A Better Way to Fish

Testing the feasibility of tunnel net 'fish trap' gear in North Queensland

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In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

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The authors also thank Dr Vinay Udyawer and Ms Blanch d'Anastasi for identifying the three sea snakes captured during the field trial, and Dr Mark Read for his valuable advice regarding crocodile behaviour and occurrence.

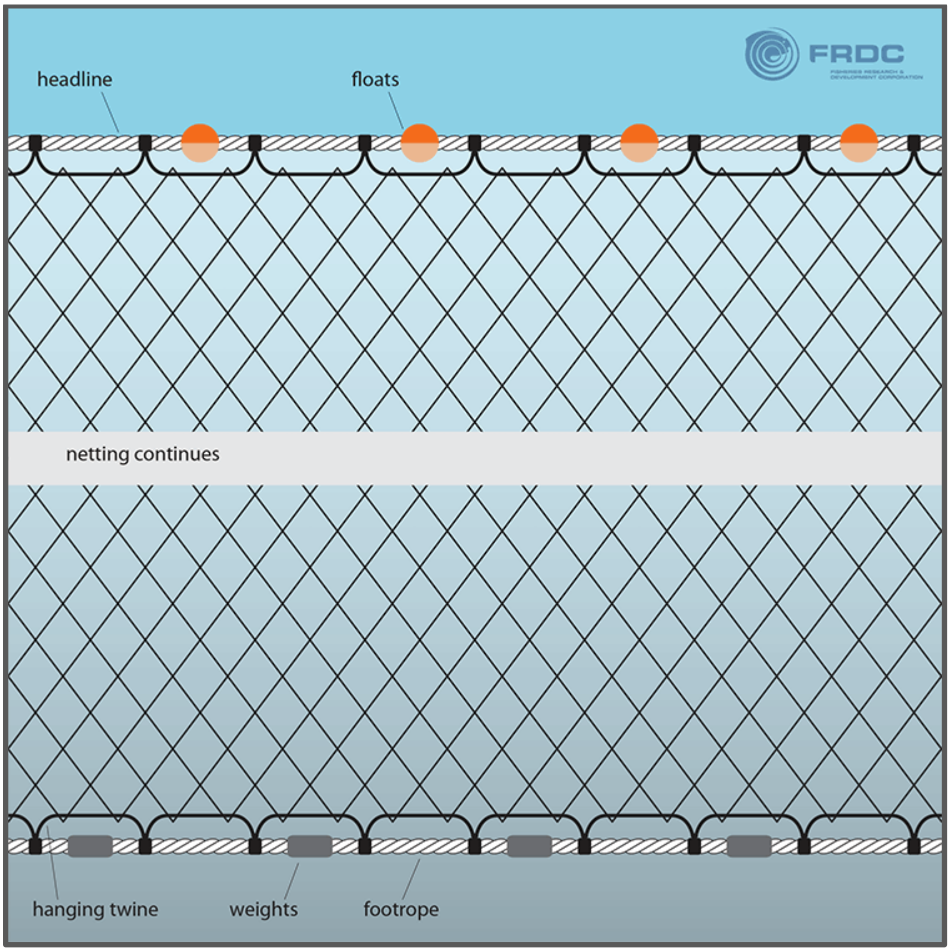
We dedicate this project to all commercial fishers who are working towards and investing in the sustainability and performance of their industry. It is our hope that this project serves as an example of genuine collaboration between scientists and fishers, and provides fishers and fisheries and marine park managers with useful information to consider in this challenging period of change and uncertainty.

Abbreviations

- DAWE – Australian Government Department of Agriculture, Water and the Environment
- ECIF – the Queensland East Coast Inshore Finfish Fishery Queensland
- EBPC Act – Environment Protection and Biodiversity Conservation Act 1999 (Australian Government)
- FRDC - Fisheries Research and Development Corporation
- GBRMPA – Great Barrier Reef Marine Park Authority
- GBRWHA – Great Barrier Reef World Heritage Area
- JCU – James Cook University
- N2 – Fishery symbol for the inshore (<2 m water depth) net fishery.
- NQ – North Queensland, unofficial term for the region between Mackay and the northern extent of Cape York
- MP – Marine Park
- MEY – Maximum economic yield
- QLD – the state of Queensland
- QQDAF – Queensland Department of Agriculture and Fisheries
- SOCI – Species of Conservation Interest

Glossary

- Brail/brailing – scooping the catch out of the tunnel net into a sorting tray. Each 'scoop is 'a brail'.
- Bycatch – generally this refers to any capture of a species that is not intended or desired by a fisher. This is a complex issue with many sub-definitions (see the FAO description of bycatch definitions)
- Cork line – a line with attached floats that flats on the water's surface. The net hangs from the cork line. Also known as the 'head line' or 'head rope'
- Discards – the act of releasing undesired fishes (alive or dead) back into the water. There are QDAFmany types of discards (see FAO descriptions of discarding)
- Mesh size – the size on a single diamond of the net mesh. Size is measured from knot to knot when the mesh is closed (i.e. the knots pulled apart to the maximum extent possible).
- Lead line -a weighted line that sinks and draws the net downwards. Also known as the foot rope.



- Selectivity – how selective a fishing gear is in securing the target species while allowing bycatch species to be released.

Executive Summary

Background

The sustainability and environmental performance of mesh net fisheries in the Great Barrier Reef World Heritage Area (GBRWHA) has been a contentious issue for decades. Concerns about interactions with Species of Conservation Interest (SOCI), as well as the mortality of discards and a lack of data on catch and effort, have driven a range of management interventions and also generated inter-sector conflict. This project aimed to find innovative solutions to resolve some of these pressing issues that have long challenged these fisheries.

The East Coast Inshore Finfish Fishery (ECIF) is a multi-species, multi-gear fishery operating in Queensland (QLD) coastal waters including within the GBRWHA. The ECIF targets a wide range such as the iconic Barramundi (*Lates calcarifer*) and King Threadfin (*Polydactylus macrochir*) and a wide range of other coastal species. Bycatch of SOCI species such as dugong, marine turtles, and certain species of sharks and rays (e.g. sawfishes, Scalloped Hammerhead shark) continue to present sustainability challenges to the fishery. Increasing regulatory pressures and community expectations are driving continual efforts to improve the environmental performance of ECIF net fisheries, especially in bycatch reduction.

Additionally, historically a commercial arrowhead trap fishery operated along the Queensland east coast. When properly maintained and operated, trap fisheries can significantly reduce bycatch mortality as the catch remains free-swimming within the trap, and unwanted catch is released from the trap alive. While the arrowhead trap fishery is no longer operating, tunnel net fisheries have been operating in Moreton Bay for decades. Tunnel nets are essentially mobile fish traps that are deployed and retrieved over a single tidal cycle. Modern tunnel net operations are perceived as having a high capacity and performance in reducing bycatch mortality.

Aims and objectives

The project aimed to *explore the feasibility of using tunnel nets to replace shallow water 'N2' gill nets in North Queensland (NQ)*. The project includes three specific objectives:

(1) Site visits and fisher knowledge exchange to develop a preliminary feasibility trial implementation plan;
(2) Community engagement resulting in community knowledge of and support for field trials; and
(3) Limited tests of the feasibility of tunnel nets in north Queensland waters at two sites Mackay and Cardwell.

Methods and results

Commercial fishers from Moreton Bay, Cardwell, and Mackay participated in a series of fisher exchanges and site inspections to explore the feasibility of using tunnel nets in north Queensland (NQ). Site inspections were carried out in Cardwell and Mackay between August and September 2020, with tunnel net experts from Moreton Bay visiting potential sites with local commercial net fishers by vessel and on foot. The factors that make tunnel netting feasible (or unfeasible) were discussed, and candidate sites identified. NQ net fishers visited Moreton Bay in September 2020 to view active tunnel net fishing operations to gauge the scale of such operations and discuss factors affecting such as operation cost, product marketing and value, management, and financial aspects of the operation.

The site inspections revealed several sites north of Cardwell that could be fished using tunnel nets. The factors contributing to their potential include favourable slope of the intertidal foreshore, water clarity, shelter from weather conditions, moderate tidal run, and separation from other water users such as recreational fishers. However, site inspections in Mackay indicated that tunnel nets could potentially only be used at two sites due to the large tidal flows, exposure to weather, the length and gradient of the intertidal flats. Concerns were also raised about potential conflict due to intensive recreational use. As a result, field trials were only conducted in Cardwell.

After observing tunnel net fisheries in Moreton Bay, NQ fishers confirmed that they would be willing to proceed with a limited field trial, noting that trials would include much smaller gear. There was also extensive discussion about how tunnel net fishing can be self-managed and monitored to maximize economic yield and avoid localised depletion.

From 5-11 July 2021, a team of four tunnel net fishers from Moreton Bay transported boats and fishing gear to conduct field trials in Cardwell with three NQ commercial fishers. The dates and times were specifically chosen to coincide with neap tides (lower water flow), with a high in the morning and low in the early afternoon. Trials were conducted in winter to reduce risks from interactions with marine stingers and crocodiles, algae fouling the nets, and to take advantage of cooler water temperatures which would reduce thermal and oxygen stress to fishes.

Unfortunately, unusual weather conditions for that time of the year resulted in marginal conditions with SE winds at 10 to 15 knots and rolling and breaking swell at low tide. This resulted in gear deployments only occurring on two days of the five-day trial due to safety concerns and operational risks. Two fishing days were conducted and the performance of the gear, and the fate and composition of the catch and bycatch was recorded.

Eight hundred and fifty-two fishes from at least 37 species were captured over the two days, with 520 individuals measured for total length (TL), and 45 fishes also tagged with Hallprint T-bar anchor tags. All fish were released and the condition (alive/dead) at time of release of the 520 measured individuals was also recorded. Importantly, four Scalloped Hammerhead sharks and three sea snakes were released alive and in good condition, as well as an estimated (from photos) combined total of over 30 stingrays, shovelnose rays, and wedgefishes. The majority of the catch (n=377) was Silver Javelin (*Pomadasys argenteus*) and Javelin fish unspecified (n=175), although the later were likely to be >98% Silver Javelin (*P. argenteus*). Of the key target species, nine Barramundi, nine Blue Threadfin, and six King Threadfin were also captured. A total of 45 fishes were tagged but no recapture reports have yet been received.

Implications for stakeholders

Tunnel nets are technically feasible in this location. In spite of the weather conditions, the fishing gear remained intact and successfully captured significant numbers of marketable fishes. Importantly, SOCI species were released alive and in excellent condition, as were other species of potential conservation interest such as wedgefishes and guitarfishes. Modifications to the gear by increasing the line strength of the 'traps' would likely increase the catch of key target species such as Barramundi and King Threadfin.

While the tunnel nets are technically feasible, their **viability** as alternative fishing gear to replace N2 mesh nets remains unknown. The drawbacks of the gear include the need (and cost) for three to four fishers to work the gear, the limited number of suitable locations to deploy the gear, and the limited seasonal and weather window when the gear can be successfully used. Establishing viability will require full scientific trials to document the financial performance of the gear, modify the configuration of the traps and the exclusion grid to better suit local species, and to establish the gear's fishing power to establish how often the gear could be deployed without causing local depletions. Further consultation and engagement would also be needed to identify opportunities to reduce inter-sector conflict. Project participants also expressed that some of the key limitations of tunnel nets could be resolved by using semi-permanent arrowhead fish traps instead, which have the same operational principles but are much less labour intensive and can be operated in more weather conditions.

Recommendations

The project team recommends that while tunnel nets are technically feasible, the team cautions that their commercial viability is as yet unknown and may be questionable. Further multi-disciplinary work would been needed to establish their viability and social acceptability. In the meantime, the feasibility of fixed location, semi-permanent arrowhead fish traps should be explored as an alternative. An arrowhead fish trap could be operated by a single fisher or two-person team (lowering costs), and could be worked in a much wider range of weather conditions. Furthermore, as they apply the same design principles as tunnel nets, it is highly likely that they would successfully catch marketable fish, while significantly reducing bycatch mortality, including that of SOCI species. This will also require further consultation and engagement to find opportunities to reduce inter-sector conflict. The project team is ready to further develop this concept for consideration.

A part of the catch being brailed from the tunnel into a sorting tray for rapid sorting. Fishes are either retained or released. Picture from Moreton Bay.

Keywords

Fish trap; fishing gear; bycatch mitigation; protected species; Barramundi; Blue Threadfin; King Threadfin; dugong; turtle; dolphin; sawfish; great hammerhead; Scalloped Hammerhead; winghead shark.

Introduction

Queensland's East Coast Inshore Finfish Fishery (ECIFF) is a major fishery that supplies a wide range of seafood product for domestic markets as well as some export components. Key species taken in N2 nets in the ECIFF include the Barramundi (*Lates calcarifer*), King Threadfin (*Polydactylus macrochir*), Blue Threadfin (*Elutheronema tetradactylum*), and a wide range of other estuarine and coastal fishes including Javelin fishes (*Pomodasys* sp.), Breams (*Acanthopargus* sp.), and Mullets (e.g. the Sea Mullet *Mugil cephalis*), as well as various shark species (Chin et al. 2019). The fishery is highly varied and dispersed with numerous small-scale operators working mostly between Cairns and southeast Queensland (SEQ). The number of active fishing licenses and reported fishing effort have declined over time, from a reported high of over 350 active licenses and 18,000 fishing days in 2004, to approximately 150 active licenses and 8,000 fishing days in 2016 (Chin et al. 2019). However, the fishery remains an important means for providing locally sourced seafood to the domestic market, and is integral to the livelihoods of Queensland commercial fishers.

The environmental performance of net fisheries has long been scrutinized, especially regarding the bycatch of non-target and/or undersized fishes, as well as the bycatch of species of conservation interest (SOCI) such as marine turtles, dolphins, and dugong (GBRMPA 2019, 2020). More recently, there has also been increasing concern about the status of sharks and rays taken in in Queensland. While some species appear to be at lower sustainability risk (Tobin et al. 2010; Simpfendorfer et al. 2017), there are concerns about the limited data availability and reporting of sharks including discard rates (Leigh 2016), potential sustainability issues for some species (Tobin et al. 2010; Harry et al. 2016). In particular, the bycatch and mortality of hammerhead sharks (*Sphyrna* sp.) has been a growing concern (Threatened Species Scientific Committee 2018), and some sawfish species such as the Freshwater Sawfish (*Pristis pristis*) and Green Sawfish (*Pristis zijsron*) have declined sharply along the Queensland coast .

The long-standing concerns about interactions with SOCI and more recent concerns regarding bycatch mortality and discards of sharks have driven a range of management responses including Dugong Protection Areas in the Great Barrier Reef Marine Park, fisheries regulations on net configuration and deployment, as well as contributing to wider marine park zoning. There have also been rounds of license buy-backs and increased reporting requirements and restrictions on the net fishery. However, concerns and scrutiny remain about some areas of the fishery including the potential impacts on hammerhead sharks (Threatened Species Scientific Committee 2018). Commercial fishers have also expressed concern that these issues could compromise the future operation of the fishery. These concerns have proved to be justified, with the recent decision by the Australian Government to revoke the ECIFF Wildlife Trade Operation approval under the Commonwealth Environment Protection and Biodiversity Conservation Act (1999), coming into effect on 30 September 2020. This revocation means that product from the fishery such as mullet roe, swim bladder, and shark fin can no longer be exported.

Trap-based fishing is an alternative fishing method that has been used extensively in Queensland. Indigenous Australians have been using fish traps to harvest fish along the Queensland coast for tens of thousands of years, building large stone traps along the coats, many of which still exist today (Rowland & Ulm 2011). More recently, commercial arrowhead fish traps were used in the 1950s and 60s to harvest coastal fishes. Similarly, the remnants of this fishing apparatus can also be seen in several locations along the Queensland coast. While trap fishing has been replaced in most areas of Queensland by mesh net gears, tunnel net fisheries have been operating in Moreton Bay in southeast Queensland (SEQ) for decades, and have been held up as model commercial fisheries (Lee 2018). Tunnel nets are essentially mobile fish traps that are deployed and retrieved over a single tidal cycle. Tunnel net gear consists of extended 'wings' that funnel fishes into a long tunnel (Fig. 1) where they can be 'brailed' (see glossary) into a boat for sorting. The gear includes 'hooks' at the ends of the wings and 'traps' within the gear to redirect fishes that may be swimming along the wings towards the shore back into the gear. This reduces the number of fish escaping the trap.

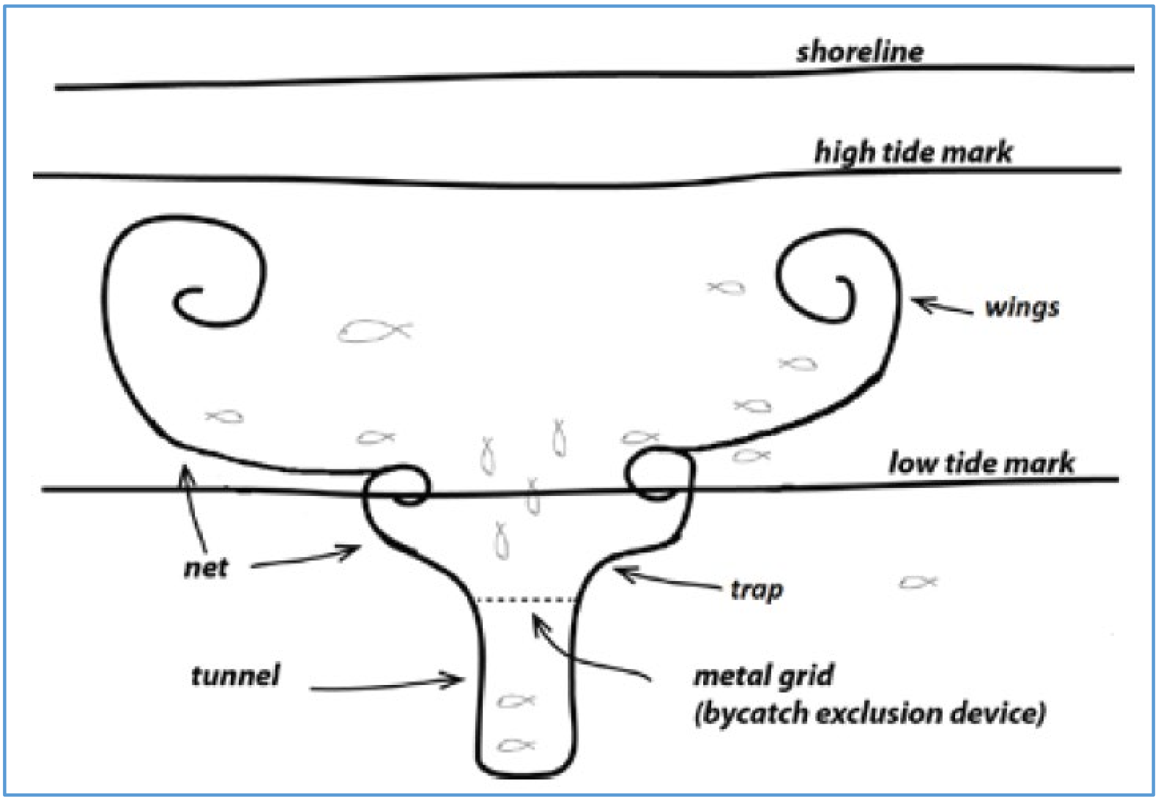


Figure 1: Tunnel net design and components (figure from Moreton Bay Tunnel Net Fishery Operators 2012)

Tunnel nets have several distinctive characters. Firstly, the wings of the tunnel net are <u>not</u> designed to catch or mesh fishes. They are typically made of thick cord with a small (e.g. 2 ⅛ inch) mesh size to prevent fish from becoming entangled in the wings. Instead, the wings act as a fence to direct fish towards the tunnel. This distinction is important as there is often misunderstanding that the wings are actually 'fishing', leading to misconceptions that tunnel nets are mesh nets stretching up to 1.8 km long. Secondly, the tunnel part of the gear is always submerged. Once fish are in the tunnel, they are free swimming until restrained into a smaller section of the tunnel and then brailed into a sorting tray. This process has several benefits:

- The small mesh size and net material of the wings prevents SOCI species such as marine turtles, sharks and rays, and marine mammals from becoming entangled in the net, and the metal grid excludes them from entering the tunnel. These species swim out of the gear as it is disassembled with the receding tide.
- Once brailing and sorting of the catch begins, bycatch species are released back into the water alive and in excellent condition within seconds to minutes of sorting.
- Undersized target species are also released unharmed and thus are returned to the fishery to support future catches.
- Target species are immediately placed in an ice slurry in excellent condition, leading to better prices and longer product shelf life. This maximizes the value of each fish.
- Fishers can ‘fish to order’, keeping the species, sizes, and quantities that are fetching highest prices. This maximizes sustainability and economic yield by only targeting and retaining species currently in demand while releasing species that are currently fetching low prices, thereby allowing these fishers to target these species when prices improve.

These characteristics of tunnel net operations, in particular the exclusion and release of bycatch species in good condition including SOCI and undersized fish, are the potential advantages that underpin this project. Existing net fisheries in the ECIFF are under increasing scrutiny and regulatory pressure. If tunnel nets can be used instead of N2 mesh nets in some parts of the ECIFF, fishers could continue to supply local markets and maintain their livelihoods while improving environmental performance, and addressing long-standing conservation concerns. There is great interest in trialling alternative trap-type gears in the fishery and has been specifically identified by the Queensland governments as a gear innovation to investigate and pursue (QDAF 2018b).

This project is intended to determine if tunnel nets can be used in NQ to replace N2 mesh nets, and if so, what factors must be considered and what conditions need to be met to ensure that it would be economically feasible, operationally practical, and environmentally sustainable in the long-term.

Objectives

This project is limited in scope and scale to a preliminary feasibility study. The overall objective is to determine whether it is feasible to use tunnel net gear in north Queensland as alternative gear in the Queensland N2 fishery[1] as a means to improve reduce bycatch interactions and mortality, particularly of SOCI.

The specific aims of this preliminary technical feasibility study are to:

- Aim 1: Conduct site assessments to identify potential technical feasibility trial sites in Cardwell and Mackay;
- Aim 2: Identify key factors that would like affect the technical feasibility and effectiveness of tunnel net gear in NQ;
- Aim 3: Provide NQ net fishers with opportunities to observe tunnel net operations to understand the scope and scale of tunnel net operations, and assess their willingness and capacity to use this gear in NQ; and
- Aim 4: IF suitable sites and willing net fishers in NQ are identified, conduct a single limited trial at these sites with participating NQ fishers to record catch and bycatch and examine the technical feasibility of the gear.

An implicit objective of this project is to enable knowledge sharing and learning between net fishers from FNQ and Moreton Bay, and to build networks between fishers to facilitate continued learning, support, and information sharing within the industry.

[1] The N2 net fishery is a set net fishery using mesh net up to 600 m with mesh size between 100 mm to 215 mm in waters < 2 m deep between Kauri Creek and Cape York

Methods (Aims 1, 2 and 3)

This project was a collaborative effort between the researchers from the Fish and Fisheries Lab at James Cook University and commercial fishers from Cardwell, Mackay, and Moreton Bay (Appendix 1). The project had three distinct activities that align with the project aims.

- Activity 1 (addresses Aims 1 and 2)– expert tunnel net fishers from Moreton Bay travel to North Queensland to conduct site assessments with participating fishers from Cardwell and Mackay
- Activity 2 (addresses aim 3) – NQ commercial net fishers from Cardwell and Mackay travel to Morton Bay to view tunnel net operations to assess operational feasibility in their respective fishing grounds

And pending favourable outcomes from Activities 1 and 2;

- Activity 3 (addresses Aim 4) Field trials of tunnel net gear in Cardwell and Mackay.

Administrative arrangements needed to launch the project were secured by June 2021 including a JCU animal ethics research permit (A2746), GBRMPA Permit (G20-43159.7) and QDAF Permit (213606). We note that changing restrictions and intermittent travel restrictions due to the COVID-19 pandemic added significant additional administrative workload as well as raised prices for costs such as airfare and accommodation in regional centres.

Communication and engagement

Communication and engagement activities undertaken include travel to Cardwell and Ingham to meet with commercial fishers and to brief the GBRMPA Hinchinbrook Local Marine Advisory Committee (LMAC) on 19 Feb 2020, and briefings to the Mackay LMAC via Zoom on 8 July 2020.

Follow up discussions have been had with recreational fisher representatives from those bodies, specifically Mr Adam Royle (President – Australian National Sports Fishing Association Qld; Chair – Hinchinbrook LMAC) and Mr John Bennett (Mackay Recreational Fishers Alliance; member QDAF inshore working group and GBRMPA Mackay LMAC). The Girringun Aboriginal Corporation in Cardwell has also been kept up to date via email and phone conversations since 2017. Several meetings and email updates have been provided to the GBRMPA (Thomas Hatley, Rohana Rogan-Darvill, Darren Cameron, Thea Walters, Carolyn Roache, John Tapim) and QDAF (Eddie Jabreen, Peter Kind, Kimberly Forster, Tony Ham) to keep managers informed.

Activity 1 and 2 – Fisher exchanges and site assessments

Operational activities were postponed due to COVID-19 travel restrictions, but after planning and rescheduling, the project team have completed the intended operational activities. These include site assessments by the JCU research team (Andrew Chin and Sushmita Mukherji) and Moreton Bay technical experts (John Page and Dave Thomson) to Cardwell from 21-24 August 2020, and Mackay from 28-31 August 2020.

Locations in Cardwell were accessed by vessel on the ebb tide, while in Mackay sites were accessed on foot at low tide, and also by vessel on an ebb tide. At each location, the fishers discussed key factors and Moreton Bay tunnel net fishers conducted site assessments and enquired about key factors including:

- Tidal range and characteristics (e.g. strength of the tidal run over the tidal cycle)
- Historical catches of key species in each location
- Substrate composition
- Depth profile of the beach, distance between the low tide mark and high water, and the area of beach that could be 'drained off' into the traps
- Exposure of the beach to weather
- Seasonal temperature range and weather conditions
- The level of activity of other users

Commercial fishers and business operators from Cardwell (Allan Bobberman) and Mackay (Mark Ahern, Debbie Ahern), and the JCU research team travelled to Moreton Bay from 27-30 September 2020 to observe tunnel net fishing operations. The team was joined by Dr Ian Tibbets from the University of Queensland who is also the chair of the QDAF scientific working group that provides advice regarding Queensland fisheries management.

The overall result of Activity 1 and 2 was that tunnel net fishing gear was deemed as being feasible in Cardwell, and the NQ fishers wished to proceed with the trials (These results are present in more detail in the Results section). This outcome led to the implementation of Activity 3.

Findings and results (Aims 1,2, and 3)

Cardwell site assessment

The project team visited Cardwell to meet with Allan and Pauline Bobberman (Hinchinbrook Seafoods) from August 21-24. Site assessments included discussions about site requirements, gear construction and deployment, logistics, and environmental challenges and constraints. Vessel based site assessments were conducted between Menuga Creek (18° 13.954'S: 146° 1.078'E) and the Tully River (18° 1.850'S: 146° 3.108'E). Five sites were assessed for bottom composition, depth profile, exposure to weather, potential fish habitat, tidal run and water flow, and access.

In general, expert tunnel net fishers feel that several sites in this location have the potential to be successful tunnel net fishing locations. Factors underpinning this assessment include:

- Suitable beach profile or 'drop'. The drop describes the slope and profile of the intertidal and subtidal zones. A beach with a suitable drop is steep enough that water (and fish) will 'drain off' into deeper water at low tide where there is sufficient water at low tide to ensure that the tunnel remains submerged. A suitable drop also ensures that the distance from tunnel to shore is short enough that wings can be a manageable length, but that the trap will drain off a sufficient fishing area.
- Moderate tidal run.
- Water clarity was much clearer than anticipated.
- The substrate was predominantly sandy and flat which is required for setting stakes and /or anchors to maintain gear shape and to keep the wing footropes flush with the substrate. This is essential to prevent fish from swimming under the footrope and out of the gear.
- The site receives some shelter from H
-

However, it was also agreed that using tunnel nets in this location would be restricted to certain seasons and conditions.

- The use of tunnel nets in this location should only occur during the winter. Tides during the winter period are smaller than the summer, meaning less drag on the gear and thus lower risk of the gear 'pulling up' or breaking under tidal runs.
- Crocodile activity and the prevalence of marine stingers are significantly reduced during the winter months. An experienced crocodile expert was consulted who advised that risk was lower in the winter months.
- Water clarity is greater in winter allowing fishers to better observe the gear and any interactions.
- Algal prevalence is reduced during the winter, meaning fewer algae fronds that could become entangled in the wings during ebb tides. Excessive algae can create so much drag that the wings collapse and can even cause gear breakage.
- The condition of both retained and released fishers is likely to be better in winter due to the cooler water temperatures in the tunnel which reduce stress and also increase dissolved oxygen levels. This will improve post release survival as well as the value of the retained catch.

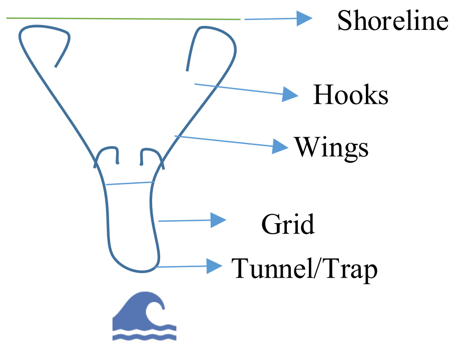
- Ideally, gear would be set on tides with a high tide in the early morning after dawn and a low tide at noon. This would enable setting the gear and fishing one ebb tide, with catch sorted and gear retrieved before the afternoon sea-breeze increases wave heights, and ensure sufficient light to monitor the gear throughout the deployment.

Figure 2: Information exchange between fishers and researchers is a key element of this project, making it possible to record fisher knowledge about how and why tunnel nets may (or may not) be suitable for use in north Queensland.

Overall, numerous sites were identified that are suitable for tunnel net trials. Notes for these specific sites and potential gear configurations are included below.

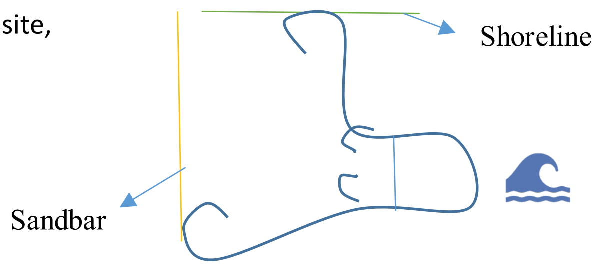
Site 1:

- Potential for a hook style method used to deploy the net
- Starting depth for the net - ~5 to 6 ft so there would be sufficient water depth for the tunnel at low tide
- Stakes will have to be used to hold the net in place
- Shallow enough to see any interactions
- Not going shore to shore (too much run)



Site 2:

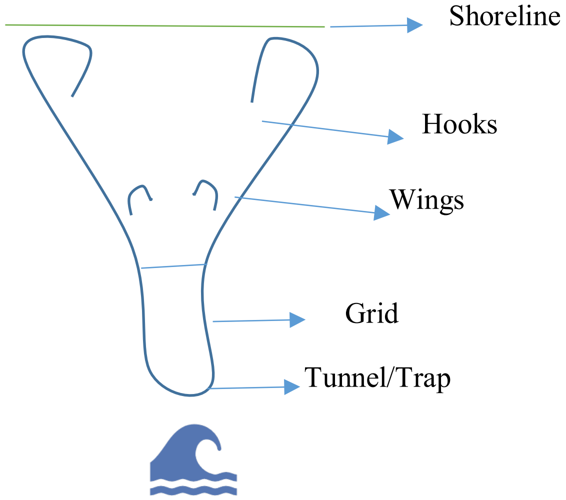
- Deep gutter present that would be an ideal location for the tunnel
- Used to have a commercial arrowhead fish trap at this site, indicating potential suitability as a trap site
- The sandbar provides a natural barrier to guide fish movement. Suggested deployment: 1 wing to shore and the other wing to the sandbar

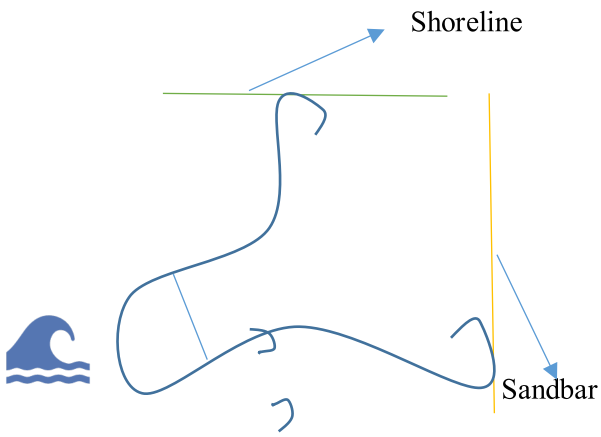


Site 3:

- A Tunnel net could potentially be set from shore to shore in ~ 6 ft of water
- A tunnel net could also be deployed in a similar configuration to site 2, wherein one wing is to shore and other wing is to a sandbar that forms a natural barrier
- There used to be an Indigenous fish trap at this location, indicating potential suitability

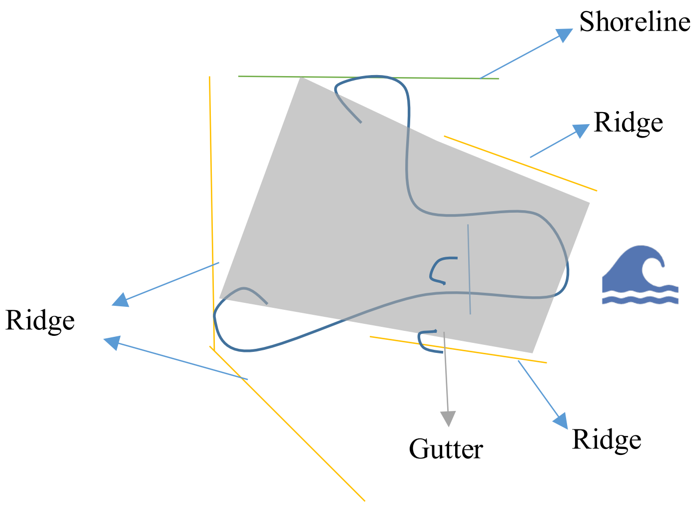
Fishers noted that there is no need to use hooks if the gear is set 'on top of the fish; when setting the net





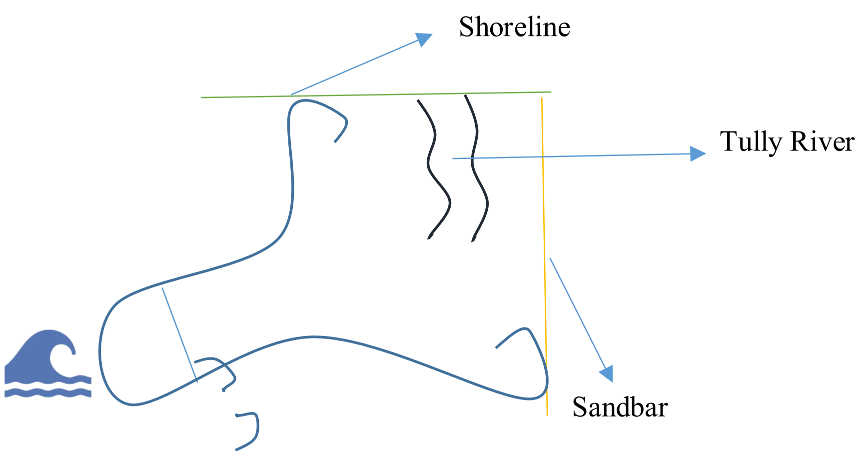
Site 4:

- A tunnel net could be deployed in the gutter between two ridges
- Depth was ~7 ft at the gutter so there would be sufficient water depth for the tunnel at low tide
- While it would be possible to deploy a tunnel net at this location, it is less preferable that other locations. The numerous gutters and ridges within the area would make it difficult to keep the footrope of the wings flush with the substrate, creating gaps that fish could escape through.



Site 5:

- A tunnel net deployed near a river mouth could benefit from fish movement in and out of rivers and creeks (it was noted that currently many net fishers fish in or near rivers to capitalize on these movements)
- Feasibility would be affected by water flow
- Site depth at low tide is ~ 5 ft which would be sufficient for a tunnel at low tide
- It was noted that any deployment of gear near river or creek mouths would be subject to permit restrictions



Mackay site assessment

The project team visited Mackay to meet with Mark and Debbie Ahern (Debbie's Seafood) from August 28-31. As in Cardwell, the site assessments focused on site characteristics, fisher requirements, gear construction and deployment, logistics, and environmental challenges and constraints.

Sit assessments included both vessel-based assessments and walking sites on foot as the large tidal range allowed the team to walk sites at low tide. Site assessments were conducted at various sites from north of Grasstree Beach (21° 20.624'S: 149° 17.970'E) to sites south of the Pioneer River (e.g. 21° 9.259'S: 149° 13.230'E). Seven sites were assessed for bottom composition, water clarity, depth profile, exposure to weather, potential fish habitat, tidal run and water flow, and access.

The tidal range and subsequent volume of water moving (e.g. > 7 m tides at Hay Point, > 6 m tides at Mackay[2]) would make tunnel netting around Mackay very challenging (Fig. 3).

Figure 3: the large tidal range of sites in Mackay will be challenging, and will restrict tunnel netting to small number of sites and conditions. For example, this creek will be inundated at high tide, but is completely dry at low tide indicating a large volume of water movement and a long drop that would need excessively long wings.

Additionally, the high volume of boating traffic, recreational use, in conjunction with the high visibility of tunnel net operations, would need careful management and consideration regarding community and stakeholder engagement. Lastly, many of the sites are highly exposed to wind and

[2] https://www.msq.qld.gov.au/Tides/King-tides#:~:text=Queensland%20has%20a%20relatively%20large,4.88m%20at%20Karumba

waves which could make operating tunnel nets challenging, and reduce the times they can be used.

Meanwhile, there were two sites that had some potential that could be investigated further. These sites were more sheltered, the beach profiles with 'shorter' drops meaning that there was sufficient water at low tide to submerge the tunnel in a location close enough to the shore to set gear, and they were less often accessed by other users.

Another significant benefit is that the local fishing operation, Debbie's Seafood, would process the catch directly and could have the capacity to differentiate the product as higher quality 'trap-caught' fish which could increase the value of each fish caught. The business sells fresh fish product (Fig. 4) but also sells and serves cooked product in an attached café.

Having multiple points of sale for product could create opportunities to educate consumers about the environmental benefits of trap-caught fish, as well as consumer benefits such as extended product shelf life and freshness.

Figure 4: Local seafood retail operations Debbie's Seafood provide opportunities to market trap-caught fish, and to educate consumers about the benefits of trap-based fisheries.

Nevertheless, while there are a small number of sites in Mackay that could be feasible, and the inclusion of fish processors and retailers provide opportunities to promote community understanding and the social license of tunnel net fishing, at this stage a more cautious approach would be beneficial. It is thus recommended that trials in Mackay not proceed until the outcomes of trials in Cardwell – where conditions are more favourable - have been conducted.

Site visit to Moreton Bay

From 27 to 30 September 2020, fishers from Cardwell and Mackay visited Moreton Bay to observe tunnel net fishing operations. The Moreton Bay tunnel net fishers provided the opportunity to observe their fishing operations on Stradbroke Island including site selection, gear deployment, gear soak, processing and handling of catch, release of bycatch, and gear retrieval. Moreton Bay tunnel net fishers and NQ fishers discussed regulatory requirements and challenges, technical aspects of the gear, and the environmental and social factors affecting the use of the gear and operation of the fishery (Fig. 5).

Figure 5: the site visit to Moreton Bay enabled NQ fishers to observe active tunnel net fishing operations and to talk to fishers about the fishery. This knowledge exchange helped to inform their assessments of whether tunnel nets are feasible in NQ.

In particular, NQ fishers were able to observe the scale of a tunnel net operation, the process and gear requirements to select a site and deploy the gear, the entire fishing process, and able to have hands-on practical experience in catch processing. This was an invaluable opportunity for NQ fishers to collect information that could inform their assessment of whether tunnel net operations would be logistically and financially feasible in Cardwell and Mackay.

Overall, NQ fishers have determined that tunnel net operations may be feasible, especially in Cardwell. While the method's long term and commercial scale feasibility will need to be properly assessed though a larger scale trial, NQ fishers believe that scaled down tunnel nets can be at least successfully trailed to test their performance in NQ waters.

Methods (Aim 4)

Activity 3: Cardwell field trials

From July 5-10, four tunnel net fishers from Moreton Bay and two commercial net fishers from Mackay travelled to Cardwell with fishing vessels and nets. These specific dates were chosen to coincide with suitable tides (neap tides with a morning high tide dropping to a low in the early afternoon), and local fishers advised that the weather was usually favourable during this time of the year (higher chances of encountering light westerly winds).

On July 5th the team deployed to the study site between Menunga Creek and the Tully River, a stretch of inshore water to the north of the Cardwell township (Fig. 6). The team used depth sounders and assessed substrate types to find specific sites to deploy tunnel nets over the following five days. Specifically, the tunnel net fishers looked for sites with water depth between 0.7 and 1.5 meters at low tide where the tunnel could be positioned, where there was suitable substrate (mix of sand mud that would allow the support stakes to stay upright, for anchors to lodge securely, and allow walking); and sites with these attributes that were a suitable distance to the high tide mark on the beach.

Tunnel nets were deployed on the early morning high tides over the following days. Before each deployment, a drone was flown over the area to check the waters for any megafauna such as dugongs, turtles, or cetaceans.

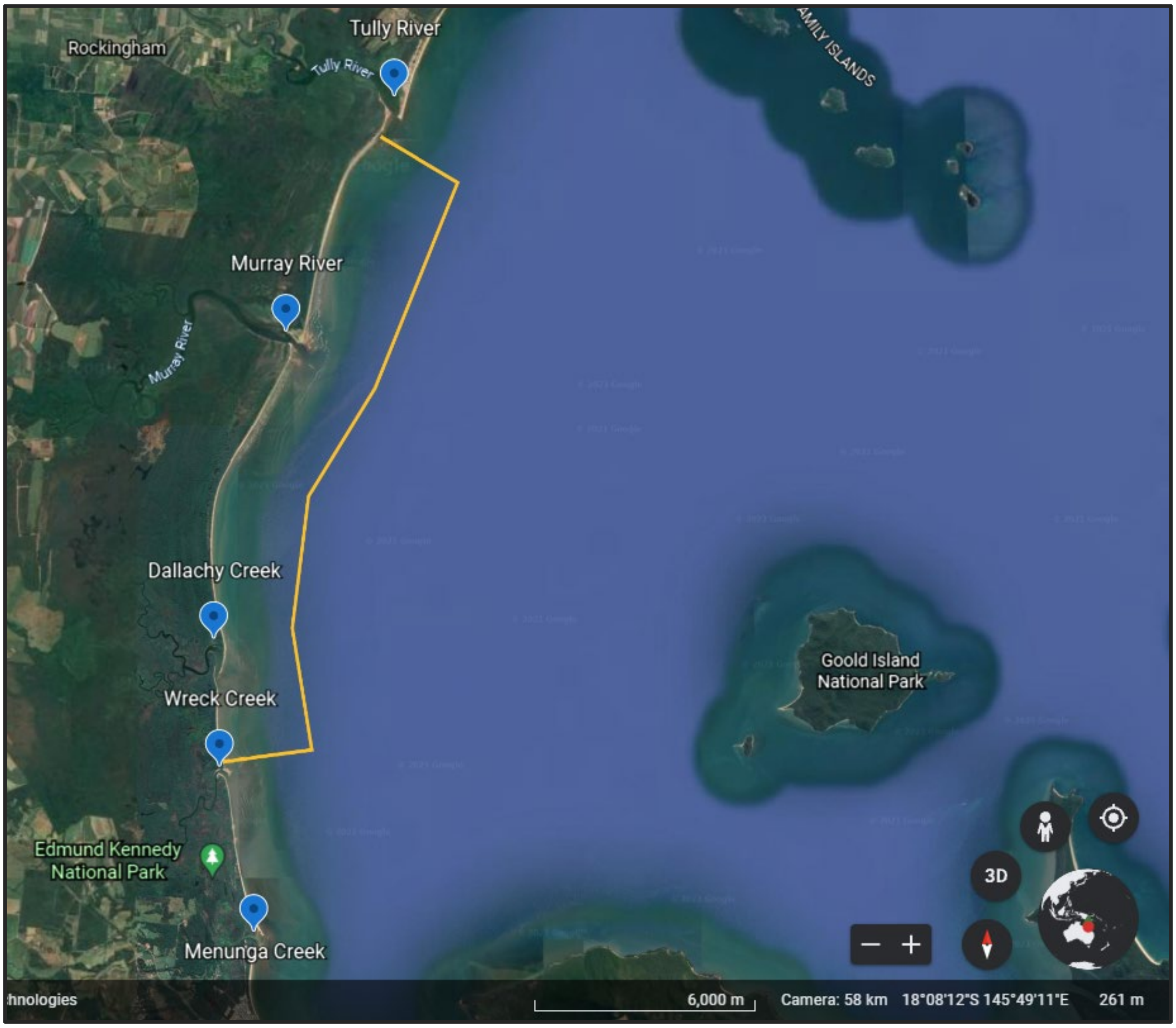


Figure 6: Locality map showing the area of the field trials bounded by the yellow box between the Tully River and Wreck Creek. Map from Google Earth Version 9.147.0.2 (2021) Online (click HERE).

Tunnel net design and specifications

Tunnel net construction and dimensions were as follows.

The tunnel net wings were constructed from 9 ply mesh of 2 ⅛ inch mesh size. Each wing was 600 m in length (1200 m total for the two wings. This small mesh size was selected to avoid any fishes or animals becoming meshed in the wings. The wings had a floating cork line to keep the wings upright, while the bottom lead line was secured with 6 lb sand anchors that were attached to the lead line with shark clips.

The two traps were constructed from 15 ply mesh of 2 ¼ inch mesh size. A heavier ply was used for the traps to reduce the likelihood of target species such as Barramundi and King Threadfin from breaking through the trap.

The tunnel was constructed from 12 ply poly netting of 1 ¼ inch mesh size. The bottom of the tunnel was constructed from nylon mesh.

The tunnel and traps were staked with wooden stakes between 2 and 2.5 m long.

An exclusion grid (Fig. 7; Fig. 10) was installed at the mouth of the tunnel to exclude large animals (stingrays, sharks) and keep them separate from the tunnel and to facilitate their release without having to handle or interact with the animals.

The completed deployed gear is show in Fig. 7.

Figure 7: aerial view of a tunnel net deployed during the field trials showing the various elements of the gear.

Daily tunnel net trials were planned for the following period from July 6-9th. Unfortunately, the weather was very unfavourable during this period resulting with trials suspended on July 7th and 9th due to safety concerns. As such, data one catch and gear performance were collected on two fishing days, July 6th and July 8th.

Recording catch and bycatch

As the tide receded, the wings were retrieved and at low tide, the traps were dismantled leaving just the tunnel submerged below low water. A vessel was tied to the side of the tunnel and an aluminium sorting tray placed on the deck. The catch from within the tunnel was manually brailed into the sorting tray. Two recorders retrieved individual fish from the sorting tray by hand and recorded fish total length (TL) to the mm using wooden measuring board. Fish species identifications and corresponding lengths were called out to two additional data recorders who recorded and verbally confirmed data.

Given the time constraints (incoming tide), only up to 250 individual fishes were measured. After this point, the fishes brailed into the sorting tray were filmed using a head mounted camera (GoPro hero Black 4, 1080 HD, 30 fps) to enumerate the catch.

A subset of fishes were tagged under the first dorsal fin using Hallprint T-Bar anchor tags to determine if released fishes were recaptured in subsequent tunnel net shots, or by fishers after the trials had concluded. Fishes selected for tagging were commercial marketable species with individuals chosen from a range of sizes.

All fishes captured were released with minimal handling and out of air exposure time (measured from the head mounted camera) was typically <60 seconds.

Two additional cameras (GoPro Hero 7, 1080 HD, 60 fps) were also deployed to record the condition of released fish. One camera was mounted underwater on the side of the vessel to record the swimming behaviour of the fishes released from the sorting tray, and another pole mounted camera was deployed after the operations to 'sweep' the area under and around the boat to measure immediate catch mortality.

Video analysis

The videos from the head mounted cameras were analysed in the lab and to enumerate the remainder of the catch that was not measured or recorded on deck. Video analysts identified and counted fishes by freezing the video frames of each brail and identified each fish to species. Where fishes could not be identified to species, they were identified to genus. Measurements could not be taken from the video data so videos were solely used to enumerate catch composition (no. of fish of each species).

Statistical analysis

As a limited feasibility study, this study only extends to descriptive analyses of catch composition with a subset of size composition data per species.

Findings and results (Aim 4 – Cardwell Field Trial)

From 5-7 July 2021, limited field trials were conducted in the Cardwell region of the Great Barrier Reef Marine Park. Trials were carried out under GBRMPA Permit #G20/43159.1 and QQDAF Permit #213606, and JCU Animal Ethics Approval A2746. Collectively these permit conditions limited the configuration and locations where tunnel nets could be deployed.

The four-day field trial involved four tunnel net fishers from Moreton Bay, three net fishers from North Queensland, and four research staff from JCU. Equipment involved four vessels and tunnel net gear.

Site inspections were carried out successfully on Monday 5th July and several candidate sites confirmed for trials for the following days. However, local conditions affected the implementation of the trials. Specifically:

- The poor state of the Hinchinbrook boat harbour mean that the channel was silted in, resulting in very limited tidal periods when vessels could be launched and retrieved.
- The weather conditions were not favourable. Although this time period was selected based on favourable tides and wind conditions, the actual field conditions were easterly to south easterly winds of up to 10 knots and a rolling swell at low tide. While the gear could be deployed, wind and swell conditions at retrieval proved to be very challenging to the extent that safety concerns were raised by the fishers. As a result, fishing gear could only be deployed on two of the days planned.

Effort and catch

Shot 1 was carried out on 6 July 2021 north of wreck creek at approximately 18°11’05”S; 146°00’42”E with the shot set at the morning high tide (2.39 m at 07:20) and fished on the ebbtide to low tide (0.82 m at 13:39). The gear was fully retrieved by 1430.

Shot 2 was carried out on 8 July 2021 north of Dalachy creek at approximately 18°09’32”S; 146°00’44”E with the shot set at the morning high tide (2.32 m at 08:15) and fished on the ebbtide to low tide (0.76 m at 14:23). The gear was fully retrieved by 1530.

A total of 852 fishes from at least 37 species were captured in the gear (Table 1). Due to the volume of fishes being processed and time constraints from tidal conditions, some species were not identified to species. These include:

- Fish (unidentified) and Herring (unidentified) These were predominantly small bait fishes from the families Clupeidae, Leiognathidae, and Gerreidae.
- Ray (unidentified). These rays were from the family Dasyatidae and were observed in the traps but were not handled. They were released as the gear was being retrieved.

Species	**Total count**
Barramundi (*Lates calcarifer*)*	11
Barred Javelin (*Pomadasys kaakan*)**	2
Barred Queenfish (*Scomberoides tala*)**	1
Black Jewfish (*Protonibea diacanthus*)**	2
Blue Catfish (*Neoarius graeffei*)	8
Blue Threadfin (*Eleutheronema tetradactylum*)*	11
Bottlenose wedgefish (*Rhynchobatus australiae*)	1
Bullrout (*Notesthes robusta*)	1
Crescent Grunter (*Terapon jarbua*)	6
Fish (unidentified)	40
Herrings (unidentified)	17
Pikey Bream (*Acanthopagrus berda*)**	47
Ray (*Dasyatidae* spp.)	2
Beaked sea snake (*Hydrophis zweifeli*)	3
Silver Javelin (*Pomadasys argenteus*)**	**377**
Silver Jewfish/Soapy Jew (*Nibea soldado*)**	56
Snubnose Dart (*Trachinotus blochii*)	14
Cowtail Stingray (*Pastinachus ater*)	1
Dusky Flathead (*Platycephalus fucus*)**	1
Garfish (*Hyporhamphus* spp.)**	1
Giant Queenfish (*Scomberoides commersonianus*)**	3
Javelin fish (unspecified)**	**175**
Giant Trevally (*Caranx ignobilis*)	1
Goldenline Whiting (*Silago analis*)**	3
Australian whipray (*Himantura australis*)	1
Jewfish unspecified (*Nibea* spp.)**	39
Scaly Jewfish (*Nibea squamosa*)**	6
King Threadfin (*Polydactylus macrohir*)*	6
Lesser Queenfish (*Scomberoides lysan*)**	1
Scalloped Hammerhead (*Sphyrna lewini*)	4
Giant Shovelnose Ray (*Glaucostegus typus*)	2
Sicklefish (*Drepane punctata*)**	4
Silver Biddy (*Gerres subfasciatus*)	1
Sea Mullet (*Mugil cephalus*)**	1
Sole/Founder (unidentified)	3
Sand Whiting (*Silago ciliata*)**	1
Giant Oystercracker (*Trachinotus anak*)	1
Tripletail / Jumping Cod (*Lobotes surinamensis*)**	1
	Total count 855

*Table 1: combined catch composition (individual fish) from two tunnel net shots. * denotes primary target species; ** denotes secondary target species in the East Coast Inshore Finfish Fishery. Numbers in bold represent >50% of the total catch (by number). Note that the beaked sea snake is not a fish, and was the only non-fish species captured.*

The catch was dominated by Javelin fish (*Pomadasys* spp.) including 377 Silver Javelin (*Pomadasys argenteus*) and 175 Javelin - unspecified. While the precise species composition of this unspecified group of Javelin fishes cannot be provided, a qualitative analysis of head-mounted video taken during measuring and processing provides strong evidence that >90% of these unidentified Javelin fishes would have been Silver Javelin (Fig. 8).

Figure 8: head-mounted camera footage suggests that the majority of Javelin fishes recorded as 'Javelin - unspecified' are Silver Javelin Pomadasys argenteus. *All five Javelin fishes in this captured image can be clearly identified as Silver Javelin.*

The predominance of Silver Javelin and Javelin - unspecified in the catch is graphically illustrated in Fig 9A and 9B.

The trial captured relatively few of the main primary target species in the fishery; Barramundi, King Threadfin and Blue Threadfin. This may have been in part to the design of the exclusion grid placed at the front of the tunnel (Fig. 7 and Fig. 10). The dimensions of the spaces in the grid were likely too small to allow the primary target species (Barramundi and King Threadfin) to enter the tunnel. Instead, these large fishes would have been retained in the traps and may have escaped. Indeed, several holes were later observed in the traps and occasionally a large fish was observed jumping over the corklines of the wings and traps into open water beyond. However, the number of Barramundi and threadfins to have escaped in the manner remains unknown.

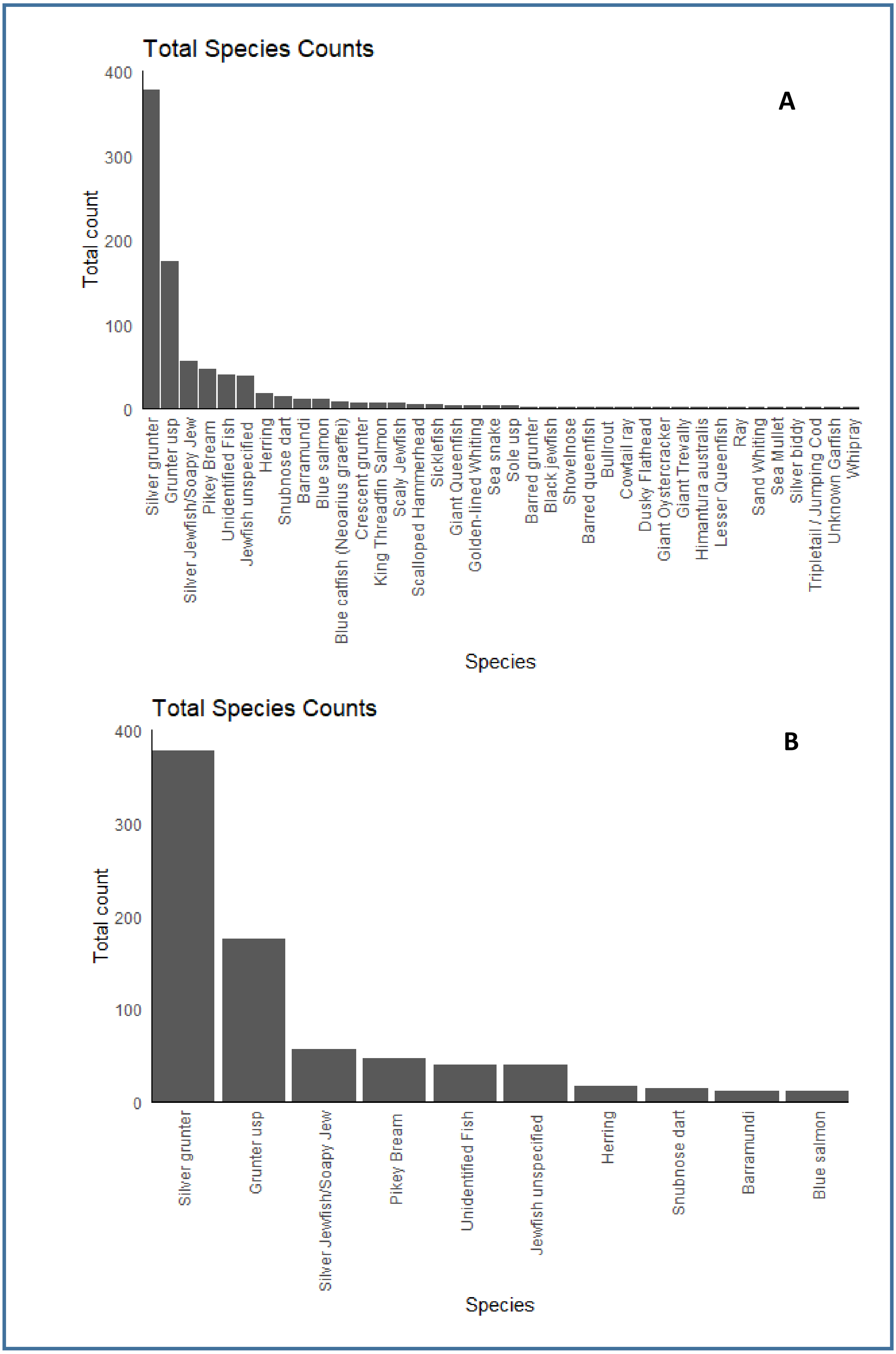


Figure 9: Catch composition of all species (A) and of the top ten must numerous species (B).

As well as these unquantified fishes that escaped from the gear, an estimated >30 individual batoids were *not handled and counted* but were released when the gear was retrieved. This number was estimated from opportunistic photos and video captured during brailing and processing.

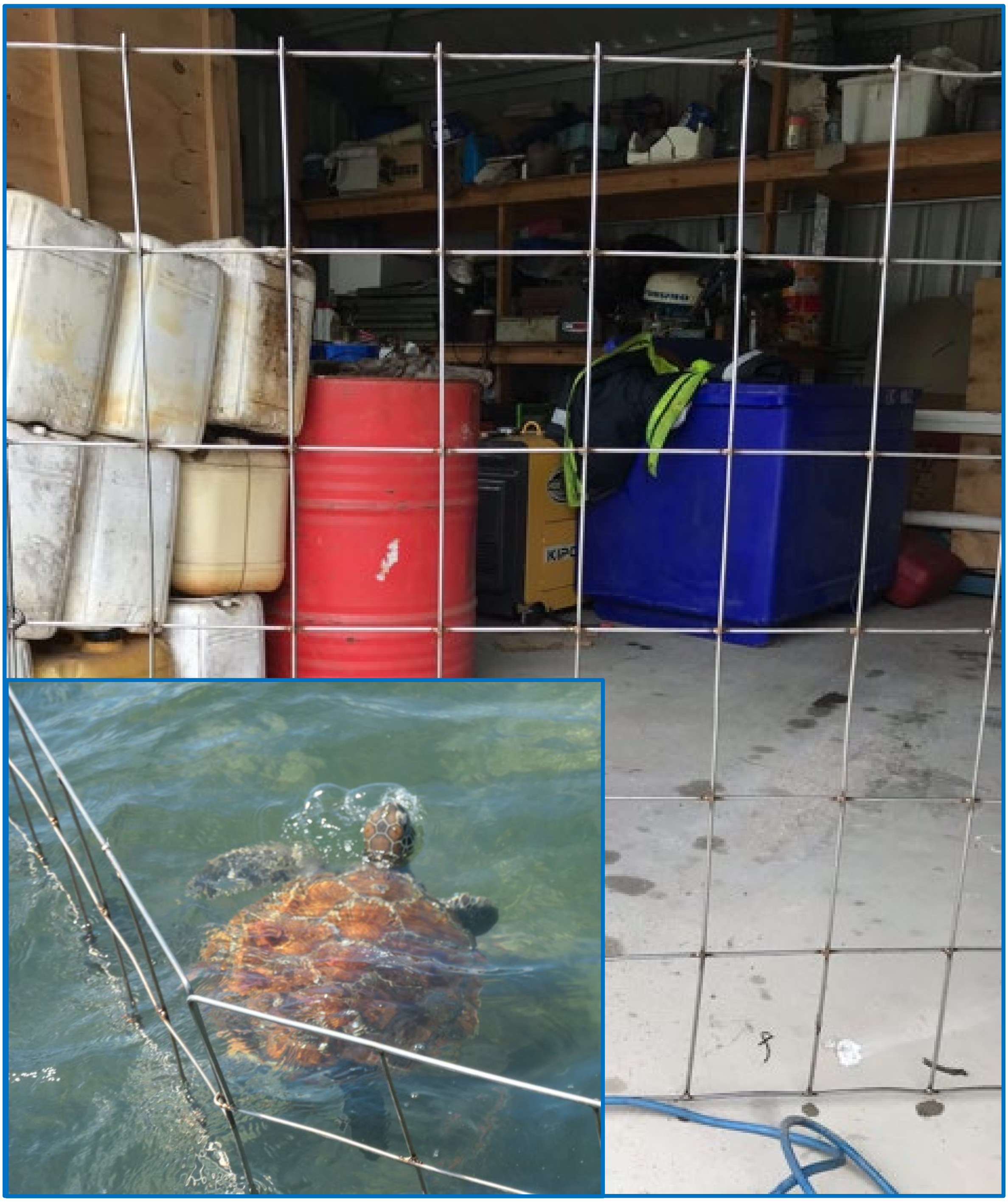


Figure 10: the exclusion grid is designed to keep larger animals such as turtles (inset) out of the tunnel. However, the dimensions of the gird used during the trials may have been too small to allow the primary target species (Barramundi and King Threadfin) to enter the tunnel. Note: inset photo was taken in Moreton Bay, no turtles were encountered during the field trial in Cardwell.

Size frequency patterns of the main species captured

The size frequency patterns of Javelin fishes captured in the gear were markedly different between the two shots. A total of 176 Javelin fishes were captured in shot 1. While these were recorded as ‘Javelin unspecified’ retrospective analysis of video footage suggests that >98% of these were Silver Javelin (*P. argenteus*). As depicted in Fig. 11, the majority of these fishes were over the legal-size limit of 300 mm (TL) and would have been able to be retained by fishers during commercial operations.

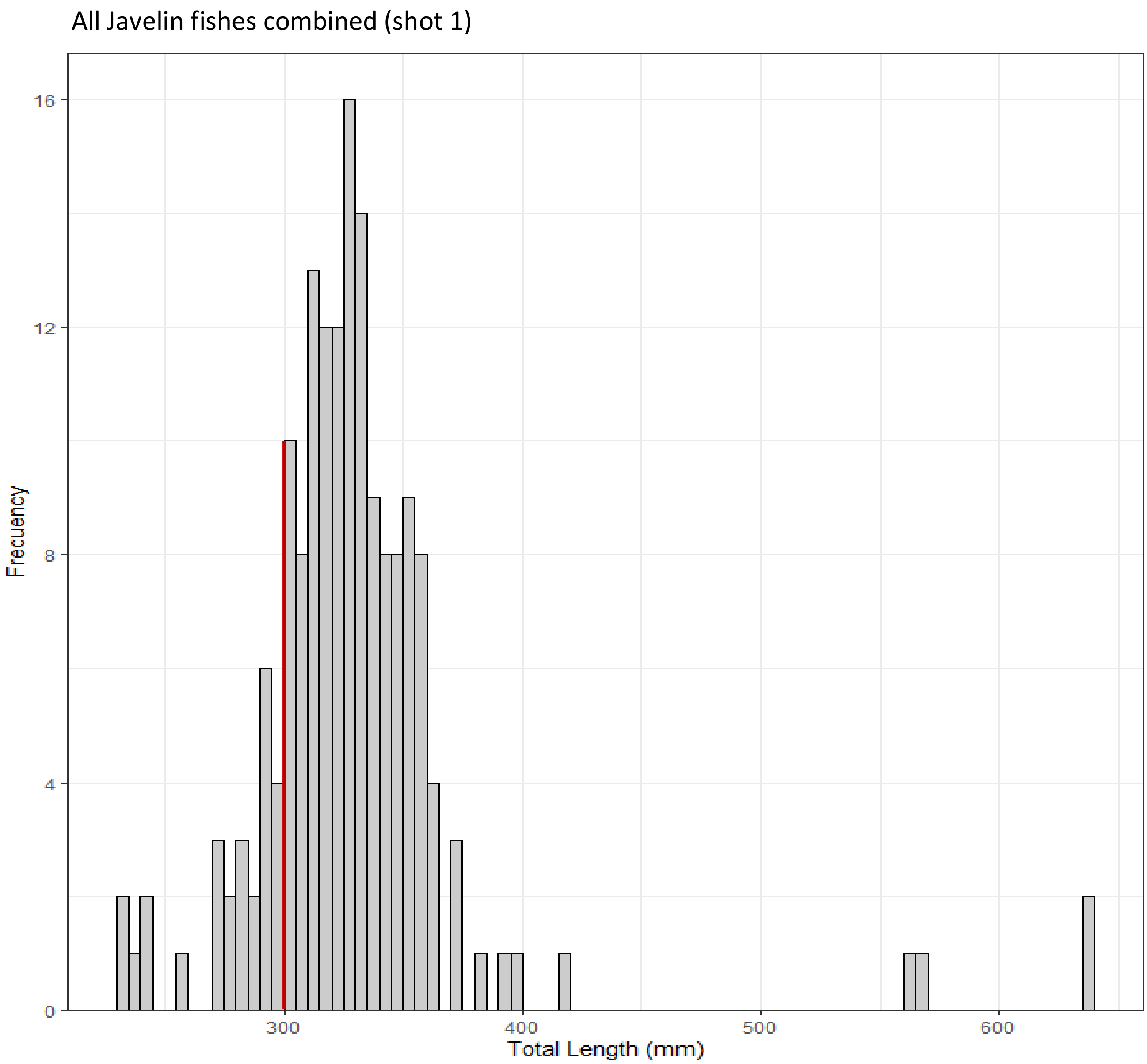


Figure 11: sizes (TL) of Javelin fishes captured in shot 1, most were over the legal-size limit of 300 mm (TL) (indicated by the red line)

A total of 185 Javelin fishes were captured in Shot 2, all of which were positively identified as Silver Javelin (*P. argenteus*) except for one Barred Javelin (*P. kakaan*). In contrast to Shot 1, the majority of these individuals were smaller than the legal-size limit of 300 mm TL and thus would not have be able to be retained (Fig. 12). This suggests that Silver Javelin fishes are structured by size even at fine spatial and temporal scales as shot 1 and 2 were only approximately 3 km apart, and occurred within two days of each other. These findings also demonstrate the potential benefit of this gear as all the fishes captured (including undersized Javelin fishes) were released alive and in excellent condition (see *Gear selectivity, bycatch, discards, and species of conservation interest*).

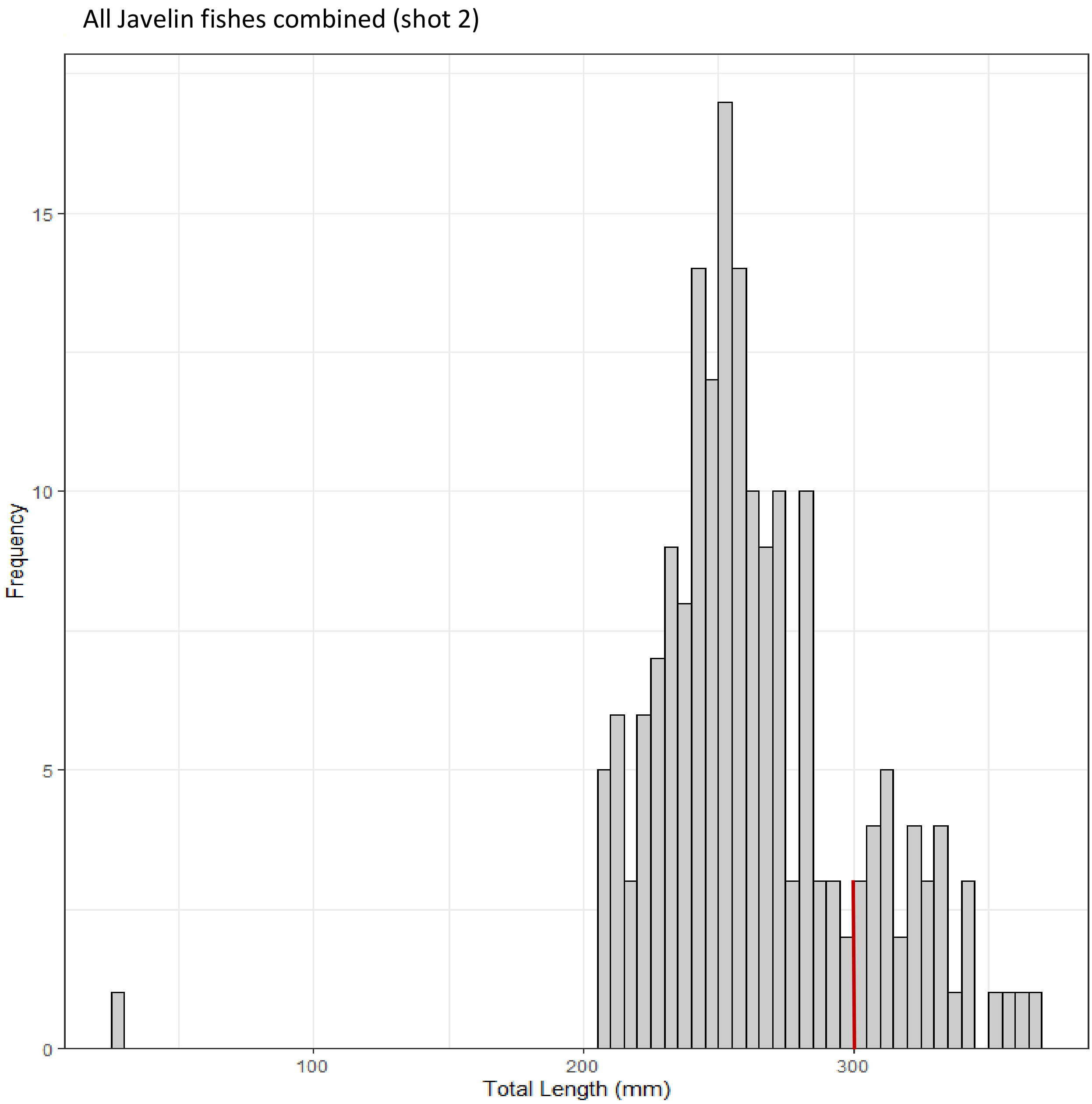


Figure 12: sizes of Silver Javelins captured in Shot 2, noting that the majority of these fishes were under the legal-size limit of 300 mm (TL)

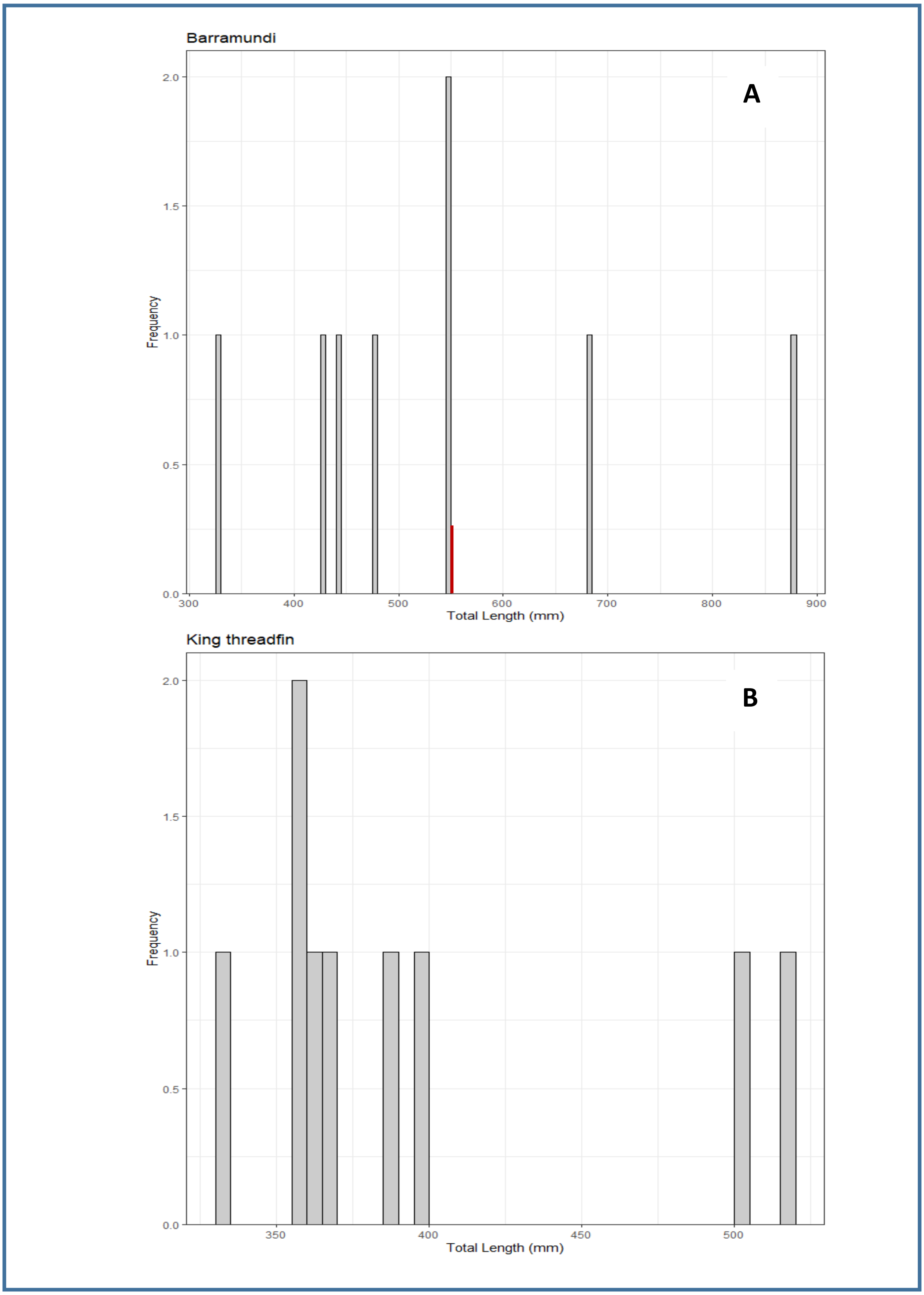


Figure 13: sizes of Barramundi (A) and King Threadfin (B) captured. Red bar indicates legal size for Barramundi. Legal size for King Threadfin is off the scale and is not shown.

Relatively few primary target species (Barramundi n=11; King Threadfin n=6) were captured. Of these, the majority of Barramundi were undersized (Fig. 13a), and all of the King Threadfin were undersized (Fig 13b).

Gear selectivity, bycatch, discards, and species of conservation interest

The catch recorded during this limited tunnel net trial highlights the importance of being specific when describing gear *selectivity*. Tunnel nets are not selective in the capture of fishes – *capture selectivity*, as seen in the wide array of species (38) encountered in the gear. However, by their design and operation, tunnel nets are *highly selective* in retention and landing – *harvest selectivity*. Only target species over legal size are retained while the remainder of the catch is discarded. Discard mortality from traditional mesh nets is a known sustainability (mortality of commercially valuable species) and environmental (capture of nontarget species) issue (Buckel et al. 2006; Uhlmann & Broadhurst 2015), and indeed, shark and hammerhead bycatch is a main driver for this trial. However, the benefit of trap-style fisheries is that fishes remain free swimming until brailing and processing meaning that physical damage, physiological stress from being enmeshed in a net, and exposure to air and physical damage being released from the meshes, is reduced. In contrast, fishes are only exposed to air for seconds before being released or retained, and trap designs are already proven to reduce mortality in other fisheries (e.g. Tuohy et al. 2019; Tuohy et al. 2020).

Unfortunately, the rough sea conditions resulted in very turbid conditions and none of the video cameras deployed to record immediate post release behaviour of released fishes provided usable footage. Meanwhile, the vast majority of the fishes discarded were released in very good condition, and were actively jumping in the sort tray and swam away strongly. Additionally, while 45 fishes were tagged with Hallprint T-bar anchor tags, no tag returns have been recorded as yet. Meanwhile, only 15 fishes were recorded as been discarded dead (one garfish, nine herrings, four ponyfishes; one silver biddy). Nevertheless, these are very preliminary data and post release survival of discards requires further investigation.

Figure 14: bycatch species of conservation concern such as Scalloped Hammerhead sharks were prioritised for release. All SOCI species were released in good condition and swam away vigorously.

A total of seven species of conservation interest were encountered from the two shots; four juvenile Scalloped Hammerheads and three beaked sea snakes. The hammerhead sharks were captured in the first few brails at the beginning of processing. All hammerhead sharks were small, measuring between 550 and 590 mm stretched total length, and all were released in excellent condition and swam away vigorously (Fig. 14). Interestingly, no other sharks were caught. Similarly, the beaked sea snakes were all released swimming away vigorously.

An unrecorded number of fishes were also released from the trap. These were mainly large stingrays that could not be safely brailed into the sorting tray and were simply released free swimming when the traps and tunnel were dismantled. A very coarse estimate from visual counts and video footage suggests that in excess of 30 batoids, mostly large Dasyatid stingrays with one large Bottlenose Wedgefish (*Rhynchobatus australiae*) were also released.

Discussion

The overall aim of this project was to explore the technical feasibility of using tunnel net gear as an alternative gear type to mesh nets in the Great Barrier Reef World Heritage Area (GBRWHA), specifically in North Queensland (NQ). In doing so, the project aimed to provide guidance on the technical and environmental considerations that need to be considered in operationalising this gear type in this region.

The project has delivered on all the stated objectives. Firstly, the project identified one location (Cardwell) that was feasible for trials to proceed, and documented the conditions that made this location feasible; while also documenting why a second location (Mackay) was less favourable. Secondly, the project allowed mesh net fishers from North Queensland to view tunnel net operations and to deliberate amongst themselves whether these gears would be feasible for their fishery. Lastly, a preliminary trial was conducted and the catch, bycatch, and interactions with Species of Conservation Interest (SOCI) examined.

This trial has established that the use of tunnel nets in selected locations NQ is **technically feasible** in that the gear can be deployed and it does catch significant quantities of fish. Nevertheless, determining whether these gears are **commercially viable i**s beyond the scope of this project. The experience gained from this trial and expert advice suggests that there would be numerous challenges that need to be overcome to make tunnel net fishing viable in the GBRWHA (see *Tunnel net performance, feasibility, and viability*).

Lastly, in the course of the project, a large amount of information was exchanged between fishers regarding the safe and efficient operation of tunnel net gear, the economics of the fishery, knowledge gaps and information needs, and potential management requirements. The key elements of these discussions are presented below.

Operational and technical considerations

- Tunnel net fishing in NQ should be regarded as a **winter only** fishery. During the winter (June to September), tides are smaller, there is less algae, fewer stingers and blubber jellyfish (which clog the net and create drag), and crocodiles and sharks are less active. The winds during this period are also generally more favourable with more westerly, offshore winds. Additionally, cooler water temperatures in winter will improve the condition (and subsequent value) of the retained catch, and the fitness and subsequent survival of released bycatch and discards.
- The substrate type is crucial. Sandy substrate that allows anchors and stakes to 'hold' is vital. The substrate also cannot be too muddy or the stakes will not hold, and will be too soft to walk on to work the gear.
- Water clarity is important as this allows fishers to spot fish and monitor gear integrity and performance. Winter conditions generally improve water clarity.
- The slope and 'drop' of the beach are crucial. There must be sufficient water (~4-5 ft) in the tunnel at low tide, with the tunnel located within a few hundred meters of the beach so that the wings can meet and guide fish from the beach into the tunnel. There also needs to be sufficient areas to 'drain off' into the tunnel to ensure a reasonable amount of fishes are captured.
- The best location scenario is a shot next to a bank that goes dry but drains into the gutter which extends beyond the low-water mark.
- Tidal run needs to be moderate to low or the wings might collapse or break away.
- The wings should be pegged when there is more run or there are lots of fish moving along the net. Multiple small sand anchors can also be clipped to the footrope as required.
- The footrope must be set flush with the substrate to avoid fish from escaping by swimming under it. This requires care in anchor placement.
- Tunnel nets should be set in the day as adequate light is needed to set the gear properly and to watch for interactions. The ideal scenario is a high tide near dawn so that the gear can be set and soaked during the ebb tide to a midday low tide.
- Fishers **must** be in direct attendance of tunnel nets at all times throughout deployment. Gear needs to be well maintained, especially the traps and tunnel.
- In some instances, a bag could be used instead of tunnels when fishers are first trialling the gear in their locations. If needed, a bag can be detached and moved into deeper water, preventing the fish from 'going dry'. However, the effect of a bag versus a tunnel on brailing and on fish behaviour and discard survival will need to be closely monitored.
- Considering the environmental constraints of tide range, tidal cycles, and weather, it is possible that a site would **only be fished once per month**. Indeed, in Moreton Bay, fishers will rotate between sites, and give sites 'a spell' of several weeks between shots. However, this will have ramifications on the viability of the gear.

Tunnel net performance, feasibility, and viability

The field trials in Cardwell showed that the tunnel gear can be successfully deployed in North Queensland. Working with four experienced tunnel net fishers, gear was successfully deployed on two days of the field trial in spite of weather conditions being marginal. On both fishing days, the gear remained intact, was successfully deployed and retrieved, and resulted in hundreds of fishes being captured.

This trial also highlights the need to distinguish between *capture selectivity* and *harvest selectivity*. The tunnel net gear had low capture selectivity as indicated by the wide diversity of species that were recorded from the tunnel. However, all of these species were released alive and were deemed to be in excellent condition. In an operational setting, this would have meant that all primary and secondary target fishes that were of legal size would have been selectively retained, while all other fishes would have been released. In this sense, the gear achieved its primary aim of allowing fishers to catch commercially valuable fishes while releasing undersized fishes, non-target fishes, and SOCI species in excellent condition. As such, the gear is deemed to be **technically feasible**.

There are some obvious improvements that could be made to the gear. The exclusion grid needs to be redesigned. In theory, the exclusion grid allows the target species to pass through into the tunnel while keeping larger animals free swimming within the traps. At the time of harvest, the tunnel is sealed and the traps are disassembled allowing all these larger animals to swim out of the gear without any handling or interaction (Fig. 10). This design feature uses the same principle as Turtle Excluder Devices in trawl fisheries (Brewer et al. 2006). However, the grid size of the exclusion grid used in these trials was too small which meant that larger fishes such as Barramundi and King Threadfin did not appear to pass through the grid. Instead, it appears that these larger individuals remained in the traps and as the tide receded, broke through the mesh of the traps and escaped from the gear. Further trials would be needed to determine the optimum grid size that allowed capture of target species while excluding non-target species. Further trials will also be needed to refine the traps. Using a heavier ply would help to retain larger fish and prevent them from breaking through the gear, but would also increase the bulk, weight, and drag of the gear which could make it more difficult to manage in adverse conditions and could narrow the windows when the gear could be used.

However, it was beyond the scope of this project to determine whether this gear is a **commercially viable** option to replace N2 mesh nets in the GBRWHA. Indeed, establishing the commercial viability of trap-type fisheries such as tunnel nets will require additional biological, ecological, and social, and economic research. Such research will need to specifically explore the cost and revenue relationship, as well as establish operating guidelines for ongoing monitoring and potential controls to avoid overharvesting and potential localised depletions. This research will also need to examine potential stakeholder conflict (see *Future considerations*).

Meanwhile, the present project has already identified several factors associated with the use of tunnel net gear that could affect its commercial viability. Tunnel net fishing is a labour-intensive exercise. It typically takes three to four fishers to deploy, manage, and retrieve the gear, which means that the income derived from the catch needs is spread amongst up to four persons. In contrast, many N2 net fishers have levels of automation and vessel custom design that enable them to operate as individuals. While there may be the potential to fetch higher prices per trap-caught fish compared to a net fish, this potential price benefit has not been quantified, and it is unknown if it would be sufficient to offset the impact of sharing the income generated per shot amongst more fishers. Additionally, tunnel net fishing requires an extensive amount of gear including wings, anchors, stakes, traps, and the grid and the tunnel. As a seasonal fishery, this gear would need to be stored and maintained for a significant portion of the year which represents additional costs and requirements for fishers.

The feasibility of this gear type will be affected by the number of potential locations a fisher can access. The catch efficiency of tunnel nets means that each location fished may require a period of time for fish populations to replenish from immigration before it can be fished again. Indeed, the weather and tidal limitations associated with the gear mean that there are already rigid environmental limitations that restrict how often the gear can be used. In Moreton Bay, tunnel net fishers advised that each location is only fished once a month, and that fishing operations rotate between a suite of established sites. For this type of fishing to be viable in North Queensland, fishers will need to be able to access a suite of sites that allows sufficient fishing effort to be commercially viable while ensuring that localised depletions are avoided.

Lastly, the project team reiterates that the environmental requirements for this type of gear mean that it will be restricted to select locations. It will not be able to replace N2 nets across the GBRWHA. However, trap-type gears could be advantageous to fishers in specific locations where interactions with SOCI are more likely to occur.

The potential for seasonal arrowhead fish traps

Fixed location arrowhead fish traps were widely used in the GBRWHA during the 1950s and 60s. There are conflicting accounts about why this fishery was phased out, but it is clear that it was a widely used gear across the Queensland coast. Given the rising concerns about SOCI interactions, bycatch and discard mortality, and the changing expectations of consumers and coastal communities, the project team feels that the potential for arrowhead fish traps as an alternative gear type should be explored. The availability of modern, lightweight materials means that an arrowhead fish trap could be installed during the winter and then removed before the cyclone season. These gears would also mitigate some of these issues involved with tunnel nets. A seasonal arrowhead fish trap would only require half the crew needed to operate a tunnel net, and with careful design, could potentially be operated by a single fisher, resulting in lower costs and higher revenue per fisher. Arrowhead fish traps could also be constructed with sturdier, rigid materials that would prevent SOCI species from becoming enmeshed, and would reduce the loss of the primary target species from breaking through netting. While the trap is not being used, the tunnel and traps could be left open and doors physically removed to allow fishes and any other animals to simply pass through the gear. A fixed trap would also simplify compliance and enforcement efforts as the gear is stationary and could be checked at any time, or even monitored remotely through remote cameras and sensors.

Future considerations

The project team identified numerous considerations regarding the future development and implementation of trap-type fishing gears such as tunnel nets and arrowhead fish traps for adoption across the region.

- Future trials of trap-type gears should include inter-disciplinary, multi-year scientific trials to explore the longer-term commercial performance of the gear at an operational scale, and the human factors that would affect the success of the gear.
- Future trials need to progress slowly and incrementally. These should start with a review of the history of the previous trap fishery; and field trials of relatively small-sized trap configurations in single sites with close monitoring. Ideally this would include close collaboration and involvement of fisheries managers.
- To begin with, careful monitoring of catch rates must occur to determine the length of time needed to allow for sufficient recruitment and/or immigration to occur before the trap is fished again. Localised depletions must be avoided.
- Trials would also need to test different mesh sizes and ply strengths of the wings, grid, traps, and tunnels. The mesh and ply of different parts of the trap needs to be small enough to prevent bycatch from becoming enmeshed in the wings, heavy enough to retain the primary target species, but not too heavy or too small to create excessive drag that could cause the gear to fail. Fishers will have to carefully refine gear to optimise it for local conditions. Optimising mesh size would could also facilitate escape of unwanted and undersized fishes from the gear.
- Scientific trials would likely need to proceed over two or three seasons to carefully monitor catch rates over subsequent shots. These data will help determine the spatial and temporal limits of fishing effort to avoid localised depletion. If catch rates at a site drop significantly between subsequent shots – and cannot be explained by temporal changes evident from previous catch records from that location – fish captured in these trials should be released until catch rates recover. Additionally, careful consideration must be made regarding the difference susceptibilities of migratory fishes (which can replenish an area through immigration) and highly resident species that are likely more susceptible to localised depletion.
- Scientific trials should also quantify post release survival of fishes and any SOCI species released from the trap. This should include retaining fish in suitable conditions for set periods of up to 48 hours to monitor post release survival, and an expanded tagging program to monitor longer-term survival.
- Trials could also provide a platform to test new electronic monitoring and independent data validation efforts being introduced in Queensland (QDAF 2018a)
- There is the opportunity to explore whether 'trap-caught' fish could be socially marketed to maximise product value, and also to selectively retain fishes that maximize profit while releasing unwanted fishes as future investment. This moves the fishery towards a maximum economic yield (MEY) operating mode which in specific contexts can improve benefits to fishers and the wider community while promoting environmental outcomes

(Hilborn 2007). Indeed, MEY is a key principle underpinning the Queensland Sustainable Fishing Strategy (QDAF 2017).

- The project team recognises that operationalising this gear will require close monitoring and carefully considered management plans that may take years to develop and implement, and will require development of appropriate regulations.
- New fisheries arrangements introduced by QQDAF in September 2021 introduced quotas for Barramundi and King Threadfin that **may help reduce conflict between fishing sectors**. However, future trials should include targeted social research and engagement activities to identify and mitigate specific potential conflicts, and sensitise other resource users to the replacement of existing mesh nets with trap-type gears.
- The project team also agrees that **this should not be considered as a new fishery** that allows for additional effort and harvest to be added to existing fishing effort. Instead, this should be **strictly considered as an alternative fishery to replace existing effort where suitable**. The project team also notes that there will likely be many locations where this gear is not suitable and should not be considered.

Conclusions

The project team considers this project to have been successful. All objectives were met, and the limited trial in Cardwell established that tunnel net gear is technically feasibly in north Queensland. The gear can be deployed, it withstood marginal weather conditions, caught significant quantities of fish, and allowed for the released of bycatch and discards, including SOCI species such as Scalloped Hammerhead sharks in excellent condition. Nevertheless, the commercial viability of the gear remains unproven. The gear can only be used in select locations, and even in these locations, the environmental limitations, costs, and technical challenges in using tunnel nets in North Queensland conditions could limit their viability. Further work is needed to explore these issues, as well as social and economic factors, and the project team cautions against considering this gear as a proven solution for the challenges faced by the mesh net fishery. More work needs to be done. The project team also highlights that semi-permanent seasonal arrowhead fish traps could overcome some of these issues, and seeing that they were historically used widely across the GBRWHA coast, would be a trap-type gear that should be considered for further investigation.

Implications

This project has important implications for the NQ mesh net fishing industry, as well as fisheries and environmental managers from the Dept. of Agriculture, Water and The Environment, The Queensland Department of Agriculture and Fisheries, and the Great Barrier Reef Marine Park Authority.

The preliminary trials demonstrated that tunnel nets are a technically feasible gear type that can enable fishers to catch primary and secondary target species, while facilitating the release of discarded fishes (undersized and non-target species), and bycatch species in excellent condition. This would help address long standing concerns about the environmental impact of **discard mortality** of mesh net fisheries in the GBRWHA. Additionally, experience from Moreton Bay shows that the landed catch from tunnel net gear can fetch higher market prices and have a longer shelf life because the fish remain actively swimming, processing times are so short, and the retained catch is immediately put into an ice slurry. This reduces wastage and increases the catch value, both of which are important considerations in holistic fisheries management. Overall, this project provides the industry with a foundation for future work to test and refine trap-type gears in the GBRWHA, and offers fishers with an alternative option to reduce their environmental footprint, to help meet regulatory requirements, and could improve the fishery's social licence amongst consumers and the community. However, we reiterate that this is only a starting point. The viability of tunnel nets as an alternative to mesh nets is not certain, and other trap-type gears, i.e. arrow head fish traps, should be considered further.

Secondly, by demonstrating the ability to release bycatch species such as hammerhead sharks in excellent condition, the project has significant implications for fisheries and environmental managers. Environmental concerns regarding discards and interactions with SOCI species have been raised for decades (e.g. GBRMPA 2009), and the fishery is under increasing scrutiny. Nevertheless, the fishery continues to raise environmental concerns (GBRMPA 2019), as demonstrated by the revocation of the fishery's approval to operate as a Wildlife Trade Operation in September of 2020. The National Threatened Species Scientific Committee is currently deliberating whether to list the Scalloped Hammerhead shark as a protected species under the EPBC Act (2019), which would have significant ramifications for fisheries management at both State and Commonwealth levels. One of key threats facing the species is the Queensland mesh net fishery. If mesh nets in high risk locations in the GBRWHA can be replaced with trap-type fisheries, this innovation could significantly reduce the risk posed to these species by fishing, and in doing so, ease the regulatory burden on some fishers while allowing managers to demonstrate improvements in the fishery that would facilitate the continuation of the fishery in some parts of the GBRWHA, and actively support species recovery and protect Australia's natural heritage. This would be especially timely given the current scrutiny placed on the Great Barrier Reef by the World Heritage Commissions mission to investigate if the site should be listed as "In Danger".

Recommendations

The project team makes three specific recommendations regarding this project.

1. The project outcomes need be disseminated to targeted representatives within the fishing industry and managing agencies (see *Extension and Adoption*) to highlight the potential of trap-type fisheries to allow sustainable and environmentally friendly fishing to continue in key locations within the Great Barrier Reef World Heritage Area while supporting environmental outcomes.

2. That the FRDC consider continuing support for research into trap-type fishing gears to explore whether gears such as modernised arrowhead fish traps could be widely adopted

to allow fishers to keep fishing in the GBRWHA, to secure access rights, and to maintain supply of high-quality local seafood.

3. That the FRDC note the project teams' intention to consult with stakeholders about developing a project proposal outlining the trial of seasonal, semi-permanent arrowhead fish traps in key locations in the GBRWHA; as well as reviews of other bycatch mitigation innovations that could be applied in the GBRWHA. This would be the logical as the next step in developing this gear innovation for wider adoption in the region.

Further development

While it is uncertain whether tunnel nets are a viable fishing gear for widescale deployment across the region, the operational principles underpinning these trap-type fishing gears has been proven. These trap-type gears can catch significant quantities of commercially valuable fish while reducing bycatch mortality and address the environmental concerns that are placing regulatory and social pressure on existing mesh net fisheries in the GBRWHA.

Meanwhile, fixed position, semi-permanent arrowhead fish traps would address many of the factors that could limit the viability of tunnel nets in the region. Firstly, as a fixed structure that does not have to be deployed and retrieved with every tidal cycle, an arrowhead fish trap could be operated by only one or two fishers instead of four, making it more profitable. Secondly, the fixed trap could allow for a more robust trap design to retain the primary target species, and could be worked in a wide range of weather conditions. Lastly, a fixed structure could also help with compliance and enforcement efforts. The QQDAF is investing efforts in independent data validation (QDAF 2018a) and electronic monitoring systems could easily be mounted to seasonal fixed structure to allow for constant polling and compliance checks 'on demand'. A concept note to develop such a trial has been prepared and indeed, the existing GBRMPA Permit allows for trials of a fixed position, semi-permanent arrow-head fish trap.

The next step in developing this gear innovation for wider use within the region is developing targeted intra-disciplinary trials to develop and test arrow-head fish traps over multiple seasons. Fisheries dimensions would examine catch composition, post release survival of discards and released SOCI species; and establish harvest practices to ensure that catches are sustainable and avoid localised depletions. Meanwhile, the human dimensions of this project would investigate the commercial viability of the gear, its potential to improve social licence of the fishery, explore the scope for social marketing of trap-caught fish, and identify opportunities to enhance community acceptance of seasonal traps and to reduce conflict between fishing sectors. The project team is eager to engage with FRDC to develop this concept further.

Extension and Adoption

There has been extensive consultation and engagement regarding this project dating to 2017 (see *Appendix 2: communication and extension plan*). In general, numerous in-person meetings have been held with fisheries managers from QQDAF and GBRMPA, with recreational fishing representatives in Cardwell and Mackay, and with Local Marine Advisory Committees in Ingham and Mackay. There have been extensive efforts to engage the Girringun Aboriginal Corporation and indeed, Girringun staff were listed as co-investigators in the initial FRDC proposal (2018).

Since the field trials were conducted in July 2021, consultation and engagement has included:

- Face to face meetings with fisheries managers from GBRMPA at the GBRMPA office in Townville three days after the trials concluded
- Telephone and email updates to fisheries managers from QQDAF in the week following the Cardwell trial.
- A zoom presentation delivered to the threated species and fisheries staff from DAWE.
- A keynote presentation (live-online) delivered at the World Fisheries Congress in September 2021
- An online research seminar presented as part of the James Cook University emerging research series.
- Presentation to the QQDAF Inshore Working Group meeting on 7 December 2021.
- In person briefings of project outcomes delivered to QQDAF staff on 9 and 10 December 2021.

Once the final report becomes available, future extension and communication plans include:

- A fact sheet and a blog post to be hosted on the Fish and Fisheries Lab website (www.fishandfisheries.com)
- An article in FRDC FISH news (discussions have begun with FRDC)
- An article in the IUCN Shark Specialist Group newsletter
- A JCU media release (upon release of the scientific paper)
- ‘Final findings’ briefings to Local Marine Advisory Committees in Ingham, Bowen, Mackay.
- A research note intended for a peer reviewed journal such as *Fisheries Research*, *Marine and Freshwater Research* or *Pacific Conservation Biology*.

Project coverage

Public media coverage of the project has not been pursued. This will occur once the final report is published and with approval from fishers, the FRDC, and other stakeholders.

Appendices

Appendix 1: Project team

Name	Role	Institution
Andrew Chin	Principle Investigator	James Cook University
Sushmita Mukherhji	Research Associate	James Cook University
Allan Bobberman	Co-Investigator	Hinchinbrook Seafoods
Pauline Bobberman	Commercial fishing representative	Hinchinbrook Seafoods
Mark Ahern	Co-investigator	Debbie's Seafoods
Debbie Ahern	Commercial fishing representative	Debbie's Seafoods
John Page	Technical fishing consultant	Private consultant
Dave Thomson	Technical fishing consultant	Private consultant
Garry Smith	Fishing contractor	Private Consultant
Matt Smith	Fishing contractor	Private Consultant

Assistance has also been provided by Michael Grant, Melissa Ciampaglia, and Rachel Mather from the JCU Fish and Fisheries lab in field work, data entry, and video analysis.

Appendix 2: Communication and Extension Plan

FRDC 2018-049

[25 September 2019]

The "Better way to Fish" project has a central principle of community focused and meaningful engagement with key stakeholders, namely commercial fishers, local communities and Indigenous communities.

Communication and extension objectives:

1. Inform key stakeholders and industry about the project and intended feasibility trials in Cardwell and Mackay (general awareness).
2. Inform managers of project activities to ensure project meets management needs.
3. Introduce community members in Cardwell and Mackay to the project to reduce confusion and potential conflict.
4. Build community support for the project, and potential subsequent tunnel net or trap research and implementation.

Scoping and development (ongoing since 2017)

The project team has engaged with commercial fishers, Indigenous communities and managers to develop the project aims and processes, and agree on likely outputs and outcomes. This is being done to build wider awareness and support for the project, and to ensure the project is designed to address stakeholder needs.

Activities included formal presentations, face-to-face meetings and phone discussions with:

- Hinchinbrook Seafoods PL [Alan Bobberman – June 2017 to present]
- Girringun Aboriginal Corporation [Phil Rist; Sean Walsh – August 2017 to present]
- Queensland Department of Agriculture and Fisheries [QQDAF] [Maclolm Keag; Lenore Litherland; Eddie Jebreen ; Claire Anderson – Feb 2018 to present]
- Establishment of an Independent Project Advisory Committee (IPAC) [Kate Barclay; Stephan Schnierer; Vern Veitch [June 2017 to present]
- Discussions with Moreton Bay Seafood Industry Association [John Page – Jan 2018 to present]
- Great Barrier Reef Marine Park Authority [Thomas Hatley; Mark Read - Nov 2017; Feb 2018; March 2019, May 2019]
- Presentation to the GBRMPA Local Marine Advisory Committee [Townsville - March 2018]
- Discussions with fisheries specialists and social scientists with relevant expertise [Dr Kate Barclay – UTAS; Dr Stephan Schnierer – SCU; Dr Richard Saunders – QQDAF; Dr Mark Read – GBRMPA; Dr Mark Hamman – JCU)]
- Presentations to potential co-funders CRC Northern Australia [Jed Metz - March 2018]

- Discussion at the QDAF Inshore Working Group bycatch workshop [Townsville – May 2019]
- Discussion with GBRMPA regarding research permit requirements [May 2019]
- Engagement with Mark Ahern, Debbie Seafoods in Mackay [May2019]
- Qld QDAF have been invited to participate as observers and to have a representative on the project IPAC. QDAF have nominated Mr Darren Roy [October 2019]

Outcomes <u>to date</u>

1. Two FRDC proposal completed and submitted with strong industry and community backing [Hinchinbrook Seafoods, Debbie Seafoods, Moreton Bay Seafood Association included as co-investigators].
2. Ongoing communication with members of the Girringun Aboriginal Corporation. Communications (emails) and informal face-to-face discussions have been held about seeking opportunities to present to the Girringun board.
3. Relevant expertise involved as collaborating researchers [Mark Hamman – turtles and dugongs; Mark Read – dugongs and crocodiles].
4. Establishment of an Independent Project Advisory Committee (IPAC) [Kate Barclay; Stephan Schnierer; Vern Veitch].
5. Managers informed and engaged about the project, broadly supportive and interested [QQDAF, GBRMPA].
6. Project discussed at the QDAF bycatch workshop [March 2019].
7. Second Qld commercial fisher has agreed to become involved as a co-investigator [May 2019].
8. Discussion with GBRMPA regarding permit requirements [May 2019].
9. QDAF representative nominated to the IPAC [Oct 2019].

Targeted engagement during feasibility study

Should this project (feasibility testing) proceed, the project team will advise communities and stakeholders that the project is progressing. Targeted engagement will begin including presentations at formal meetings, through informal face-to-face communications with stakeholders in Cardwell and Mackay, and through industry and community avenues. The aim is to advise key stakeholders about the intent to carry out site visits followed by limited feasibility trials, and for specific groups, to invite their participation as observers.

Prior to site visits:

- The CEO and Ranger Coordinator of Girringun Aboriginal Corporation were advised in 2017 of the original, full scope project, and provided in-principle support. However, this support is yet to be formalised, and additionally, this revised project is significantly reduced in scope from the original project. Informal emails and face-to-face meetings have been held with Girringun rangers and members of the community seeking an opportunity for a formal presentation to the Girringun board to inform the community about the project, and to invite Girringun Rangers and elders to be present during site visits in Cardwell. This meeting also seeks to lay the foundation for more in-depth involvement in full scientific trials should such trials proceed, i.e. inviting Girringun once again to become involved as co-investigators.
- Presentations given to the GBRMPA Local Marine Advisory Committees (LMACs) for Townsville, Mackay and the Whitsundays, Cardwell, and Cassowary Coast.
- Briefings for the QQDAF Inshore Fisheries Working Group.

- Media releases prepared with industry and FRDC input about the project aims and approach, and the community focused and collaborative nature of the project.
- Project information flier will be prepared, social media strategy developed (focusing on facebook, twitter, and Instagram). Andrew Chin has over 3000 followers on social media.
- Project poster and communication products developed for display at local tackle shops, dive shops, and volunteer marine rescue facilities.
- Project information disseminated through informal networks such as GBRMPA LMAC newsletter, GBRMPA information networks for tourism staff, FRDC newsletter, QSIA networks.
- Together with industry, QDAF, GBRMPA and the IPAC, develop a communications protocol and response plan should interactions occur with *Species of Conservation Interest* (SOCI). This plan – the *SOCI Interaction Response Plan* will include details of who will be notified and how such notification will occurs, and what communications material will need to be developed. The process and communications materials must be developed *jointly*, will ensure use of existing handling tested handling guides and practices, and will be developed during the first site visit where all parties are present.

During initial site visits and feasibility trials:

- Site visits in Cardwell and Moreton Bay attended by commercial fisheries, managers, and collaborating scientists.
- Meeting of the IPAC during a site visit at one location.
- During site visits, project team will visit local tackle stores and fishing club representatives to meet recreational fishers; dive shops; and with representatives from local volunteer marine rescue. The team will seek permission to display project posters at these locations.
- Advice will be sought form FRDC Recfishing Research representative Dr Owen Li for best avenues to disseminate information to recreational fishers.
- During site visits and feasibility trials, representatives from QDAF, Qld Parks and Wildlife Service, GBRMPA, and Girringun Rangers will be invited to attend.
- Articles will be in Queensland Fisherman, FRDC newsletter, a blog article (Fish and People Blog), Hakai Magazine (Canada), GBRMPA magazine, Secretariat of the Pacific Community Fisheries News (Pacific wide distribution).
- Regular updates on social media.

Once the feasibility study has concluded, a final report will be prepared and project outcomes communicated.

- Articles prepared for the aforementioned publications.
- Targeted fact sheets for industry, Indigenous groups, and communities summarising project findings.
- Social media focusing on project outcomes, lessons learnt, and ‘next steps’.
- Summary briefings to QQDAF Inshore Fisheries Working Group, GBRMPA LMACs, Girringun community, and local community groups

- Depending on the outcome of the trials, a 2-3 page print *Preliminary*[3] *best practice guide* for the use of tunnel nets in north Queensland, including guidance on managing interactions with SOCI. To ensure consistence and avoid redundancy, where possible this information will draw upon existing publications for the safe and considered handling on SOCI species.

All communication products will be developed closely with industry representatives, the advice of managers from QDAF, GBRMPA, and from the IPAC.

[3] This material will be **preliminary** only. A formal adoption plan will only be developed **IF** the feasibility trials are successful, and **IF** scientific trials (Phase 2) demonstrate that the method is *economically feasible* and meets social and environmental objectives.

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