To avoid dugong interactions. In response to a couple of dugong deaths by "out-of-towners"	Other
No longer set at night for mackerel due to the increase in whales	To avoid whale interactions.	Time and place
Arrives at fishing spots in the dark (usually) so always waits and listens for dugong breaching/breathing before setting the net	To avoid dugong interactions with nets	Vigilance

5.2 Gear changes

Gear changes	Why	Grouping
In offshore sets, a reduced depth of net is used	To avoid/minimise whale interactions	Net depth
Acoustic pingers used sometimes	Believe they work (on dugong and dolphins)	Pingers
Reduced depth of net (# of meshes) for some areas to minimise risk of interactions	Reduce likelihood of interactions with SOCI	Net depth
Shorter nets (3 x 120m max)	To avoid dugong interactions. In response to a couple of dugong deaths by "out-of-towners"	Net length
Shorter nets (3 x 120m max)	Reduces likelihood of interactions with dugong and turtle, and, if meshed, more likley to be able to get up for a breath due to less net and less weight	Net length
Use lighter mesh so that larger animals break it	DPAs raised their awareness of dugongs, etc and so he "got smarter"	Breaking strain
Use lighter twine for hanging the net.	Larger animals more likely to break through rather than get entangled (inspired by an interaction with a whale many years ago)	Breaking strain
Use very light gear	To allow big animals (bigger that that targeted) to bust through (improve SOCI interactions)	Breaking strain
Hang the net looser	To reduce SOCI intersctions (dugong and turtle populations were much higher back then)	Hanging ratio
Grid across tunnel nets	Avoid turtles in the tunnel net (used to get heaps and would take time to herd them out; now zero turtles)	BRDs
Breakaway panels in all nets and heavier nets	When dugong and/or big sharks hit the net the panel comes away from the cork/leadline and the animal swims away; also rehanging can be done at home in the shade and in 1/3 of the time	BRDs

Gear changes	Why	Grouping
The use of escape panels	To allow turtles and rays to escape	BRDs
Layout of vessels has been changed	To make it easier and safer to assist an entangled animal (mostly used for big sharks). Never had to use it for a dugong (improve SOCI interactions)	Operational
Using a lead rope makes the net consistently taut increasing the likelihood that SOCI will bounce off nets rather than entangle	Reduce likelihood of interactions with SOCI	Hanging ratio
Shallower nets on foreshores and flats (16 meshes)	To avoid dugong interactions. In response to a couple of dugong deaths by "out-of-towners"	Net depth
Shallower nets on foreshores and flats (16 meshes)	Reduces likelihood of interactions with dugong and turtle, and, if meshed, more likley to be able to get up for a breath due to less net and less weight	Net depth
Use shorther net lengths so better able to deal with SOCI in the event of an interaction	DPAs raised their awareness of dugongs, etc and so he "got smarter"	Net length
Use lighter gear in Hervey Bay due to increased number of dugong there	Higher number of dugong there and they are less likely to get entangled in light gear	Breaking strain
For inshore sets increase the mesh size	To ensure smaller fish (juveniles) don't get meshed	Selectivity
Has moved to using 12 ply so the net breaks easier if hit by large animals, eg. dugong	To reduce SOCI interactions (dugong and turtle populations were much higher back then)	Breaking strain
Uses small cork (flotation) and configures cork and weight (leadline) to keep the net taut	Just buoyant enough to hold net up when fish are in it and with larger corks large fish were breaking the net (too much strain from extra flotation), and stays taut to the bottom reducing the likelihood of SOCI entanglement; also doesn't sag and drag damaging the bottom	Hanging ratio
Offshore nets with extra flotation helps keep the net tauter (see gear change 2)	Reduce likelihood of interactions with SOCI	Hanging ratio

Gear changes	Why	Grouping
Use lighter twine for hanging nets	DPAs raised their awareness of dugongs, etc and so he "got smarter"	Breaking strain
Tried pingers for an Oceanwatch project until batteries ran out (no interactions but very few prior)	Oceanwatch talked him into it	Pingers
Use of escape panels: every 200m of net there is a 1-10m gap.	Allows big animals to swim along the net and swim through gaps when pulling in the net (improve SOCI interactions)	BRDs
Use of shallower wings in tunnel nets	They sink to the bottom and because they are only 5 ft high there is usually a gap at the top (surface) and allows SOCI to swim over the top. Downside is it is light net so if a big shark/dugong hits it they go straight through (big hole)	Net depth
using a net reel increases the speed the net can be retrieved in the event of a SOCI interaction	Reduce likelihood of interactions with SOCI	Operational
Use lighter weights	DPAs raised their awareness of dugongs, etc and so he "got smarter"	Hanging ratio

5.3 Most pressing issue affecting the ECIFF

Most pressing issue	Issue grouping
Being able to access fishing grounds; also net fishers from other areas moving in and not following local rules (suggest that instead of compulsory VMS should make it compulsory for fishers to notify that they are in the area and are fishing)	Fishing ground access; Effort displacement
Access to fishing grounds; How many fishers you cram into particular areas	Fishing ground access; Effort displacement
1. Access to fishing grounds; 2. Education of commercial fishers; 3. Education of recreational fishers of commercial fishing	Fishing ground access; Lack of fisher education
Ignorance of non-commercial fishers spreading stories to the point that he will (may) be shut down	Fishing ground access; Misinformation
Bad political decisions - losing access to fishing grounds	Fishing ground access; Politics
Politics and the threat of losing access to fishing grounds	Fishing ground access; Politics
Access to fishing areas (recreational pressure to close off commercial areas)	Fishing ground access
Illegal netting (mostly recreationals and some commercials)	Illegal netting
Uninformed political decisions leading to displacement of effort (closures) and uninformed fishers coming into the area	Politics; Effort displacement
Pressures and influence from NGOs creating a false perception of the net fishery - results in a cloud of uncertainty in businesses and future investment areas, etc	Politics; Misinformation
Conflict with indigenous fishers (from Yarrabah) when fishing. As a result of zoning forced to fish new areas; more conflict including being threatened with spears (area just south of Yarrabah). Has had nets cut.	Resource user conflict; Effort displacement
Water quality - land-based runoff and toxic materials killing animals plus turbidity decreasing seagrass beds; Increasing human population	Water quality

Appendix 6 – Project information flyer

Net Fishing and SOCI

Queensland Research

Recent industry-driven research on the Queensland East Coast Inshore Finfish Fishery has explored ways to improve interactions between Species of Conservation Interest and fishing nets. Fishing is one of several threats to dugong and other iconic marine animals, however fishers in the Queensland net fishery have been at the forefront of research to minimise this threat.

Background

Between 2009 and 2011 the number of dugong mortalities on the Queensland east coast rose, sparking significant concern and shining the spotlight firmly on all threats to their survival, including net fishing.

These mortalities, along with the desire of some motivated and pro-active commercial fishers to highlight their stewardship in this fishery, provided the genesis for this project. A key objective of the project was to identify strategies that industry can employ to further minimise the risk of net fishing to Species of Conservation Interest (SOCI).

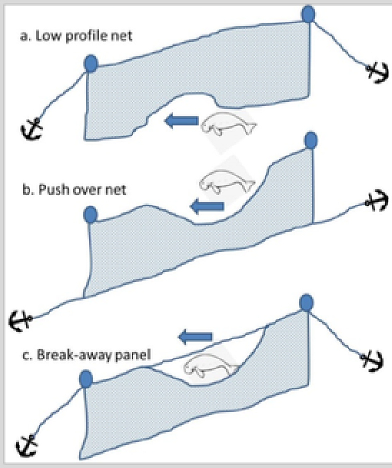
Scientists from James Cook University and the Queensland Government teamed up with commercial fishers and managers from the Great Barrier Reef Marine Park Authority to trial modified gillnets – designed by commercial net fishers – and assess their effectiveness in reducing the risk of interactions between fishing nets and SOCI.

Innovative fishing net designs were field tested to assess the outcome of an interaction with species such as dugongs, turtles and dolphins. The project also assessed the fishery performance of each net design to ensure there were no detrimental effects on the catch rates of target species or on the level of unwanted catch.

As part of the project the team also interviewed fishers of the Queensland East Coast Inshore Finfish Fishery to identify the fishing practices adopted by commercial net fishers that are intended to improve day-to-day interactions with SOCI.

Field Methods

Field trials tested two nets in Moreton Bay (a 'standard' net and a modified 'breakaway' design), as well as three nets in Bowling Green Bay (a local modified net or 'push-over' net, the breakaway net, and a 'low-profile' net).



Fishers were interviewed along the east coast to identify: voluntary gear and behavioural changes, and perceived 'risk' of SOCI interactions.

"I like to tinker and innovate, and I think lots of other net fishers do, too. As a group, net fishers should share more about their gear and the fishing behaviours they think reduce impacts on SOCI and the ecosystem at large. We can do good things."

Anonymous ECIFF fisher

Findings

Although the concept behind the breakaway net was shown to work, the project was not able to produce evidence that the modified net designs reduce the risk to SOCI due to the lack of SOCI interactions.

Overall, although regionally variable along the east coast, the risk of SOCI interactions with fishing nets is likely to be low. Regardless of location, poor fishing practices increase this risk.

For many years fishers have voluntarily adapted their fishing practices to minimise risk to SOCI. While certain gear changes may be beneficial by reducing the risk of entanglement, behavioural changes by fishers (e.g. avoiding known dugong haunts) may reduce the chance that SOCI will encounter nets. Therefore focusing efforts on behavioural changes be more effective in reducing the overall risk of SOCI interactions.

Individual fisher knowledge, experience, and the desire to "do the right thing" play a pivotal role in the risk nets present to SOCI.

Implications

Commercial net fishers demonstrate a willingness to continually improve their fishing practices to be ecologically friendly, but their efforts are poorly recognised. Though fishers demonstrate innovation and stewardship, this has not been enough to alter poor perceptions about the fishery from the wider community.

Initiatives to promote improved fishers' behaviour and fishing practices that are adopted are likely to have the greatest positive impact on the level of interaction between SOCI and fishing nets.

Recommendations

- **Better reporting and data** on SOCI interactions are required.
- **Regional Codes of Conduct** developed by fishers are likely to be an effective means of reducing the risk of SOCI interactions with nets. This may best be achieved in the future through regional management approaches to Queensland fisheries.
- **Championing responsible fishing practices and stewardship** may be the strategy most likely to minimise SOCI interactions and improve the outcomes of unavoidable interactions when they occur.
- **Better understanding of fisher attitudes and perceptions** of SOCI may be key in helping improve approaches aimed to reduce fishery-wide SOCI interactions.
- Given the perception of net fishing, the overall risk of SOCI interactions with net gear should be established, and the appropriateness of SOCI specific fishery **regulations should be reviewed** with a relevant regional context.

Reef Guardian Fishers

The GBRMPA **Reef Guardian Fishers** program recognises commercial fishers who are fishing sustainably and maintaining the health of the Great Barrier Reef. Fishers use practices that go beyond what is required by State and Federal laws.

Participants of the program set robust voluntary protocols for their operations, develop innovative practices to minimise environmental impacts, and share knowledge with other fishers and their communities.

reef guardians

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Or visit

www.gbrmpa.gov.au/our-partners/reef-guardians