FRDC
FISHERIES RESEARCH & DEVELOPMENT CORPORATION

Progress in bycatch reduction in trawl fisheries:

Are the findings, outcomes, and recommendations from FRDC funded bycatch reduction projects acted upon?

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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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Abbreviations

AFMA - Australian Fisheries Management Authority

BRD - Bycatch Reduction Device

CTS - Commonwealth Trawl Sector

DPI - Department of Primary Industries

FRDC - Fisheries Research and Development Corporation

NMFS - National Marine Fisheries Service (USA)

NPF - Northern Prawn Fishery

NPFAG - Northern Prawn Fishery Advisory Group

NPFI - Northern Prawn Fishery Industry Pty. Ltd.

NSWPTF - NSW Estuarine and Oceanic Prawn Trawl Fisheries

QECOTF - Queensland East Coast Otter Trawl Fishery

SAFE - Simple Anterior Fish Excluder

SED - Seal Exclusion Device

TED - Turtle Exclusion Device

Executive Summary

This report describes an investigation by Stephen Eayrs (Smart Fishing Consulting) into the recommendations from FRDC-funded bycatch reduction projects in the Commonwealth Trawl Sector, the NSW Oceanic and Estuarine Prawn Trawl Fisheries, the Queensland East Coast Otter Trawl Fishery, and the Northern Prawn Fishery. This investigation included a survey completed by principal investigators, other project researchers, fishers, fishery managers, and others that were engaged in these projects to understand i) the circumstances and conditions that resulted in project recommendations being followed-up, and ii) the impediments and bottlenecks that may have hampered or prevented recommendations from being followed-up. The survey also provided an opportunity for respondents to comment on what the FRDC, researchers, and others got right or could have done differently to reduce bycatch, identify reasons why many fishers are reluctant to reduce bycatch, and to explore their readiness to further pursue a reduction in bycatch. These findings can be used to inform and guide future FRDC-funded efforts to reduce bycatch, including related extension activity, so that project outcomes and recommendations are widely known and can be acted upon.

The FRDC has been funding bycatch reduction projects in Australian trawl fisheries for more than three decades. These projects have contributed to a significant and important body of knowledge and helped shape the direction of this research around the country. However, despite this progress it remains unclear to what extent the recommendations from any of these projects have been directly acted upon by researchers, fishers, or others, and the circumstances and conditions that resulted in such recommendations being followed-up. Where no such follow-up activity has been made, it is unclear why this was the case, including impediments and bottlenecks that may have hampered or prevented such activity.

The goal of this project was to investigate past FRDC-funded bycatch reduction projects in trawl fisheries, identify the fate of cited project recommendations, and attempt to understand why some recommendations are followed-up with and others are not. Project objectives were:

1. Review the findings, outcomes, and recommendations of bycatch reduction research in multiple trawl fisheries around Australia, based on review of FRDC project final reports and other literature
2. Assess if the findings and outcomes of this research have translated into changes in fishing practice or behaviour
3. Assess if the recommendations of this research have been acted upon subsequently, and if not, identify reasons why not to the extent practicable
4. Identify impediments to the adoption of bycatch reduction devices or other options to reduce bycatch in these fisheries, and recommend remedial solutions.

Project methodology included an initial review of all FRDC final project reports with a focus on bycatch reduction in trawl fisheries. Project reports from four fisheries were then considered for deeper evaluation on the basis that each fishery was known to impact threatened, endangered, and protected (TEP) species, and/or was responsible for significant volumes of bycatch. A survey was then developed seeking information regarding the uptake or otherwise of project recommendations. Survey respondents were principal investigators and project collaborators, fishers, fishery managers, and others with a history of close engagement in one or more of FRDC-funded bycatch reduction project in one of the four fisheries. The survey included questions regarding progress since project completion, the drivers and motivators for any cited project recommendation being acted upon, and any impediments and bottlenecks that may have prevented such recommendations being acted

upon. Survey questions also focussed on perceived attitudes and readiness of fishers to further reduce bycatch, as well as what the FRDC and others got right or otherwise and what they should be doing in the future.

The number of survey respondents was seven or less for each fishery although this reflected a significant proportion of the population of suitable qualified respondents. Respondents indicated that for many projects there had been limited or little follow up activity. Impediments and bottlenecks to reduce bycatch were attributed to FRDC, researchers, fishery managers, and fishers themselves. Respondents indicated fishers were reluctant to voluntarily reduce bycatch primarily because of economic and operational concerns, particularly if testing new devices was constrained to the fishing season. Other suggestions included they were unaware of project outcomes and recommendations, or because gear testing protocols were too limiting or take too long to follow to their conclusion, and they require fishers to accept the risk of economic impact. Not all respondents agreed there are impediments to fishers further reducing bycatch, and some argued in favour of regulation rather than encouraging voluntary efforts in bycatch reduction.

Several respondents noted that fisheries managers seemed little interested in reducing bycatch, given that regulations often took many years to introduce, if at all. Furthermore, BRD testing protocols take too long to complete, regulations are frequently weak and can be easily circumvented by fishers, and the ability of compliance officers to police and enforce regulations was sometimes less than desired.

Many respondents suggested that project extension activity was frequently inadequate and that fishers were often unaware of project outcomes and recommendations. To a large extent this is the fault of the principal investigator and other researchers involved in the project, although part of the problem is that extension activity often occurs towards the end of a project and is compromised due to insufficient remaining time or funds. The professional development of some researchers is incumbent upon them publishing project results in a scientific journal, not engaged in extension activity, which is a seldom considered metric of personal development. Many researchers are also unable to continue extension activity upon project completion without additional funding.

According to respondents the FRDC has played an essential role in bycatch reduction in trawl fisheries around the country. Others were grateful the FRDC funded multi-year projects, noting that several years are typically required to test one or more BRDs and report their performance. Some respondents were critical that recommendations from completed projects could not be pursued immediately because no further funding from FRDC was available. They noted this resulting in a loss of momentum and that sometimes project recommendations were never followed-up.

Based on survey results, the reluctance of fishers to voluntarily reduce bycatch is associated with their concerns over the economic impact of such activity. Deeper investigation into their readiness to further reduce bycatch suggests they do not appreciate the need to do so nor do they think it is appropriate. They also feel there is inadequate principal support from fishery managers, peers, and others. It is imperative that steps are taken to work closely with fishers and mitigate these concerns.

Based on the outcomes of this project the following recommendations are made:

- The cited recommendations from **FRDC Project No. 2017/065** should be pursued immediately.
- Develop specific bycatch targets and ensure industry engagement from the onset, and consider the model applied by NPFI to achieve a 30% reduction in bycatch in the NPF.

- Extension activity to fishers must be strengthened, during the life of individual projects and beyond. Communication needs to be ongoing beyond the life of a project and repeated. Questions also need to asked regarding the efficacy of various forms of communication and information transfer, and the potential for alternatives such as dedicated industry champions of project activity and gear technicians working with fishers at sea to test and develop new BRDs. These are early steps in addressing fisher concerns regarding the need and appropriateness of further efforts to reduce bycatch.
- Extension activity to fishery managers, researchers, and the public must also be strengthened. Respondents suggested that fishers do not perceive they have principal support from these groups to further reduce bycatch. This is consistent with the findings of **FRDC Project No. 2017-046**, where fishers cited lack of consideration and support from fishery managers and others can increase safety risks at sea.
- Fishery managers should consider how to streamline gear-testing protocols and the regulatory process. Testing should be timed to coincide with the off season, to minimise economic impacts on fishers, or consideration given to a cost recovery model. Increase understanding of fishing gear to develop regulations that cannot be circumvented by fishers, and improve policing and enforcement of regulations. Fishery managers should take a more active role in bycatch reduction projects, and they should consider modelling various management scenarios with the new BRD in mind during the life of a project.
- FRDC should take responsibility for driving and facilitating the recommendations cited above.

Keywords - bycatch, survey, impediments, bottlenecks, recommendations

Introduction

The Fisheries Research and Development Corporation (FRDC) has been funding bycatch reduction research in Australian fisheries for more than three decades. A large body of such research has now been completed and outcomes include improved knowledge and capability in bycatch reduction and the development of numerous gear modifications to reduce bycatch mortality, including overfished species and those considered Threatened, Endangered, and Protected under the Environmental Protection and Biodiversity Protection Act (1999). The outcomes of this research also include closer ties being forged between fishers, researchers, and fisheries managers, the introduction of fishing gear regulations designed to reduce bycatch, and the provision of information and support to fishers so they can respond and adapt their fishing gear to reduce bycatch.

The funding of this research has contributed significantly to a large body of knowledge applicable to commercial fisheries around Australia, which is now widely regarded as a global leader in bycatch reduction. Well over 100 bycatch reduction projects have been funded by the FRDC in trawl fisheries alone. However, despite these efforts, it is unclear to what extent this success is the result of researchers, fishers, or others following up on recommendations cited in final project reports or otherwise. The circumstances and conditions necessary for project recommendations to be followed-up by these individuals are also not well known, as are the impediments and bottlenecks that may have hampered or prevented such follow-up activity. The efficacy of project extension efforts by researchers and others to stimulate follow-up activity is also not well understood.

The goal of this project was to investigate the recommendations of past FRDC-funded bycatch reduction projects and identify the conditions and circumstances that resulted in follow-up activity and the impediments and bottlenecks that hampered or prevented such follow-up activity. With FRDC funding of similar projects likely in the future, it is important to improve our understanding of the relationship between project recommendations and follow-up activity. This information can help inform why some project recommendations are followed-up with and why others are not. It can also help guide future efforts to avoid or remove impediments and bottlenecks to recommended follow-up activity. To achieve these outcomes, it is necessary to review the research of past FRDC-funded bycatch reduction projects and understand the impact of project recommendations on changes in fishing practice or behaviour. It is also necessary to investigate fisher behaviour, and in particular their level of interest in further reducing bycatch and readiness to do so in the future.

Objectives

The objectives of this project were:

1. Review the findings, outcomes, and recommendations of bycatch reduction research in multiple trawl fisheries around Australia, based on review of FRDC project final reports and other literature
2. Assess if the findings and outcomes of this research have translated into changes in fishing practice or behaviour
3. Assess if the recommendations of this research have been acted upon subsequently, and if not, identify reasons why not to the extent practicable
4. Identify impediments to the adoption of bycatch reduction devices or other options to reduce bycatch in these fisheries, and recommend remedial solutions.

Methods

A total of 101 FRDC final project reports dating back to 1987, with a focus on bycatch reduction in trawl fisheries, were reviewed for relevance to this project. Final project reports were culled and not deemed relevant if they focused on quantifying bycatch spatially or temporally, conducted a risk-based approach to bycatch management, explored the effect of bycatch on stock or ecosystem health, or attempted to reduce bycatch through non-gear related means such as spatial or temporal controls.

The remaining final project reports were then categorised by fishery, and reports from four fisheries were considered for deeper evaluation on the basis that each was known to impact threatened, endangered, and protected (TEP) species, and/or was responsible for significant volumes of bycatch (Table 1). The four identified fisheries were the Commonwealth Trawl Sector, the NSW Estuarine and Oceanic Prawn Trawl Fisheries, the QLD East Coast Prawn Trawl Fishery, and the Northern Prawn Fishery. It was assumed that pressure to reduce bycatch in these fisheries had been high and that remedial efforts had been relatively extensive.

Table 1. Prioritised fisheries, key bycatch issues, and relevant FRDC project numbers.

Fishery	**Bycatch issue**	**Relevant FRDC project numbers**
Commonwealth Trawl Sector	Seals/Undersized and non-commercial finfish	2019/027, 2007/039, 2005/049, 2001/008, 2001/006, 1998/204
NSW Estuarine and Oceanic Prawn Trawl Fisheries	Undersized and non-commercial finfish	2017/097, 2011/010, 2005/056, 2001/031, 1993/180, 1988/108
QLD East Coast Trawl Fishery	Turtles, Undersized and non-commercial finfish, sea snakes	2015/014, 2008/101, 2005/054, 2005/053, 2000/170, 1996/254, 1993/229
Northern Prawn Fishery	Turtles, Undersized and non-commercial finfish, sea snakes, sawfish	2016/058, 2005/051, 2000/173, 1996/254, 1993/179

From each of these reports, only recommendations related to reducing bycatch were considered of interest to this project, including recommendations pertaining to fishing gear design, operational and economic impact of bycatch reduction devices, management of these devices, and associated extension activities (Table 2); recommendations that pertained to stock or ecosystem health, such as changes in biomass resulting from bycatch reduction, were considered outside the scope of this project. In addition, three additional projects relevant to more than one of the four fisheries, **FRDC Project No. 2017/065**, **2016/057**, and **2006/308**, were also reviewed because they involved holding one or more industry workshops in various locations around Australia, with a primary focus on bycatch reduction through gear modification.

Information gleaned from these reports was then used to understand how much progress in bycatch reduction had been made in each fishery, and to identify why follow-up activity related to project recommendations in bycatch reduction had occurred or otherwise. A search in the scientific and

other literature was also made to investigate progress in bycatch reduction in each fishery, including review of federal, state, and industry body websites.

Table 2. Examples of recommendations by category. Figures in parentheses represent FRDC project number.

Category	Recommendation
Fishing gear and animal behaviour	"Continue to examine the utility of these and other designs in other prawn fisheries." (2017/097)
	"…other mitigation measures should be investigated." (2016/058) "Further research into the use of lights attached to the headline to promote an escape response by bycatch species should be undertaken." (2006/308)
	"The results of this study suggest that even further increases of mesh size in the trawl body (possibly 60 mm) warrants investigation." (1998/226)
	"The second area of development following the project would be in undertaking studies to better understand the behaviour of sea snakes and fish species in trawl nets." (2005/051)
Fisheries management	"Management jurisdictions should try to develop more streamlined processes by which fishers can trial alternative gear designs." (2017/065)
	"The spatial and temporal extent of interactions between dolphins and the fishery make it difficult for fishery management measures to reduce the level of interaction without reducing fishing effort across the fishery." (2008/048)
Extension and outreach	"ACPF, ICIC and FRDC should work together to organise a "travelling roadshow" to reach as many prawn fisheries and fishers as possible throughout Australia." (2016/057)
Economics	"…more data are required to fully quantify the loss of commercial catch and whether this can be somewhat offset by improved prices of the other retained catch." (2007/063)

A survey was then developed seeking information regarding the uptake or otherwise of cited project recommendations (Appendix 1). Survey respondents were principal investigators and other project researchers, fishery management staff, fishers and other industry personnel with a history of close engagement in one or more of the relevant projects. These individuals were contacted via telephone and invited to complete the survey regarding their efforts and those of others to act on project recommendations. If project recommendations were acted upon, questions were asked regarding perceived drivers and motivators for this outcome, and if they were not, questions were asked to understand perceived impediments and bottlenecks to progress. Survey questions also focussed on their perceived attitudes of fishers to change, including efforts to reduce bycatch in their fishery, as well as what FRDC and others got right or otherwise and what they should be doing in the future, including how to mitigate the impact of any identified impediments and bottlenecks.

Respondents were also asked to score their level of agreement with a number of statements regarding the perceived readiness of fishers to voluntarily reduce bycatch. The statements were grouped into six categories of change readiness, discrepancy, appropriateness, efficacy, principal support, valence, and affection, with each category contributing to an understanding of readiness to change (Rafferty *et al*., 2013). The first two components help understand if fishers perceive further steps are required to reduce bycatch, while a perception that their operating environment will facilitate their efforts is assessed by the components, efficacy, principal support, and valence. The final component, affection, helps to understand if their visceral sense of belonging in the fishery will

be influenced by future voluntary bycatch reduction efforts. A 5-point Likert scale was used to score responses to each statement, and the weighted average of scores from each respondent were used to determine the perceived readiness of fishers to reduce bycatch in each fishery. A weighted average less than 3 was deemed to indicate a low level of readiness.

Results and findings

Commonwealth Trawl Fishery

The Commonwealth Trawl Fishery targets a variety of teleost species including blue grenadier (*Macruronus novaezelandiae*), tiger flathead (*Neoplatycephalus richardsoni*), pink ling (*Genypterus blacodes*), orange roughy (*Hoplostethus atlanticus*), blue-eye trevalla (*Hyperoglyphe antarctica*), and silver (spotted) warehou (*Seriolella punctata*) (AFMA, nd; Patterson *et al*., 2020). Total landings of quota species in the 2019-20 fishing season were 12,346 t. Commercial fishing activity is based on using midwater and demersal trawls and Danish seines, and during 2016-17 there were 32 active trawlers and 20 active Danish seine vessels (Patterson *et al*., 2020).

Midwater trawling activity primarily targets blue grenadier and has almost no bycatch, although fishers are required to use seal excluder devices as well as seabird scaring lines (AFMA, nd). They are also not permitted to discharge fish offal at sea.

Demersal trawling activity results in the bycatch of undersized or unmarketable fish species, as well as crustaceans, chondrichthyans, and molluscs (AFMA, nd; AFMA, 2020). On rare occasions it also includes marine mammals, seabirds, and reptiles. Total discarded bycatch is 40-50% of the total catch by weight (Kennelly, 2018; Patterson *et al*., 2020). In 2019, 168 pinniped (mainly fur seals) interactions were reported, with 80% being reporting from demersal trawling activity. In the same year there were 9 interactions with dolphins (all were dead) and 98 interactions with seabirds (Patterson *et al*., 2020), although the proportion of interactions by fishing method is unclear.

Bycatch reduction efforts and cited recommendations

FRDC funded efforts to address this bycatch in this fishery were associated with FRDC Project Nos. **2019/027**, **2007/039**, **2005/049**, **2001/008**, **2001/006**, and **1998/204**.

In this fishery large mesh trawl netting helps the escape of small and undersized species. The mesh size in the wings and mouth of a trawl must not be less than 115 mm and codend mesh size must not be less than 90 mm single twine or 102 mm double mesh (AFMA, nd). If one or more bycatch reduction devices are used, 90 mm double twine may be used in the codend. Permitted bycatch reduction devices include a 90 mm (or more) square mesh panel in the upper side of the codend, measuring 15 bar lengths x 20 bar lengths, or a 90 mm (or more) T90 mesh in the upper side of the codend measuring 15 meshes x 18 meshes.

The most recent FRDC funded effort to reduce bycatch in this fishery is **FRDC Project No. 2019/027**. This project is ongoing at the time of this report, and hopes to improve trawl selectivity, reduce environmental impacts, and reduce fishing costs through trawl modification. Project objectives include identifying and prioritising a range of potential trawl modifications to improve selectivity, evaluating their efficacy, and encouraging wide spread voluntary adoption of any proven modifications. As this project is ongoing there are no project recommendations.

Previous to this project, **FRDC Project No. 2007/039** focussed on reducing catches of several discard species including blacktip cucumberfish, spikey dogfish and small silver dory using a new high-lift net (Koopman *et al*., 2009). This net caught about 50% fewer discards than the control net by volume although the catch of commercially valuable deepwater flathead was also reduced. The authors' noted that project success will be evaluated by the future uptake of industry of the net. Cited project recommendations are summarised in Table 3.

Table 3. Cited recommendations FRDC funded projects related to the Commonwealth Trawl Fishery.

Project No.	Recommendations (specific bycatch reduction)
2007/040	1. It was recommended that further research is required to: a. Examine the behaviour of Eastern School Whiting in response to codends as part of efforts to reduce bycatch in the Whiting fishery b. Further evaluate the impact of T90 codends on the profitability of fishing activity, based on accurate logbook reporting 2. Evaluate the effectiveness of bar-wing nets in reducing the catch of Spiny Pipehorse in an alternative haul study with point-wing nets.
2007/039	1. No specific recommendations were noted although it was suggested that additional fieldwork is required to improve knowledge of the effectiveness of the high-lift net
2005/049	1. No specific recommendations were provided, although it was noted that SETFIA members are already trialling SEDs on wet boats in the fishery. This work should continue as well as improved reporting of seal interactions.
2001/008	1. For the midwater trawl fleet: a. Use open forward facing tophatch SEDs or a more effective SED if developed in all midwater trawl shots b. Continue the application of the Code of Practice c. Continue shot-by-shot recording of seal bycatch by fishers d. Maintain level of observer coverage and biological data collection e. Continue trials of the tophatch SED and use underwater cameras to film the timing and depth-entry of seals, and the circumstances of entry that place seals at risk 2. For the demersal fleet (trawl and danish seine) a. Assess the nature and extent of seal interactions across the fishery b. Apply the Code of Practice where practicable c. SED use should be confined to the midwater trawl fleet
2001/006	1. Seek legislation requiring the mandatory use of selective codends such as T90 selector panels and T90 lengtheners 2. Investigate the post-capture survival of escaping fish
1998/204	1. Investigate factors that trigger particular behaviours in fish, both targeted and non-targeted 2. Assess the effectiveness of new gear technologies that might be applied to reduce bycatch 3. Investigate the survival rate of escapees.

In 2005, **FRDC Project No. 2005/049.20** attempted to raise fisher awareness and encourage their increased reporting of seal interactions in the fishery (Knuckey & Stewardson, 2008; Knuckey & Koopman, 2011). This project also established an industry-based seal monitoring program. No specific recommendations were provided for further development, although it was noted that there has been a substantial increase in rates of seal reporting by fishers and the trialling of SEDs. While this new rate of reporting was still lower than that for observers a further increase was anticipated after the conclusion of this project. Cited project recommendations are summarised in Table 3.

This project built upon the outcomes of **FRDC Project No. 2001-008** which attempted to improve the effectiveness of a seal exclusion device (SED) in blue grenadier midwater trawl nets (Figure 1), assess the effectiveness of other fishing techniques designed to reduce seal bycatch, gather information on seal movements, and gather biological information from seal fatalities (Tilzey, et al., 2006). This

project also evaluated the efficacy of the newly developed industry Code of Fishing Practice, which was aimed at avoiding seal capture and mortality. Modification to the SED reportedly overcame earlier issues of fish loss and a top opening SED was found to significantly lower the incidence of seal bycatch (Knuckey & Stewardson, 2008). Trials with this device were reportedly continuing after the conclusion of the project; subsequently no performance data was provided. This project was supported by an extension program to inform fishers of SED developments, including a booklet describing guidelines for reporting seal interactions, a poster describing identifying features of each seal species, and a DVD to explain why seal bycatch was an issue, how to identify seals by species, and how to collect necessary data. This project also appointed an experienced fisher to act as a program liaison officer. Cited project recommendations are summarised in Table 3.

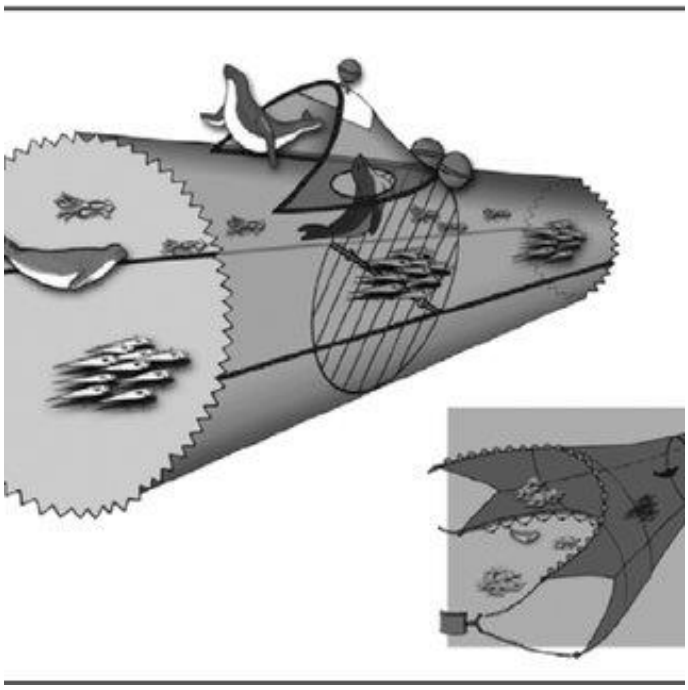

Figure 1. Seal Exclusion Device (SED). Source. Baker et al. (2014).

Additional recommendations included assessing the nature and extent of seal interaction across the entire fishery and the application of the Code of Practice across the entire trawl fleet, whilst cautioning the use of SEDs by the demersal trawl fleet until further assessment of SEDs was completed. Notably, the objectives of the subsequent project, **FRDC Project No. 2005/049**, did not include further assessment of SED performance, and it does not appear that further assessment was funded by the FRDC.

In 2008, the National Heritage Trust funded research to evaluate the efficacy of three SED designs on demersal trawl vessels (wet boats). Each of these SEDs were tested on commercial vessels but due to limited seal interactions their efficacy remains questionable (Roberts, 2009). The Guarnaccia soft SED and the Bennett's soft SED were constructed from flexible combination rope while the Motnet's SED comprised of three rigid, articulated sections. A core design requirement of all SEDs was that they could be wrapped around a net drum without damage to the grid or trawl and were manageable by crew. The performance of each SED was reportedly modest, in part being limited by a low number of interactions with seals. Problems with grid blockage were experienced, with

associated catch loss through the escape opening of the SED. The size and location of the escape opening on at least one SED was thought to hamper the escape of sponges, skates, and seals. It was claimed the Bennett SED was the most promising device for this fishery, being easiest to handle and wind around a net drum. It was also claimed that fishers were keen to continue these trials, and that further research was required to improve SED design in order to improve bycatch reduction performance.

In 2001, **FRDC Project No. 2001/006** attempted to facilitate improvement in gear modifications and build upon the outcomes of earlier efforts (**FRDC Project No. 1998-204**) to reduce bycatch and discards (Walker *et al*., 2010). It also attempted to improve the voluntary uptake of modified gear by fishers, and specifically, compare the performance of a T90 selector panel against a 90 mm diamond mesh codend. Subsequent to these efforts, there was a substantial increase in the number of fishers using large diamond-mesh netting in their codends or the T90 codend. Fishers also sought legislative changes in support of these modifications, and it was reported that this demonstrated a willingness of fishers to adopt the new modifications. It was noted that by the end of 2005, the use of 100-119 mm codend mesh size had increased to 35% of tows, and that use of 120 mm codend mesh size or large had increased to 5% of tows. Additionally, information was provided to fishers describing fish behaviour in trawl nets, as well as information describing the new modifications, which enabled many fishers to trial these modifications themselves. It was specifically mentioned that both projects contributed to these outcomes, as did pressure from government authorities, including the Federal Minister for Agriculture, Fisheries and Forests, on fishers to reduce bycatch and discards. At the same time, the economic returns in the fishery were poor, in part due to rising fuel prices, management levies, quota leasing costs, and other costs (Knuckey & Ashby, 2009), although it was expected that further evolution in codend selectivity would occur as the economic performance of the fishery improved (Walker *et al*., 2010). It was also noted that an outstanding issue was the post-capture survival of fish that escaped the trawl gear or were discarded overboard. Cited project recommendations are summarised in Table 3.

FRDC Project No. 1998-204 was the first FRDC-funded project designed to reduce bycatch in this fishery. Project objectives included the evaluation of trawl modifications designed to reduce the capture and discard of small fish, including juvenile fish of commercial importance, quantification of the economic impacts of these gear modifications on industry, and application of an extensive extension program to ensure industry were informed of project progress and outcomes. It was reported that many fishers were proactive in trailing these modifications once fieldwork ended, and that fishers had made many modifications to improve performance. Cited project recommendations are summarised in Table 3.

Survey results

Only 2 respondents completed the survey, one researcher and a fishery manager. Both had been closely involved in at least one FRDC-funded project and had good knowledge of the remaining projects.

Following-up on FRDC project recommendations

According to one respondent, most cited recommendatations with respect to **FRDC Project No. 2001/008** and **2001/006** were followed up with including mandatory use of T90 selector panels and SEDs, industry application of the code of conduct, and testing of a forward facing SED. These were apparently not too burdensome for fishers and had little impact on commercial catches. The respondent noted that observer coverage and reporting of TEP interactions for each haul is a requirement under the EPBC Act. It was not known if SED or T90 follow-up activity had been

quantified, and therefore how effective such activity had been, and it was suggested this was because such quantification had not been a priority. It was also suggested that such quantification is expensive and not a burden fishers would want to shoulder, particularly given concerns over their impact on commercial catches.

The other respondent was familiar with all FRDC projects in this fishery but responses were focused primarily on **FRDC Project No. 1998/204**. This respondent noted that a significant reduction in bycatch occurred as a result of this project and associated follow-up changes in fishing practice. Follow-up activity also included **FRDC Project No. 2001/006**, which attempted to further improve codend selection and survival of escape fish. It also contributed to a code of conduct signalling the voluntary uptake of modified gear, such as large mesh codends to reduce the capture of non-commercial species and undersized commercially important species. The development of the high-lift trawl net was an industry-led initiative to reduce bycatch, which ultimately resulted in **FRDC Project No. 2007/039** being funded. It is believed that some fishers still use this trawl when deemed appropriate.

One respondent indicated that while industry associations are probably aware of cited project recommendations, most fishers would not be aware of these recommendations. However, according to one respondent several boats in the GABT have voluntarily begun using 4-seam square-mesh panels in their codends to reduce bycatch, and in recent years Danish seine fishers have voluntarily adopted a 5 mm increase in codend mesh size as a concession against changing quota levels.

Drivers and motivators for bycatch reduction regulation

Both respondents indicated a core driver for bycatch reduction was a legislative requirement to minimise the environmental impact of fishing. It was also noted that many fishing businesses probably resisted this change, as did skippers due to concerns for negative economic impacts.

Industry buy-in to regulation in recent times is probably better than it used to be, according to one respondent, because their relationship with AFMA has improved as a result of dedicated and persistent efforts to improve communication.

Impediments and bottlenecks to voluntary or non-FRDC funded attempts to reduce bycatch

Both respondents cited a key impediment to voluntary efforts to reduce bycatch is concerns over the loss of commercial catch and associated economic impact, and that such efforts will only come about if regulated with clear evidence of long-term benefits to the fishery. Co-management and co-design are important in any bycatch reduction initiative, acording to one respondent, but ultimately regulation may be necessary to ensure change.

One respondent indicated that initial enthusiasm to reduce bycatch was tempered by the realisation that others in the fishery were not responding similarly, due to fears for loss of catch. Subsequently, enthusiasm to reduce bycatch slowed across the fishery, and many fishers circumvented gear regulations by introducing non-regulated gear modifications to reduce the loss of commercial catch. These modifications also reduced the ability of the modification to reduce bycatch. This respondent noted that in recent years there has been little pressure on fishers to further reduce bycatch, despite approximatley 40% of the catch being discarded. Other perceived reasons for the reluctance of fishers to reduce bycatch include lack of incentives, concerns that such efforts will never end, be costly or painful, and uncertainty how they might be impacted (Table 4).

One respondent indicated that fleet size is important, that individuals in smaller fleets are often more cohesive and engaged than otherwise, particularly if supported by an effective industry

association. This respondent also indicated that fishing companies are often more willing to entertain changes, because they are bigger, have greater resources, and are more familiar relevant with legislation. Another respondent indicated they are much more aware of their social licence and public perceptions towards the industry.

Table 4. Perceived reasons why fishers are reluctant to further reduce bycatch for each fishery, by weighted average. Score and ranking: 1.0 - Very important, 2.0 - Important, and 3.0 - Not important. Number of respondents = 2.

Statement	**Wt. avg**
Perceived lack of incentives to offset any catch loss from additional bycatch reduction efforts	1.00
Concerns that pressure to further bycatch will never end	1.00
Concerns that further bycatch reduction efforts will be costly or painful	1.00
Uncertainty about how they might be affected by additional bycatch reduction efforts	1.00
Mistrust of individuals responsible for promoting a need to further reduce bycatch, including their motives	1.50
Perceived lack of opportunity, benefit, or reward from further bycatch reduction efforts	1.50
Perception that bycatch reduction using their current trawl gear is sufficient/adequate	2.00
Disinterest or apathy regarding additional bycatch reduction efforts	2.00
Perception there is insufficient time to become adjusted to the idea of additional bycatch reduction efforts	2.00
Concerns that past efforts to reduce bycatch will be ignored or dishonored	2.00
Fundamental, pathological, or ideological resistance to additional bycatch reduction efforts	2.00
Perceived lack of consultation regarding a need for additional bycatch reduction efforts	2.00
Perceived loss of control over their fishing operation or business as a result of additional bycatch reduction efforts	2.50
Perceived lack of understanding of the need/reason for additional bycatch reduction efforts	2.50
Perceived concerns that further bycatch reduction efforts will unevenly affect other fishers in the fishery	2.50
Concerns they will appear incompetent in the face of additional bycatch reduction efforts	3.00

What worked, should have been done differently, and should be done in the future

According to one respondent, tapping into genuine concern by some fishers to reduce catches of small or unwanted species, particularly if they do not affect the bottom line, is key to their engagement in bycatch reduction. A cohesive and engaged industry is more likely to make voluntary changes to their gear, particularly if accompanied by specific bycatch reduction strategies with

implications for failing to achieve performance goals. Where voluntary adoption is not evident, this may be the only option.

The other respondent indicated the management of gear modifications to reduce bycatch was not strict enough and should have gone further. While the introduction of regulations was an important step, they did not go far enough and prevent fishers from further altering their gear to minimise the escape of commercial and non-commercial fish. As a result, the efficacy of gear modifications to reduce bycatch has been undermined. It was also noted that fishers are reluctant to further reduce bycatch because there is little pressure from fishery managers, environmental groups and others to do so, despite it being well known that 40% of the catch is discarded and there are other negative environmental impacts such as marine mammal fatalities. Combined with concerns over catch loss, this is not an ideal environment to encourage interest in bycatch reduction.

One respondent was unclear if FRDC should have done anything differently. This individual indicated it is the responsibility of the regulator to develop and enforce the changes, but also noted that promulgation of project outputs to industry and others may have led to a smoother transition. They also stated it is essential that FRDC promotes the outcomes of future projects and engages more closely with industry. The other respondent suggested that FRDC should have adopted a stricter approach to ensure that fishery management needs were more closely aligned funded project activity, that while a project prioritisation process already does this to some extent, it does not go far enough. This respondent also suggested it is essential that managers and industry are heavily involved in any project with researchers, beyond writing a support letter. Fishery managers must be involved from the beginning of the project, and they should test various management scenarios based on perceived project outcomes, rather than waiting to learn of these outcomes from a completed project report. This would ensure their closer interest and engagement in the project, and potentially reduce the lag time between project conclusion and introduction of associated regulations. An economic analysis of each management scenario would also be an important step, with researcher and fisher input, to assist with informed decision-making and socialising of potential project outcomes.

Both respondents indicated a need for improved outreach and extension activity. One noted the excellent work done by SeaNet and Oceanwatch in the past, and that their role had been diminished in recent years. Researchers are not necessarily adept at explaining project results and outcomes to fishers, and in any case, they usually have limited capacity to do so once a project has been completed.

NSW Estuarine and Oceanic Prawn Trawl Fisheries (NSWPTF)

Prawn trawl fisheries in NSW operate in estuarine waters and oceanic waters. The estuarine fisheries operate in the Clarence, Hawkesbury, and Hunter Rivers, and primarily target school prawns (*Metapenaeus macleayi*) for domestic consumption or bait as well as eastern king prawns (*Penaeus plebejus*) (NSW Fisheries, 2003; NSW Government, 2018). Bycatch species in these fisheries includes those of commercial and recreational importance, such as whiting, yellowfin bream, tarwhine, snapper, leatherjacket, flathead, tailor, and mulloway.

In the estuarine fisheries a trawl net must be constructed using a mesh size between 34-40 mm (NSW Government, 2019). Additional regulations include limits on the number of trawls towed simultaneously and their size and headline length (NSW Government, 2018). Diamond mesh codends must be constructed from 40-60 mm mesh netting, with a twine diameter no more than 2.5

mm and a circumference no more than 200 meshes. Square-mesh netting is permitted in the wings and side panels of the trawl, providing mesh size is between 34-40 mm. All prawn trawls must be fitted with a BRD and a range of options are available including the composite square-mesh panel, blubber chute, and Nordmøre grid. Specifications for each of these devices is available at NSW Fisheries (2003). Discards are an estimated 20% of the total catch weight (Kennelly, 2018).

The oceanic prawn trawl fishery is managed as part of the Ocean Trawl Fishery, which includes a fish trawl sector. The oceanic prawn trawl fishery comprises of an inshore fishery targeting mainly eastern king prawns and school prawns, and an offshore and deepwater fishery, the latter which primarily targets royal red prawns. School whiting, sand flathead, and cuttlefish are also landed (NSW DPI, 2004). Bycatch is usually discarded and primarily comprises small commercially important and non-commercial fish and invertebrates. In these fisheries, trawl mesh size must be 40-60 mm and codend mesh size must be 40-50 mm (NSW DPI, 2017). There are also restrictions on total headline length and sweep length. In this fishery, discards account for approximately 66% to the total catch (Kennelly, 2018).

A suite of gear modifications is currently available for fishers to use in the estuarine fishery designed to reduce bycatch and/or habitat impact, some of which can also lead to fuel savings (NSW DPI, 2019). Modifications include the use of small, hydrodynamically efficient otter boards, shorter sweeps between otter boards and the nets, smaller gauge ground chains, soft-brush ground gear, hanging ratio and wingend height modification, steeper side tapers, and the use of a simple anterior fish excluder (SAFE). If a knotless square-mesh codend is used the mesh size must be at least 27 mm, or at least 29 mm if a knotted square-mesh codend is used (NSW DPI, 2016). Twine diameter can be no more than 2.5 mm, and the codend must be 1-3 m in length and have a circumference less than 3.2 m (NSW Government, 2018). In the Clarence River, fishers may use a diamond bycatch reduction device provided each side of the diamond is longer than 11 bar-lengths long and the point of the diamond closest to the codend drawstring is no more than 3 meshes of where the codend is attached to the trawl (NSW Government, 2019). Codend length must be no more than 80 bar-lengths long.

In the inshore and offshore prawn trawl fisheries, a similar suite of gear modifications is available to reduce bycatch, habitat impact, and in some cases, fuel consumption (NSW DPI, 2020). This includes the use of small, hydrodynamically efficient otter boards, shorter sweeps between otter boards and the nets, smaller gauge ground chains, soft-brush ground gear, hanging ratio and wingend height modification, square-mesh netting in the wings and side panels, and the use of a simple anterior fish excluder (SAFE). It also includes mesh size less than 100 mm, and codend mesh sizes between 40-50 mm and 50-60 mm for square-mesh and diamond mesh codends respectively. Several BRDs are permitted including the modified big-eye, fish eyes, and the large-mesh panel BRD. Regulations for these BRDs are available at NSW DPI (2020). Additional regulations restrict trawl size and mesh size when fishing for school prawns within 2 nm of the coastline.

Bycatch reduction efforts and cited project recommendations

Many options to reduce bycatch are already available to prawn fishers in NSW, as described above, reflecting the long and dedicated history of bycatch reduction efforts in this state.

FRDC funded efforts to address bycatch in these fisheries were associated with FRDC Project Nos **2017/097**, **2011/010**, **2005/056**, **2001/031**, **1993/180**, and **1988/108**. The most recent FRDC funded effort to reduce bycatch in this fishery (**FRDC Project No. 2017/097**) focussed on testing the efficacy of headline height reduction, the FLEXSELECT (Figure 2), and the SAFE bycatch reduction devices

(Figure 3). The headline height reduction included reducing the vertical opening of the trawl by 33% and 46% of conventional trawl opening. The FLEXSELECT consisted of a series of steel wire ropes extending from the otter boards to the trawl that are designed to stimulate fish escape away from the trawl mouth (Kennelly *et al*., 2018), and the SAFE consisted of a length of canvas extending between the otter boards, designed to herd fish upwards and over the approaching trawl.

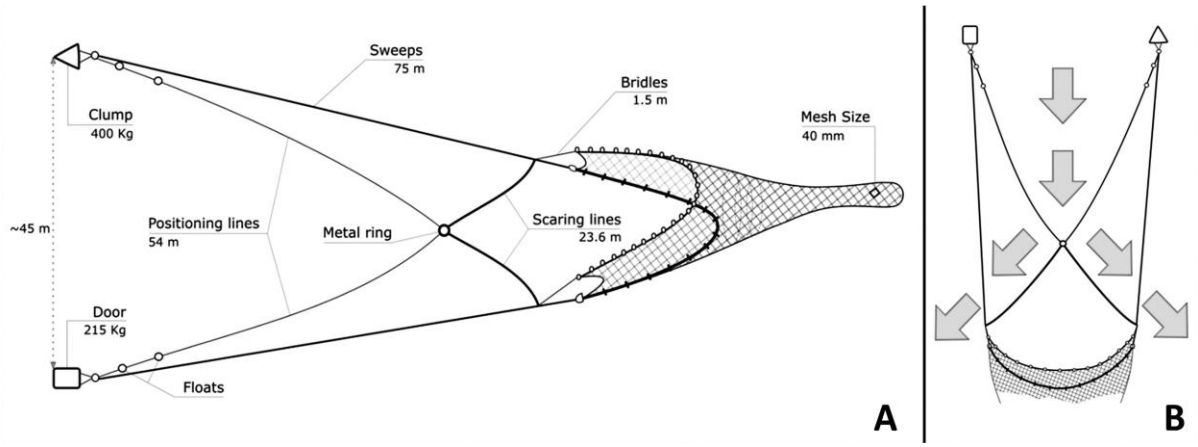

Figure 2. The FLEXSELECT fish herding device. Source. Melli et al., 2018.

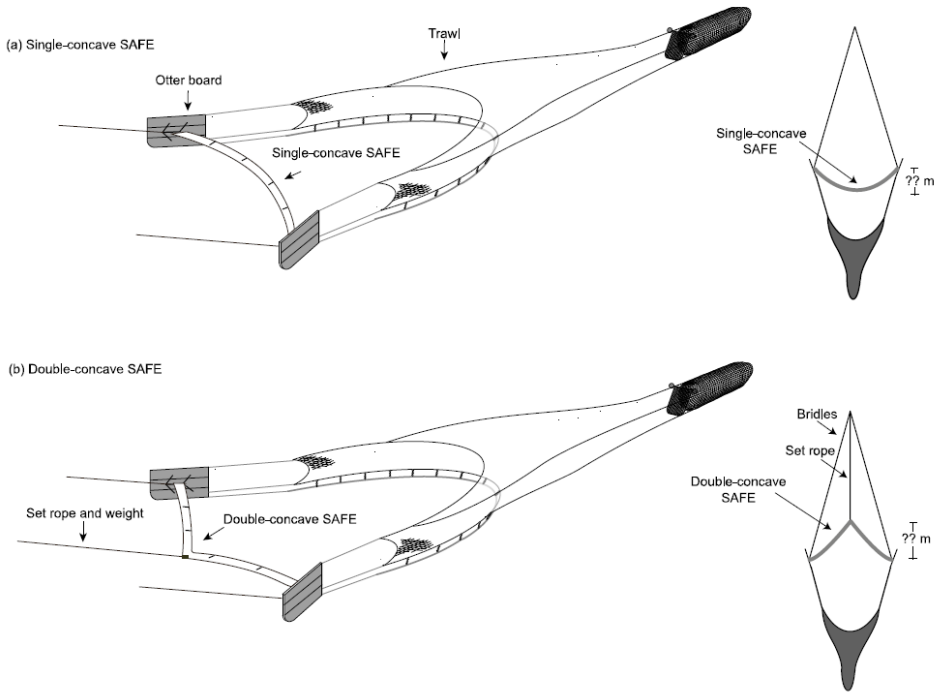

Figure 3. The single- and double-concave SAFE. Source. Kennelly et al., 2018.

Both headline height modifications resulted in a significant reduction in bycatch, by over 80% for some fish species (Kennelly *et al*., 2018). They had no significant impact on the prawn catch, although there was a tendency for the conventional trawl to catch more prawns by number. The

SAFEs had no significant impact on the prawn catch compared to a conventional trawl, although they reduced the weight of southern herring bycatch by up to 52%. The FLEXSELECT had little impact on bycatch reduction. Cited project recommendations are summarised in Table 5.

Table 5. Cited recommendations FRDC funded projects related to the NSW Oceanic and Estuarine Prawn Trawl Fishery.

Project No.	Recommendations (specific to bycatch reduction)
2017/097	1. Further refine the SAFE to minimise its impact on trawl spread and improve its ability to elicit fish escape responses, including influence of artificial light 2. Evaluate the impact of lower headline height in other fisheries, with and without headline floats and lead ahead. 3. Continue to evaluate these modifications and other designs in other prawn fisheries, and encourage industry engagement through streamlined approval processes 4. Greater focus on easily implemented solutions e.g., headline height modification, to allow fishers to be more flexible and adaptable.
2011/010	1. Develop and refine additional modifications to those tested, including SAFE variations, SAFE + lights, reduced otter board angle of attack, alternate spreading mechanisms, and ground gear modifications to recue impact. This will need to be tested across fleets and fisheries. 2. Promote the adoption of modifications tested in this project via dedicated extension activities
2005/056	1. Consider the use of acoustic, light, or electronic devices attached to the anterior sections of a trawl to elicit fish escape responses, to minimise the risk of post escape mortality 2. Consider options to compartmentalise catches, e.g., smaller separate codends to reduce contact between organisms, or use of smaller, multi-net trawl systems, or soft knotless netting to minimise abrasion. 3. Holistic quantification of the full range of impacts by trawl gear (and other fishing gears) to facilitate ecosystem-based management
2001/031	1. Adoption of 27 - 29 mm knotless polyamide square mesh codends
1993/180	1. Support prawn trawl fishers to further develop and refine bycatch reduction devices 2. In the meantime, focus selectivity research on other fishing methods (for the time being)
1998/108	1. Seek follow-up funding to further test and develop bycatch reduction devices

This project built on the success of **FRDC Project No. 2011/010**, which evaluated several anterior gear modifications designed to reduce bycatch, fuel consumption and habitat impacts of prawn trawls. Importantly it provided a framework and direction for future improvement of trawls in Australian prawn fisheries. Key project findings included bycatch reduction up to 95%, reduced groundgear and otter board contact by 60% and 85% respectively, and reduced drag by up to 20% (Figure 4) (Broadhurst & Sterling, 2016). While project fieldwork occurred in NSW, project findings are applicable to many prawn fisheries around the country. Cited project recommendations are summarised in Table 5.

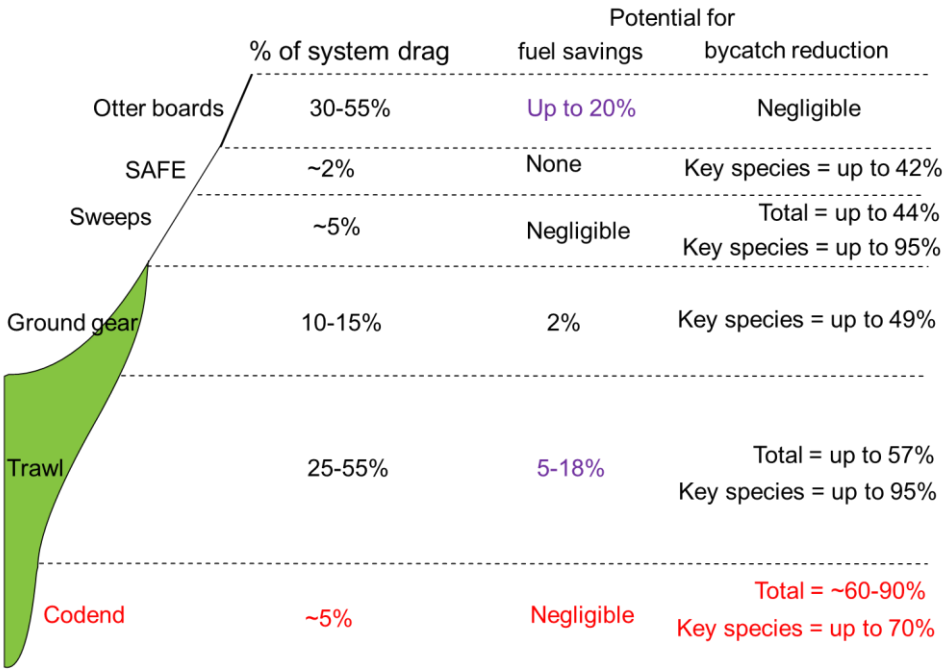

Figure 4. Potential bycatch reduction and fuel consumption by system component. Source. Broadhurst & Sterling, 2016.

FRDC Project No. 2005/056 attempted to identify and quantify practices and procedures to reduce the mortality of discarded bycatch species, examine the efficacy of practices to reduce this mortality, and determine appropriate strategies to assist fishers and fishery managers implement, adopt, and legislate such strategies (Broadhurst, 2008). This project focused on estuarine prawn fisheries as well as beach seine and gillnet fisheries. A number of methods were evaluated to reduce discard mortality, and it was hoped that fishery managers would use this information to establish appropriate regulatory measures. These included reducing towing duration and sorting the catch in a purpose-built water tray, the latter which was found to reduce the mortality of yellowfin bream by an average of 26% and school prawns by 33%. It was suggested that the efficacy of modifications to the anterior section of a trawl to evoke an escape response, such as noise generators or lights, should be evaluated in the future. Smaller, softer codends may also serve a similar purpose. A review of catch mortality in towed fishing gear including prawn trawls and potential mitigating options is provided in (Broadhurst *et al*., 2006) and (Suuronen & Erickson, 2010). Cited project recommendations are summarised in Table 5.

FRDC Project No. 2001/031 was an attempt to develop and test multiple modifications and fishing practices designed to reduce the bycatch and discarding of small school and king prawns (Broadhurst *et al*., 2005). In addition to modified prawn trawl designs, modifications were made to haul, push, and scoop nets, seines, stow nets and trap nets. Various diamond and square-mesh codends were tested in multiple locations such as Lake Woolooweyah, Clarence River, and the Hawkesbury River, including variation in codend hanging ratio (to reduce the fishing circumference of the codend and open codend meshes), larger diamond mesh, reduced twine diameter, and use of square meshes. It was found that square mesh netting in the codend, with a mesh size between 27-29 mm, was most effective in reducing the catch of small unwanted prawns while maintaining the commercial catch. These codends allowed up to 99% of individual sizes of unwanted school prawns to escape and up to

91% of total fish bycatch, while maintaining the commercial catch. Cited project recommendations are summarised in Table 5.

FRDC Project No. 1993/180 was funded to evaluate the efficacy of multiple bycatch reduction devices in the estuarine and oceanic prawn fisheries and successfully encouraged the majority of skippers to voluntarily test a device (Kennelly & Broadhurst, 1998). This included half and full square-mesh codends, composite square-mesh panels, separator mesh panels, Nordmøre grids, blubber chutes, fisheyes, extended mesh funnels, as well as the effect of haul back delays, codend circumference, and larger diamond mesh in the codend of fish trawls. Descriptions and images of these devices is available at Kennelly & Broadhurst (1998). Many of these devices significantly reduced bycatch, in some instances by up to 95% for some species, and some resulted in an increased prawn catch. The Nordmøre grid and the composite square-mesh panel were generally considered the best performing devices for the estuary and oceanic fisheries respectively. A significant focus was working closely with fishers throughout all stages of this project, and keeping them informed of all developments via a significant extension program. This program resulted in significant numbers of fishers voluntarily testing a bycatch reduction device, including new devices and re-tuning old ones to further improve performance. Project outcomes also included a very high number of scientific publications and contributions to conference proceedings, and they were used to help draft regulations mandating the use of these devices in each fishery. Cited project recommendations are summarised in Table 5.

The first FRDC funded project to reduce bycatch in NSW, **FRDC Project No. 1988/108**, was an attempt to identify and quantify the spatial and temporal differences in bycatch in local prawn trawl fisheries. This information was used to extrapolate total catch and bycatch for different fishing grounds and times. The effect of different sweep lengths and a soft TED were tested in the oceanic fishery. Square-codends were also tested to reduce the catch of juvenile mulloway in the Hawkesbury River. The potential of these modifications was successfully demonstrated, and resulted in a follow-up application to FRDC for funding (**FRDC project No. 1993/180**). Cited project recommendations are summarised in Table 5.

Survey results

A total of four respondents completed the survey, two researchers, one industry member, and a fishery manager. All had been closely involved in at least one FRDC-funded project and most had some knowledge of the remaining projects. Few respondents commented specifically about **FRDC Project Nos. 1993/179**, **1996/254**, and **2000/173**, given they were completed so long ago, although there was tacit acknowledgment by some respondents that these projects had influenced later research.

Following-up on FRDC project recommendations

It was noted by several respondents that a considerable body of work had been completed following-up on project recommendations. For example, **FRDC Project No. 2017/097** was an attempt to follow-up on recommendations cited in **FRDC Project No. 2011/010**, which in turn followed-up on **FRDC Project No. 2005/056**. While this follow-up work was successful in terms of funding for new projects, it was noted that the development and introduction of regulations based on project outcomes usually took many years. It was also noted that many fishers were aware of these recommendations as the source of follow-up activity and responsible for new legislation. FRDC funded projects were clearly very successful and apparently largely responsible for the introducton of new legislation to reduce bycatch.

Another respondent noted that some Clarence River fishers had now adopted the use of quad-gear and steeper tapered trawls as a result of **FRDC Project No. 2017/097**, while another noted keen industry adoption except for the Safe BRD.

According to respondents, key motivators for these changes included increased catching capacity, greater profitability due to increased catches and reduced fuel consumption, reduced bycatch, and legislation. Another simply said, because they worked, except for the SAFE BRD, but noted that additional work with this BRD was probably required. These changes were linked to Section 37 orders which was established by NSW DPI to encourage voluntary testing of BRDs in the estuary prawn fisheries, although apparently only a limited number of fishers had exploited this opportunity to date.

Drivers and motivators for bycatch reduction regulation

A key reason for bycatch reduction regulation, according to several respondents, was the quality of underpinning research and subsequent peer-reviewed publications, and the close relationship between fishers and researchers. Another indicated that regulation occurred because industry asked for it based on confidence in the research. However, another respondent indicated that some fishing companies, boat owners, and fishers were not accepting of the changes but they got on with it and used them once regulations were introduced, while another said attitudes were negative because using the BRDs was new, but that many fishers changed their minds once they realised the benefits of these devices.

One respondent noted that ultimately there was adequate political will to follow through and introduce bycatch regulation, underpinned by a close relationship between senior fisheries staff and relevant Ministers. Another indicated that the success of many of these initiatives was due to the persistent involvement of several fishers in the Clarence River in conjunction with researcher Matt Broadhurst.

Impediments and bottlenecks to voluntary or non-FRDC funded attempts to reduce bycatch

One respondent indicated that delays in implementing research findings and recommendations was that fishers do not like change and were therefore not motivated to adopt new gears to reduce bycatch. In addition, fisheries managers and their superiors apparently did not understand the modifications and were subsequently reluctant to introduce new regulations, in part because it made the regulations less “tidy”, despite being well aware of the success of the modifications. Overcoming this apparently requires fisheries managers to be trained in fishing technology, and their determination to introduce regulations despite causing angst with fishers. It also requires overcoming the lack of political will by the NSW Department of Primary Industries and for them to respond in a timelier manner.

Another respondent noted the limited attempts by fishers to voluntarily change their gear to further reduce bycatch, and that these attempts were frequently led by fishers from the Clarence River. Impediments to fishers further reducing bycatch included perceived challenges obtaining permits to test a new gear or modify an existing gear. Permits were previously approved by the Chief Scientist at NSW Fisheries but now a permit application passes through the hands of several middle managers, most who have no understanding of fishing gear or fishing. Respondents indicated other reasons for the reluctance of fishers to further reduce bycatch include a perceived lack of consultation, incentives, opportunity, benefit, or reward, coupled with concern that pressure to reduce bycatch will never end and be costly or painful (Table 6).

Table 6. Perceived reasons why fishers are reluctant to further reduce bycatch for each fishery, by weighted average. Score and ranking: 1.0 - Very important, 2.0 - Important, and 3.0 - Not important. Respondent number = 4.

Statement	**Wt. avg**
Perceived lack of incentives to offset any catch loss from additional bycatch reduction efforts	1.50
Concerns that further bycatch reduction efforts will be costly or painful	1.50
Perceived lack of opportunity, benefit, or reward from further bycatch reduction efforts	1.50
Perceived lack of consultation regarding a need for additional bycatch reduction efforts	1.75
Concerns that pressure to further bycatch will never end	1.75
Perception that bycatch reduction using their current trawl gear is sufficient/adequate	2.00
Disinterest or apathy regarding additional bycatch reduction efforts	2.00
Uncertainty about how they might be affected by additional bycatch reduction efforts	2.00
Concerns that past efforts to reduce bycatch will be ignored or dishonored	2.00
Mistrust of individuals responsible for promoting a need to further reduce bycatch, including their motives	2.00
Perceived loss of control over their fishing operation or business as a result of additional bycatch reduction efforts	2.25
Perceived lack of understanding of the need/reason for additional bycatch reduction efforts	2.25
Perceived concerns that further bycatch reduction efforts will unevenly affect other fishers in the fishery	2.25
Perception there is insufficient time to become adjusted to the idea of additional bycatch reduction efforts	2.25
Fundamental, pathological, or ideological resistance to additional bycatch reduction efforts	2.25
Concerns they will appear incompetent in the face of additional bycatch reduction efforts	2.50

Fleet size would have had no effect on past bycatch reduction efforts according to several respondents, although it was noted by one that a larger fleet size presents great communication and education challenges. In any case, once legislated all fishers must comply with regulations irrespective of fleet size. Several respondents felt that changes in the mix of owner-operated to company-owned vessels would probably have had no effect. One respondent felt that fishers rarely embrace and accept voluntary change in their fishery, one indicated they occasionally accept voluntary change in their fishery, and two indicated they sometimes accept voluntary change in their fishery.

What worked, should have been done differently, and should be done in the future

One respondent indicated that stronger education of managers in fishing technology, the proposed changes, and their responsibilities to enact change should have been done in the past. Several respondents indicated more extension work was required, and that a key lesson was that extension

programs need to be ongoing, not limited to a three-year period of FRDC funding, with financial assistance provided to fishers to offset catch loss. Several respondents suggested this would have facilitate greater momentum and improvement, although one noted that implementation by industry can be long and slow irrespective of incentives.

One respondent noted the application of a testing 'framework' to rigorously test a BRD was key to their success and would not need to be changed if testing was repeated. Another suggested an important motivator to facilitate change in this fleet in the past was the use of respected industry champions working with key researchers, and that this, combined with momentum to drive through necessary legislation are important lessons that could be applied in the future or elsewhere.

Several respondents indicated the FRDC did all they could in the past to facilitate bycatch reduction in this fishery, and that without the efforts of the FRDC, Australia would not enjoy its success in BRD development and implementation. In contrast several others said that funding of bycatch reduction research should have been ongoing, not sporadic, due to impacts on the momentum to change by fishers and managers. This was a particular concern to respondents given a long history of research findings successfully triggering management regulations in this fishery. Another respondent was critical of some individuals who sit on the FRABs because they do not listen to industry.

Future efforts in this and other fisheries, according to one respondent, includes joint industry and management workshops in BRD design, operation, and implementation, facilitated by expert fishing technologists. It was noted however that recent FRDC funded bycatch reduction workshops in NSW invited fisheries managers but only a few attended; despite this setback a renewed attempt is considered by this respondent to be sufficiently important. Future efforts should also include educating fishers to look at the bigger picture and that social licence is an important construct that can easily be damaged.

QLD East Coast Otter Trawl Fishery (QECOTF)

This fishery targets Tiger prawn (*Penaeus esculentus*, *P. semisulcatus* or *P. monodon*), Endeavour prawn (*Metapenaeus endeavouri* and *M. ensis*), Red spot king prawn (*Penaeus longistylus*) Banana prawn (*Penaeus merguiensis*), Eastern king prawn (*Penaeus plebejus*). Other targeted species include Moreton Bay bugs (*Thenus australiensis* and *T.parindicus*), Squid spp., and scallops (Queensland Government, 2020). Several incidentally-caught species can be also be landed including blue swimmer crabs, cuttlefish, three-spotted crabs, and Balmain bugs.

Fishers are permitted to tow multiple trawl nets simultaneously when targeting prawns, bugs, squid, or scallops (State of Queensland, 2021). Their access to various locations in the fishery is determined by the type of licence they hold, and their fishing gear must satisfy various gear regulations for that area, including trawl number and size, mesh size, sweep length, codend covers, and ground chains. All prawn trawls must be fitted with a TED and a BRD, with the exception of using TEDs in rivers or creeks. Five BRD designs are permitted for use in the fishery: square-mesh codend, fisheye, bigeye, square-mesh panel, and v-cut with bell codend. Specifications for TEDs and BRDs is available at State of Queensland (2017). Notably, the weight of discards in this fishery is approximately 77% of total catch weight, and equivalent to 27% of discards from all Australian commercial fisheries combined (Kennelly, 2018).

Bycatch reduction efforts and cited project recommendations

FRDC funded efforts to address bycatch in this fishery were associated with FRDC Project Nos **2015/014**, **2008/101**, **2005/054**, **2005/053**, **2000/170**, **1996/254**, **1993/229**.

A range of options to reduce bycatch are available to prawn fishers in the QECOTF, as described above. Like most other prawn fisheries in Australia, this outcome reflects a long history of bycatch reduction research including testing of numerous bycatch reduction devices. The most recent FRDC funded effort in this fishery (**FRDC Project No. 2015/014**) aimed to evaluate the survival of elasmobranchs that are caught and discarded at sea, quantify reductions in bycatch over the past 20-30 years, describe how these reductions have come about, and assess the risk trawling poses to the sustainability of high-risk species (Campbell *et al*., 2017). The post-trawl survival of two elasmobranch species was found to be highly variable, ranging from 17% for male common stingarees to 87% for Eastern shovelnose rays of both sexes. Both a reduction of fishing effort and the introduction of TEDs and BRDs were cited as key contributors to an overall reduction of bycatch. Of 47 elasmobranch species assessed, one was found to be at high risk from trawling activity and six were found to be medium risk. It was suggested that steps should be taken to mitigate the risk to these species, including a decrease in the bar spacing of TEDs and that efforts are required to facilitate the post-trawl survival of elasmobranchs. Cited project recommendations are summarised in Table 7.

Prior to this project, efforts were made to improve overall bycatch reduction performance in this fishery (**FRDC Project No. 2008/101**), including reducing sea snake mortality using a fisheye, increasing the use of square-mesh codends in the scallop sector, improving the use of TEDs, and qualifying the benefits of fishers using improved BRDs (Roy & Jebreen, 2010). This project included a substantial extension program to raise industry awareness of the need and benefits of using these devices, including TED construction and use guidelines, provision of independent expert technical advice, a gear library for display purposes, port visits for face-to-face engagement, provision of devices for fishers to test voluntarily, and the involvement of a net maker to encourage industry involvement in the project. Subsequently, industry uptake of improved TEDs and square-mesh codends reportedly occurred, supported by an industry rebate scheme. The components of a successful extension program were described, including face-to-face discussions with fishers, hands-on workshops for fishers to view and handle gear, supported by technical experts to field questions and offer advice, clear guidance to fishers regarding how they can get involved, industry-generated information sharing, and a project officer with the ability to build industry trust and partnerships. The success of this program reportedly resulted in additional funding to further evaluate fisheyes and square-mesh codends in the fishery. Cited project recommendations are summarised in Table 7.

In 2005, extensive testing (**FRDC Project No. 2005/054**) of square-mesh codends in the deepwater king prawn, scallop, and black tiger prawn fisheries were completed by Courtney *et al*., (2007). This BRD was selected because much of the bycatch is small in size compared to targeted prawns and scallops. It was also known through **FRDC Project No. 2005/053** that square-mesh codends could effectively reduce the capture of sea snakes. Square-mesh codends with a 50 mm mesh size were loaned to fishers to test voluntarily. Project staff made numerous port visits to discuss and promote the use of these BRDs, they liaised closely with netmakers, and published numerous articles and a DVD to inform fishers and others about the project, including performance of the codends. Flume tank testing of the codends was also completed to evaluate potential impacts on trawl drag and fuel consumption. A survey of fishers using the codends found that almost all continued to use the codends after the initial testing period, with 90% of fishers reporting a bycatch reduction, with reductions sometimes approaching 50%. Half of the fishers involved reported no reduction in prawn

catch while 14% reported an increase. Over 80% of fishers indicated they would persist with this codend. Codend drag was reduced by less than 3%. Cited project recommendations are summarised in Table 7.

Table 7. Cited recommendations FRDC funded projects related to the Queensland East Coast Otter Trawl Fishery.

Project No.	Recommendations (specific to bycatch reduction)
2015/014	1. Efforts should be made to quantify the effect of reduced bar spacing in TEDs on elasmobranchs. 2. Fishers should facilitate further research to determine the post-trawl survival of elasmobranchs
2008/101	1. No specific recommendations were provided
2005/054	1. There is a need to review the minimum acceptable mesh size that used in the construction of square-mesh codends 2. There is also a need to investigate the application of knotless material in codend construction 3. Investigate the potential biomass increase as a result of using square-mesh codends, particularly in the shallow water king prawn fishery 4. Investigate the effect of square-mesh codends on net drag and fuel consumption
2005/053	1. Seek legislation requiring the mandatory use of selective codends such as T90 selector panels and T90 lengtheners 2. Seek legislation requiring the mandatory use the fisheye BRD no more than 50 meshes from the codend drawstring, to reduce the incidental catch and mortality of sea snakes, particularly in the redspot king prawn fishery 3. Investigate the post-capture survival of escaping fish 4. Improve accuracy of monitored interactions between trawlers and protected species, particularly reporting by fishers in the Species of Conservation Interest (SOCI) logbook
2000/170	1. No specific recommendations were provided
1996/254	1. Monitor the ongoing development of TEDs and BRDs to ensure they achieve stated goals, and document changes in bycatch composition and quantity. 2. Continue to support opportunities for fishers, researchers, and others to build relationships and exchange information and expertise. 3. Support industry interest in further trawl modification to reduce environmental impact, for example, alternative ground gear designs
1993/229	1. Further monitoring the incidence of turtle bycatch in trawl nets is required off the QLD coast 2. The impact of prawn trawling on the post-release survival of turtles should be studied

In 2005, efforts by Courtney *et al*. (2010) were made to reduce the impact of trawling on protected sea snakes (**FRDC Project No. 2005/053**). These efforts including reviewing existing data and literature on sea snake distribution and abundance, implementation of a crew-based observer data collection program, quantification of post-trawl mortality of sea snakes, and evaluation of the effectiveness of BRDs to allow sea snake escape. The project reported that over 100 000 sea snakes were caught in the fishery each year, of which 26% died as a result of capture. Almost 85% of deaths occurred in the red spot king prawn fishery. The fisheye and the square-mesh codend (50 mm mesh)

reduced sea snake catch rate by 63% and 60% respectively compared to a standard trawl (no BRD). The fisheye was recommended for use instead of the square-mesh codend, because it was expected to outperform the latter over time due to having a larger escape opening. It was also recommended that the fisheye is installed no more than 50 meshes from the drawstring. Cited project recommendations are summarised in Table 7.

Prior to this, **FRDC Project No. 2002/170** attempted to describe bycatch species composition and catch rates across much of the fishery, both with and without TEDs and BRDs installed, evaluate different combinations of TEDs and BRDs, provide advice on the guidelines and definitions of these devices to Boating and Fisheries Patrol staff, and review the biology and distribution of so-called 'permitted' fish species and quantify key population parameter estimates of these species (Courtney *et al*., 2007). Key project outcomes included improved understanding of the catch rates and composition of bycatch across the fishery, increased number of fishers using square-mesh codends in the scallop and eastern king prawn fisheries, bycatch reduced on average by 77% in the scallop fishery when a using a square-mesh codend, and greater understanding of the impacts of TEDs and BRDs on bycatch composition. It was posited that the square-mesh codends would reduce fuel consumption as a result of bycatch reduction. Cited project recommendations are summarised in Table 7.

One of the first bycatch reduction projects in this fishery and the Northern Prawn Fishery was **FRDC Project No. 1996/254**. This project sought to inform and encourage the use of TEDs and BRDs through a major outreach effort that included hands-on workshops, presentations at industry meetings, informal wharf meetings, bycatch newsletters, at-sea assistance with testing TEDs and BRDs and the Prawn Trawling Innovation and Adoption Award (Robins *et al*,, 2000). Approximately 30% of Queensland prawn fishers and 60% of fishers in the NPF engaged with the project. Seventy TEDs and 13 BRDs were lent to fishers to test voluntarily across both fisheries, and supervised field tests occurred on 36 trawlers. TED and BRD performance was recorded over 750 commercial tows. Prior to this project less than 2% of both fleets used a BRD and only two trawlers used a TED. Cited project recommendations are summarised in Table 7.

The first FRDC-funded effort (**FRDC Project No. 1993/229**) focussing on bycatch in this fishery attempted to quantify turtle-trawl interactions, determine the post-release fate of turtles, educate fishers in the treatment and release of turtles, and investigate a population monitoring method for turtles using catch and effort data (Robins & Mayer, nd). More than 90% of turtles were reported in a healthy condition when first landed onboard. Real-time tracking systems monitored the release of seven trawl-caught turtles, and an appreciable behaviour change i.e., increased number of turtles surfacing was reported. No delayed post-trawl mortalities were reported. Project staff were involved in a number of visits to fishing ports to raise fisher awareness about turtle protection measures including soon-to-be mandated use of TEDs and turtle recovery procedures. These conversations were reportedly "energetic". Cited project recommendations are summarised in Table 7.

In addition to these projects, a notable bycatch reduction effort in this fishery involved the evaluation of the AusTED. Funded by the Australian Fisheries Management Authority, the Northern Territory and Queensland Departments of Primary Industry and Fisheries, the AusTED was a flexible grid designed to exclude turtles and other large animals from the trawl (Robions-Troeger *et al*., 1995). The flexible grid design was a response to industry concerns that rigid grids pose a risk of injury to crew. Turtles and large stingrays were excluded from the AusTED but prawn loss and there was no significant loss of prawns at any testing site. Commercial fishermen testing this TED reported prawn losses of up to 50%, and it was reported that this was likely due in part to skipper inexperience using the device.

Survey results

A total of 7 respondents completed the survey, three researchers, three industry members, and a fishery manager. All had been closely involved in at least one FRDC-funded project and most had good knowledge of the remaining projects. Few respondents commented specifically about **FRDC Project Nos. 1993/229**, **1996/254**, and **2000/174**, given they were completed many years ago and substantial developments had been accomplished by more recent projects.

Following-up on FRDC project recommendations

Several respondents indicated a substantial body of work had been attempted by fishers, net makers and others to refine BRDs performance and handling and develop more selective trawl designs. Technical specifications and regulations for TEDs and BRDs were also developed and introduced, most recently fisheyes and square-mesh codends in the red spot king prawn fishery, and square-mesh codends in the scallop sector, which apparently reduced the amount of bycatch by approximately 77%, an estimated several thousand tonnes annually. According to one respondent square-mesh codends have also shown strong potential in the deepwater eastern king prawn sector, but as no attempt was made to mandate and regulate these devices fishers are using less effective BRDs.

Several other respondents suggested there had been very limited follow-up activity, although one respondent noted that some netmakers are continuing to develop nets, codends, and BRDs to reduce bycatch, although their performance is not well documented or verified. This respondent also noted that a few fishers have been trialling the Kon's fisheye and T90 codends recently in lieu of square-mesh netting. Another noted that knotless square-mesh netting known as Ultracross had been keenly pursued by industry but that this material was ultimately deemed cost prohibitive, and that some fishers are avoiding areas of high bycatch density using automatic try gear, which permit a regular and relatively hassle-free way to identify areas of high bycatch as well as prawn hot-spots.

Drivers and motivators for bycatch reduction regulation

Some respondents noted that a driver for mandating TEDs and BRDs was pressure by GBRMPA, conservationists, managers and researchers to reduce bycatch, particularly sea turtles, with pressure being applied to adopt TEDs a response to pressure from the United States. One respondent noted that regulation was necessary because the desired bycatch reduction could not have been achieved any other way. Drivers for square-mesh and TED regulation in the scallop sector was similar, but also included pressure on managers to respond after peer-reviewed evidence demonstrated this combination reduced bycatch by 77% without loss of legal-sized scallops. It was however also noted that this process took over a decade to implement.

Several respondents suggested that most fishing companies, vessel owners, and skippers resisted the introduction of TEDs and BRDs because they feared catch loss and potential economic and operational impacts on their fishing operation, particularly as they spend time sewing holes closed rather than cutting them in to the net. They also noted that many fishers struggled to believe the results of BRD testing and resented the government and others telling them what to do with their nets, although in contrast, one respondent claimed that many fishers offered to trial fisheyes in different positions in the codend but were discouraged by fishery management. Another noted that justification for change could have been more robust, to raise awareness of the need for change.

Impediments and bottlenecks to voluntary or non-FRDC funded attempts to reduce bycatch

One respondent indicated there were no impediments to fishers further reducing bycatch on a voluntary basis given that a protocol instituted by Fisheries Queensland allows fishers to test new BRD designs. Another noted that a few fishers will modify or try a new BRD if suggested by their net maker, while another mentioned that changes in grid shape had been made to reduce clogging of the grid and so the escape cover sits more firmly over the escape opening. In contrast, several respondents claimed a reason for limited follow up activity was that many fishers were unaware of project outcomes and recommendations, with one noting that Fisheries Queensland tightly controls information shared with fishers, even that from FRDC funded projects, possibly due to fear of information misuse on social media. Two respondents indicated that fishers were aware of project recommendations but they generally wait for devices to be mandated before using them. Another noted that a 50% rebate to fishers to offset the cost of TEDs and square-mesh codends was an important development that facilitated uptake, although they also noted that fishers became increasingly jaded by ongoing and costly changes to TED regulations.

There are numerous other reasons why fishers are apparently reluctant to change but it seems that most important are concerns that further bycatch reduction efforts will be costly or painful, perceived loss of control over their fishing operation or business, uncertainty about how they might be affected and perceived lack of opportunity, benefit, or reward (Table 8). Supporting these results, several respondents noted that a bottleneck holding up voluntary attempts by fishers to further reduce bycatch is lack of motivation and inducement, particularly when catch loss is not an uncommon outcome. They noted the absence of bycatch reduction targets at the individual or fleet level, the absence of financial incentives or otherwise for fishers to engaged in this issue, and the absence of sustained pressure by any stakeholder group including the Queensland government on fishers to further reduce bycatch. Elaborating further, one respondent claimed that policing and enforcement was weak, in part because patrol officers are unable to confidently identify ineffective BRDs. Prosecution rates are also poor due to inadequate regulation, with specifications sometimes watered down and less effective than that tested by researchers, and the judicial system is unfamiliar with the subject matter. Collectively this makes further efforts to reduce bycatch an almost futile exercise, unless tackling these issues is a focus of any future effort.

One respondent noted that very few fishers use the fisheye BRD despite the Queensland Government spending several hundred thousand dollars purchasing multiple fisheyes for all fishers. This respondent also noted there have been no effective regulatory changes to capture the benefits of these devices in reducing sea snake capture, that encouraging voluntary attempts to reduce bycatch by fishers does not work, and that changes need to be mandated and enforced. Other respondents reiterated that fear of catch loss influences interest in voluntary testing by fishers, and that new BRDs must not make it harder to operate or handle the trawl. The pace of change was also strongly influenced by the personalities of key players in the fishery and management.

Several respondents indicated that fleet size would have had no impact on the success of past bycatch reduction efforts, while others were either uncertain if fleet size mattered or they felt that successful extension programs and fleet buy in of research findings was more difficult as fleet size increased. One respondent claimed that company operators are less concerned with bycatch issues than owner operators, while another claimed that company boats are more responsive to change, citing that most BRD innovation in the fishery has come from company operators. Others similarly indicated that companies are more likely to accommodate and facilitate change.

One respondent felt that fishers never embrace and accept voluntary change in their fishery, three felt they rarely embrace and accept voluntary change in their fishery, two indicated that sometimes they did, and one indicated they readily did.

Table 8. Perceived reasons why fishers are reluctant to further reduce bycatch for each fishery, by weighted average. Score and ranking: 1.0 - Very important, 2.0 - Important, and 3.0 - Not important. No. of respondents = 4.

Statement	**Wt. avg**
Concerns that further bycatch reduction efforts will be costly or painful	1.25
Perceived loss of control over their fishing operation or business as a result of additional bycatch reduction efforts	1.33
Uncertainty about how they might be affected by additional bycatch reduction efforts	1.50
Perceived lack of opportunity, benefit, or reward from further bycatch reduction efforts	1.50
Fundamental, pathological, or ideological resistance to additional bycatch reduction efforts	1.75
Perceived lack of incentives to offset any catch loss from additional bycatch reduction efforts	1.75
Concerns that pressure to further bycatch will never end	1.75
Mistrust of individuals responsible for promoting a need to further reduce bycatch, including their motives	1.75
Perception that bycatch reduction using their current trawl gear is sufficient/adequate	1.75
Perceived lack of understanding of the need/reason for additional bycatch reduction efforts	2.00
Disinterest or apathy regarding additional bycatch reduction efforts	2.00
Perceived lack of consultation regarding a need for additional bycatch reduction efforts	2.25
Perception there is insufficient time to become adjusted to the idea of additional bycatch reduction efforts	2.50
Concerns they will appear incompetent in the face of additional bycatch reduction efforts	2.50
Concerns that past efforts to reduce bycatch will be ignored or dishonored	2.75
Perceived concerns that further bycatch reduction efforts will unevenly affect other fishers in the fishery	3.00

What worked, should have been done differently, and should be done in the future

Key lessons from bycatch reduction efforts according to respondents includes working with key fishers to help with the testing and introduction of new devices, early engagement with netmakers, gear libraries that loan gear to fishers to test, and knowledgeable technicians to provide support services.

Overcoming bottlenecks, according to one respondent, required quantification of the seriousness of the bycatch issue, scientifically robust testing of a BRD that demonstrates significant improvement is

possible, and pressuring the government to mandate and regulate the improved device. Several others noted that better communication with fishers, through port visits and other means, would have gone a long way to inform fishers and encourage follow-up activity on cited recommendations. One respondent suggested that serious efforts should be made to explore the potential utilisation of some bycatch species, particularly given that bycatch is so diverse, variable over time and space, and removing a significant proportion is so problematic. Another respondent noted that additional extension work was required beyond that that was delivered during the period of project funding, while another commented that bycatch reduction efforts have and continue to be a low a fisheries management priority, both in Queensland and the rest of Australia. This respondent claimed that bycatch reduction rates could be substantially lowered but there is currently little political will or interest in achieving this outcome. The protection of sea snakes was a cited example, with only limited interest in minimising trawl capture because they not have the charismatic profile or public appeal of other protected species such as sea turtles. Next steps include demonstrating the seriousness of the bycatch issue, proving that significant bycatch reduction is possible, and leveraging the support of GBRMPA, conservation agencies, and the public to pressure the government into responding appropriately and introducing regulations to address bycatch issues.

The support of FRDC was gratefully acknowledged by several respondents, although it was noted that the successful implementation of research outcomes is ultimately driven largely by fisheries management who are often influenced by personalities and politically. Three respondents did not think the FRDC should have done anything differently given they supported projects when needed, one noted that funding extension work was a positive outcome, while another claimed this work was inadequate and that better communication was required. Another respondent suggested that FRDC could have pushed harder and demanded that project findings were implemented, including promotion of the need for ongoing efforts to reduce bycatch.

Several respondents indicated the FRDC needs to fund future bycatch reduction efforts in priority areas, while another noted there is not much the FRDC should do in the future but noted that fishers and others should attempt to determine the optimum bar spacing in TEDs to exclude elasmobranchs from the trawl. One respondent noted that industry forums designed to advance best practice, that allow fishers an opportunity to learn and discuss latest developments in bycatch reduction, similar to the recent LIFE workshops (**FRDC project No. 2017/065**), are desperately needed across the fishery. Another suggested that in the future any new BRDs or changes must be tested across a wide area of the fishery, to evaluate efficacy with different species composition, and that ten-minute tows are inadequate to evaluate BRD performance. A suggested priority area was evaluation of benthic flora and fauna in the deep-water king prawn fishery. One respondent suggested that steps must be taken to mandate effective BRD solutions for sea snakes, that relevant research has been completed and it is now up to the Queensland government to take the next step, while another suggested that greater steps are required to facilitate the testing and development of industry innovations.

One respondent suggested fishers and others need to do a better job communicating their ideas for improvements so they can be tested and developed, while another suggested that FRDC and others need to do a better job educating the public about changes that have been made, including impact on fishers. The public apparently has little idea what fishers have given up in the past, including the economic impact of using TEDs and BRDs and what they go through on a daily basis. Promotion of the fishing industry and progress in bycatch reduction is important to build public trust.

Northern Prawn Trawl Fishery

The Northern Prawn Fishery targets Tiger prawn (*Penaeus esculentus* and *P. semisulcatus*), Endeavour prawn (*Metapenaeus endeavouri* and *M. ensis*), and Banana prawn (*Fenneropenaeus merguiensis* and *P. indicus*). The fishery is divided into two seasons; between April and June the fishery mainly targets banana prawns and between August and November the fishery mainly targets tiger prawns. Byproduct species include bugs, scallops, and squid (AFMA, 2014).

Fishers can tow two or more nets simultaneously but must hold the appropriate gear statutory fishing rights (AFMA, 2020). They are also required to use TEDs and BRDs on each net. Until recently, seven BRDs were approved for use in this fishery including square-mesh codend, square-mesh panel, radial escape section, fisheye, Yarrow fisheye, Popeye fishbox, and modified TED (AFMA, 2014), although since 2020 all fishers have been required to use either a Tom's fisheye, Kon's covered fisheye, FishEX70, or the Popeye fishbox (AFMA, 2020). The weight of discards is approximately 80% of total catch weight in the tiger prawn fishery and approximately 58% of total catch weight in the banana prawn fishery (Kennelly, 2018). The NPF is currently certified as sustainable by the Marine Stewardship Council.

Bycatch reduction efforts and cited project recommendations

FRDC funded efforts to address bycatch in this fishery were associated with FRDC Project Nos **2016/058**, **2005/051**, **2000/173**, **1996/254**, and **1993/179**.

Like most other prawn fisheries in Australia, a long history of bycatch reduction research has resulted in a range of bycatch reduction devices being available for use by fishers. The most recent research (**FRDC Project No. 2016/058**) attempted to evaluate the potential of electric fields to reduce sawfish bycatch. This project subjected two sawfish held in tanks to a range of electrical fields that varied by polarity, voltage, frequency, pulse shape and duration (Abrantes *et al*., 2020). While each sawfish sensed and reacted to each electrical field, their response was typically within 1.2 m of the electrodes, a distance considered too close to be considered for application in trawl fishing. The response of each sawfish was inconsistent to the electrical stimuli. It was suggested that other potential mitigation measures should be considered until advances in technology permit cost-effective propagation of electrical fields that can elicit an escape response at greater distances. Cited project recommendations are summarised in Table 9.

Previous to this project, Milton *et al*. (2008) attempted to assess temporal and spatial trends in sea snake catch rates in this fishery, develop semi-quantitative sea snake population models, and assess the performance of various management options and mitigation measures to reduce rates of sea snake capture (**FRDC Project No. 2005/051**). A fisheye located 66 meshes from the codend drawstring was found to reduce sea snake bycatch by at least 43%, and the Popeye fishbox located 70 meshes from the drawstring reduced sea snake catch bycatch by 85%. This is closer to the codend that the maximium legally required distance of 120 meshes (where most fishers locate their BRDS); at this distance there were no detectable reductions in sea snake catch. There was no significant prawn loss when the devices were located closer to the codend, and fish bycatch was reduced by 17% compared to nets with the BRDs in the usual location. Subsequently, a few fishers voluntarily moved their brds closer to the codend. This project also engaged in a significant outreach program that including presentation at pre-season workshops in Cairns, Karumba, and Darwin, attendance and presentations at various meetings including NPFAG, and various articles and papers. It also included development of an industry fact sheet highlighting effective BRD designs and their performance. Cited project recommendations are summarised in Table 9.

Table 9. Cited recommendations FRDC funded projects related to the Northern Prawn Fishery.

Project No.	Recommendations (specific bycatch reduction)
2016/058	3. Revisit the use of electrical fields when technology allows for propagation of electrical fields to elicit a sawfish escape response at greater distances 4. Develop other sawfish mitigation measures in the interim 5. Develop a greater understanding of the spatial-temporal overlap between sawfish distribution and the fishery
2005/051	2. Further study of the trade-off between reducing BRD distance from codend drawstrings and expected increases in prawn loss in these situations. 3. Test BRDs during the banana prawn season 4. Test BRDs relocated to 70 meshes from the codend drawstring when fishing for tiger prawns 5. Improve BRD design to improve sea snake exclusion rates
2000/173	1. Disseminate project results to major stakeholders 2. Improve and promote BRD performance to fishers and other stakeholders 3. Investigate methods to improve the exclusion of sawfish and sea snakes 4. Reconsider the use of BRDs in the banana prawn season 5. Development of a cost-effective grid blockage detection device 6. Improve knowledge of bycatch species behaviour to a trawl
1996/254	1. Introduce monitoring capability to ensure TEDs and BRDs are achieving intended goals. 2. Continue to engage closely with industry, as this helps establish and maintain relationships, and contribute positively to fishery development 3. This project found some interest in ground gear modification to reduce habitat impact.
1993/179	1. Further refine TED and BRD performance 2. Investigate and collect information on bycatch survival to more fully assess the effectiveness of BRDs 3. Investigate the economic costs and benefits of using TEDs and BRDs 4. Provide training in the use of TEDs and BRDs 5. Investigate the possibility of manufacturing BRDs in Australia 6. Consider detailed studies of prawn and fish behaviour in response to trawl stimuli

Efforts to evaluate and improve the performance of TEDs and BRDs in this fishery (**FRDC Project No. 2000/173**) were reported by Brewer *et al*. (2004). This project attempted to optimise TED and BRD performance, document changes in bycatch reduction performance using these devices, in particular charasmatic and vulnerable species, prawns and byproduct, assess the economic impacts of these devices, identify factors that affect their performance, and establish a protocol for their ongoing development and testing. This project included a significant outreach program that included a gear technologists working at sea helping fishers use TEDs and BRDs, numerous industry articles describing how to optimise performance, and information transfer at industry workshops. Overall this project was a substantial boost to the development of effective TEDs and BRDs in the fishery, although it was noted that few attemtps were being made by industry to improve BRD performance. At the time most fishers were focusing on improving TED performance to reduce prawn loss, rather than reducing catches of fish and other bycatch species, and consequently there was little interest in improving BRD performance. A commonly cited industry concern was a lack of opportunity to evaluate BRD performance against a control net with no BRD fitted, as well as concerns over grid blockage in TEDs. As part of this project a three-phase TED and BRD testing protocol was developed that included initial assessment of a written proposal for a new TED or BRD , a visual assessment of

the device in the AMC flume tank, and at-sea testing and assessment of the device. Cited project recommendations are summarised in Table 9.

In preparation for impending TED and BRD regulation, efforts were made to inform and consult with fishers in the NPF and Queensland East Coast Otter Trawl Fishery about ways and means to reduce bycatch (Robins *et al*., 2000). This project (**FRDC Project No. 1996/254**) embarked on a substantial bycatch technology extension program that included bycatch workshops for fishers, newsletters, videos, booklets and information sheets, a gear library for testing devices, and field tests accompanied by experienced gear technologists. It also included a prawn trawling innovation and adoption award to recognise the efforts by fishers to reduce bycatch, a survey of TED and BRD use, and testing of a multi-level beam trawl to evaluate the height of prawns and bycatch ahead of a trawl and their vertical escape responses. Over 30% of fishers in Queensland and 60% in the NPF engaged in this program. Over 400 individuals attended the workshops, 70 TEDs and 13 BRDs were lent to fishers for trial, and supervised field tests of TEDs and BRDs occurred on 36 boats, over 375 days and 750 trawl shots. Almost no fishers were using or had tested a TED or BRD prior to this project. Cited project recommendations are summarised in Table 9.

The first FRDC funded bycatch reduction project (**FRDC Project No. 1993/179**) in the NPF attempted to develop and test a range of TEDs and BRDs, investigate the damage and survival of escaped bycatch, describe the response of prawns and fish to trawl stimuli, and promote project results to industry. A total of 17 different TEDs and BRDS, or combinations of TEDs and BRDs were tested over three research cruises. This project provided an opportunity to gain experience in how different rigging and operational considerations influence TED and BRD performance. Industry outreach was substantial, with project results presented at multiple industry workshops, including one held onboard the research vessel, publications in industry literature, and various presentations. This project spawned two new projects, **FRDC Project No 1996/257**, Ecological Sustainability of Bycatch and Biodiversity in Prawn Trawl Fisheries and **FRDC Project No. 1996/254**, Commercialisation of Strategies and Devices to Reduce Bycatch in Northern Australian Prawn Trawl Fisheries. Cited project recommendations are summarised in Table 9.

A thorough list of bycatch reduction research projects in this fishery, including those not funded by the FRDC, is available in AFMA (2014).

Survey results

A total of 7 respondents completed the survey, two researchers, four industry members, and a fishery manager. All had been closely involved in at least one FRDC-funded project and most had some knowledge of the remaining projects. Few respondents commented specifically about **FRDC Project Nos. 1993/179**, **1996/254**, and **2000/173**, given they were completed so long ago, although there was tacit acknowledgment by some respondents that related project recommendations had influenced later research.

Following-up on FRDC project recommendations

Some respondents indicated there has already been progress following up on project recommendations to **FRDC Project No. 2016/058**. One respondent indicated that NPRAG had considered the results of this project and that alternative options were required. Funding through the Our Marine Parks Grant program is investigating the effect of TED and net configuration on sawfish entanglement and escapement using crew member photos and videos. Charles Darwin University is investigating the population dynamics of the narrow sawfish, and a proposal submitted to the FRDC will conduct a close kin mark recapture analysis of this species.

The main motivator for these discussions according to several respondents is that three species of sawfish are listed as vulnerable under the EPBC Act 1999 and that continued interaction with these species poses a threat to ongoing export approval of the fishery. While the Marine Stewardship Council placed no condition on the fishery to mitigate the impact of these species, there is concern that this may change in the future when the fishery seeks reassessment. Notably, several respondents were unaware of these developments, based on their responses that suggested only informal discussions between industry and others had been made regarding methods to prevent sawfish entanglements.

Respondents indicated there has been progress following up on project recommendations to **FRDC Project No. 2005/051**. It was noted that a primary motivator for this activity was an NPFI-led goal of reducing fish bycatch in the fishery by 30%. This ultimately resulted in several new fisheye BRDs being developed, the FishEX70, Tom's Fisheye and Kon's Covered Fisheye. A financial prize was offered to individuals that developed a success BRD, although this does not appear to have been a primary motivator. Achievement of this bycatch target also resulted in relocation of the BRDs closer to the codend drawstrings. The Tom's Fisheye is now used almost exclusively by the fleet during the tiger prawn season, located 60 meshes from the codend drawstrings, while during the banana prawn season the Yarrow Fisheye or Square-mesh panel is required. These developments are underpinned by a recently developed code of conduct pertaining to the use of these BRDs when tiger prawn fishing during the banana prawn season. Two respondents noted that since the introduction of BRD regulations in 2000, notable changes in BRD design or operation have only been made by fishers in the last few years, although tinkering and finessing of these devices has been ongoing to improve efficiency and durability.

Drivers and motivators for bycatch reduction regulation

The introduction of bycatch reduction regulations in the fishery was apparently driven primarily by AFMA, environmental groups, and others amid growing concerns for the impact of fishery activity on threatened and endangered sea turtles and other bycatch species. A desire to maintain access to markets in the United States was by considered a positive outcome from the introduction of regulations, however, attitudes by many fishing companies, boat owners, and skippers to these regulations was not positive and characterised by uncertainty at the time, because using these devices was new, concerns for catch loss associated with bycatch reduction, concerns of injury to crew due to TEDs, and pressure from various environmental and other groups to reduce bycatch. One respondent indicated these concerns were underpinned by ignorance and dismissal of research findings indicating only minor economic impact as a result of TEDs and BRDs, while another indicated fishers were not in favour of something different until they saw it proven and beneficial, although noting that attitude began to change following the introduction of regulations. Another commented that many skippers are contractors working for fishing companies, not employees, and there is no recompense for catch loss to their crew or themselves.

It was also noted that once fishers began using regulated BRDs, many thought they had done enough and there was little momentum or motivation to improve bycatch reduction performance. Recent changes to BRD regulations i.e., the use of fisheyes and their location closer to the codend drawstrings, was deemed primarily to have been associated with efforts by NPFI to introduce and act on an industry-driven bycatch reduction strategy. One respondent noted these changes were accompanied by a high level of support across the industry, although some smaller operators were not actively engaged in this initiative, possibly due to concerns over impacts on their efficiency.

Impediments and bottlenecks to voluntary or non-FRDC funded attempts to reduce bycatch

Most respondents indicated there had been little or no voluntary or non-FRDC funded attempts to further reduce bycatch of marine mammals, sharks, sawfish, or seahorses in the fishery. With respect to large shark bycatch this was deemed in part to be due to the success of TEDs and subsequent lack of need to change TED design, although one respondent noted that modification to TED escape covers had been made in an attempt to reduce sawfish capture. Some attempt had been made by NPFI to reduce sea snake capture and mortality using the Tom's fisheye, and the aforementioned improvements in fisheyes to reduce fish bycatch, while another suggested that tinkering of BRDs by fishers has, in a general sense, contributed and led to the success of bycatch reduction efforts overall. One respondent noted anecdotal evidence that fishing a 'line' during the tiger prawn season has reduced bycatch due to the dispersal of bycatch species. Funding for much of this work was apparently provided by AFMA or through Marine Park funding.

Two respondents indicated there are no impediments or bottle necks to fishers further reducing bycatch, that they can do so if they desire but chose not to, while another noted they can seek a permit to voluntarily test a BRD during the fishing season if it meant replacing a regulated BRD. It was also noted that fishers could do almost as they wished to reduce bycatch, without need for a permit, providing regulated BRDs were also installed. Another noted that interest by fishers to improve BRD performance was tempered by an ability to test the device only during the fishing seasons, when they are primarily focused on making money. It was noted that until recently there had been no motivators to encourage fishers to improve bycatch reduction performance, underpinned by lack of clear objectives or repercussions for not seeking improvement. The recent motivator was NPFI leading efforts to set a bycatch reduction of 30% compared to contemporary catches

Perceived reasons why fishers are reluctant to reduce bycatch in this fishery are indicated in Table 10. Respondents deemed the most important reasons being that fishers are disinterested in further efforts, they perceive that recent bycatch reduction efforts using current gear are adequate, they are concerned that pressure to reduce bycatch will never end, that future efforts will be costly or painful in an operational sense, and there are insufficient incentives to offset any catch loss. Several respondents that motivators, conditions, or circumstances important to facilitate change by fishers included a desire to maintain 'world leader' status and potential impacts associated with MSC certification, although one respondent indicated that over all there was little motivation for fishers to change and further reduce bycatch. Another respondent suggested that moving forward was important to maintain their sustainable reputation and social licence.

Improved and ongoing communication and education was a widely suggested step to overcoming reluctance by fishers to further reduce bycatch. Many fishers have little knowledge of past bycatch reduction efforts, which otherwise could result in duplication of efforts. AFMA and others need to provide a clear vision and objectives, including what is expected from fishers, they need to be reminded they are custodians of a public resource, and the benefits of being proactive, not waiting until MSC or others force greater effort. It was also suggested that NPFI leading such efforts, with support from much of the industry, was preferred compared to CSIRO or other research organisation, that fishers must be involved in such efforts from the beginning, and there are an increasing number of fishers that really want to do their bit and reduce bycatch. Another indicated there is a need for greater investment in trialling new approaches, that incentivises experimentation by fishers, underpinned by greater repercussions for failing to overcome impacts on TEP species as required by the EPBC Act 1999.

Table 10. Perceived reasons why fishers are reluctant to further reduce bycatch for each fishery, by weighted average. Score and ranking: 1.0 - Very important, 2.0 - Important, and 3.0 - Not important. Number of respondents = 6.

Statement	**Wt. avg**
Disinterest or apathy regarding additional bycatch reduction efforts	1.17
Perception that bycatch reduction using their current trawl gear is sufficient/adequate	1.33
Concerns that pressure to further bycatch will never end	1.33
Concerns that further bycatch reduction efforts will be costly or painful	1.33
Perceived lack of incentives to offset any catch loss from additional bycatch reduction efforts	1.67
Uncertainty about how they might be affected by additional bycatch reduction efforts	1.83
Perceived lack of opportunity, benefit, or reward from further bycatch reduction efforts	1.83
Perceived loss of control over their fishing operation or business as a result of additional bycatch reduction efforts	2.00
Fundamental, pathological, or ideological resistance to additional bycatch reduction efforts	2.17
Concerns that past efforts to reduce bycatch will be ignored or dishonored	2.33
Perceived lack of understanding of the need/reason for additional bycatch reduction efforts	2.50
Mistrust of individuals responsible for promoting a need to further reduce bycatch, including their motives	2.50
Perception there is insufficient time to become adjusted to the idea of additional bycatch reduction efforts	2.67
Concerns they will appear incompetent in the face of additional bycatch reduction efforts	2.67
Perceived lack of consultation regarding a need for additional bycatch reduction efforts	2.83
Perceived concerns that further bycatch reduction efforts will unevenly affect other fishers in the fishery	3.00

No respondents felt that a substantial difference in fleet size would have impacted the outcomes of bycatch reduction research in this fishery - that the legislated requirement to implement TEDs and BRDs would have been introduced irrespective of fleet size, and two respondents commented on the challenges of working with owner-operators compared with companies given the former are often not as well-resourced and cannot share costs over multiple vessels. Another responded that industry cohesion and support for the most recent bycatch reduction efforts would have been more difficult with a larger fleet size. One respondent felt that fishers rarely embrace and accept voluntary change in their fishery, three felt they occasionally embrace and accept voluntary change in their fishery, and three indicated they sometimes accept voluntary change in their fishery.

What worked, should have been done differently, and should be done in the future

One respondent indicated that nothing should be changed if bycatch reduction efforts were repeated in this fishery, that success was ultimately driven by industry and that change takes time.

Several responded similarly and suggested that industry must be involved from the beginning, while another indicated that the system to encourage industry development should be changed, that the time for a fisher to test a device, get a good result, take it to industry, and get a scientist onboard takes too long, typically a year or more. Another suggested there should have been greater focus on small fish bycatch, sea snakes, and sawfish, with clear drivers for doing so articulated, while another indicated that sawfish mitigation efforts should have commenced earlier, and that industry has been less proactive in tackling this issue than it should have been.

Limited specific feedback was provided regarding what FRDC got right with respect to bycatch reduction in this fishery, with respondents mainly commenting on what should have been done differently and should be done in the future. One respondent did however indicate that the typical three-year funded period for FRDC projects was advantageous as it provided a good amount of time to get the job done, while noting that several other funding sources would not fund projects for this duration.

Suggestions regarding what FRDC should have done differently included a stronger push for researchers to share their results with stakeholders and that FRDC should not have reduced their focus on bycatch reduction in this fishery following the projects in the early 2000's, particularly a focus on small fish bycatch and threatened species. It also included mention that there was seemingly little momentum to communicate project results beyond that initially made during the period of funding, and that an industry champion dedicated to communicating project developments from start to finish and beyond would be a useful consideration.

It was recommended that in the future the FRDC should investigate and monitor project recommendations, host a forum to discuss such recommendations with project teams, fishery managers, and industry to discuss and evaluate their cost-benefits, and be more proactively involved in facilitating discussions around what's next. Steps also need to be taken to explore how best to subsidise catch loss when testing new devices, rather than fishers wearing the cost themselves, and to provide targeted funding when costs are deemed high. It was suggested that fishers and others need to be more open to the non-economic benefits of continuous improvement in TEDs and BRDs.

There was strong ongoing support for industry involvement in any future efforts, to bring perspective, validity, and leverage their in-kind capacity and knowledge. It was also suggested that an industry champion, to share past results, support future bycatch reduction efforts, and to make sure industry is aware of any related research and results, would be a useful consideration in the future.

National Projects

Three FRDC projects involved hosting multiple workshops in various prawn fishing ports around the country. The workshops were designed to share information and describe the latest developments in bycatch reduction.

FRDC project No. 2017/065 involved a series of port workshops around the country to i) provide fishers updated information on bycatch reduction research, habitat reduction options, and fuel efficiency options in Australia and overseas, ii) identify bycatch reduction options that might be suitable for each prawn trawl fishery around the country, and iii) identify any technological, administrative, or other gaps that may be hindering bycatch reduction efforts (Kennelly, 2019). Subsequently, the focus of this project was all prawn fisheries around the country, not just in NSW alone. The workshops identified a number of issues and recommendations relevant to most prawn fisheries around the country (Table 11), although little evidence was found that any had been

followed-up with, most likely because this project concluded only a few years ago. A number of fishery-specific issues and recommendations were also identified, which are described in the final project report (see Kennelly, 2019).

FRDC Project No. 2016/057, which hosted a national gathering of commercial prawn fishers and others to identify future research needs to reduce bycatch and improve fuel efficiency, subsequently resulting in so-called low impact fuel efficient (LIFE) prawn trawls. The workshop involved presentations and discussions around bycatch reduction and attendees agreed that a next-step was a road show to key fishing ports to present latest developments in bycatch reduction to fishers and identify their needs with respect to bycatch reduction and fuel efficiency. The intention was that this would renew and galvanise interest by fishers in testing bycatch reduction devices and other low impact gear options. Recommendations from this project are presented in Table 11.

A decade prior, the FRDC funded a workshop to investigate options to improve bycatch reduction in tropical prawn trawl fisheries (**FRDC Project No. 2006/308**). This workshop attempted to increase knowledge of latest developments in bycatch reduction, assess a suite of innovative bycatch reduction options and their potential application in these fisheries, engage fishers in the uptake of suitable BRDs, and engage fishers in the development of a coordinated BRD R & D plan (Rawlinson & Eayrs, 2009). A two-day workshop was held in Cairns and was attended by 58 people, including fishers, fleet managers, researchers, and presenters from overseas. This was followed by a workshop for NPF fishers in Darwin. Workshop recommendations are also presented in Table 11.

Table 11. Recommendations for all prawn trawl fisheries.

Project No.	Recommendations (specific to bycatch reduction)
2017/065	1. Fishers unfamiliar with bycatch reduction (and habitat reduction and fuel efficiency) options should liaise with fishers and others who attended the project workshops, and/or review project presentations and literature 2. Management authorities should streamline the process for testing alternative gear designs 3. Researchers should consider the issues and potential solutions (Table A1) when developing relevant projects 4. Researchers should consider the following when considering projects with a broader focus a. A system that trains fishers and provides them access in the use of FRDC's portable acoustic net measurement sensors and load cells b. The utility of LED lights, electromagnetic stimuli, and other anterior modifications to reduce bycatch, including sawfish c. Test recently developed Kon's, Tom's, of FishEX 70 fisheyes to reduce small fish d. Check knot orientation and its impact on bycatch and fuel consumption e. The development of low angle of attack otter boards f. Use oval/round TEDs instead of rectangular TEDs g. Consider soft brush ground gear to reduce benthic impact and drag 5. That funding agencies require future funding applications to consider the concepts listed above. 6. That at-sea extension work with the assistance of gear technologists is preferable to workshops in the future
2016/057	1. ACPF, ICIC and FRDC should collaborate to organise a "travelling roadshow" to reach as many prawn fisheries and fishers as possible around Australia 2. The roadshow should explain the various options available to reduce bycatch and improve fuel efficiency in trawl gear

	3. The roadshow should include the expertise of one or more of Australia's fishing gear technologists 4. In each fishery, efforts should be encouraged to select, trial and modify options in the fishing gear toolbox, subsequent to the roadshow 5. These trials should involve proper scientific oversight, design, analysis and reporting, with funding provided by the fisheries themselves or representative bodies 6. The approval processes to facilitate such work should be streamlined to assist the trialling this gear 7. Fisheries management agencies and scientists from other fields (stock assessment, etc.) should be briefed about this roadshow and its tools 8. Overseas developments in this field should be monitored—particularly the work occurring in Europe—to identify additional tool that could be added to the Toolbox.
2006/308	1. Provide opportunities for rigorous testing of current BRDs in more effective positions in the trawl 2. Additional testing of the Popeye fishbox incorporating modifications to improve the flow-field around the escape opening, including testing in the AMC flume tank 3. Trial the BRD enhancer, that creates a low-flow area around the escape opening of the fisheye and square-mesh panel 4. Evaluate the use of a black plastic tunnel behind the square-mesh panel to stimulate fish escape 5. Evaluate the use of T90 netting 6. Improve understanding of the behaviour of key bycatch species to acoustic signals 7. Where possible/feasible, convert bycatch into byproduct 8. Include industry knowledge in bycatch reduction research 9. Trial new BRDs out of seasons with options for keeping the catch 10. List interested fishers and companies willing to trial innovative options 11. Encourage greater industry participation in future workshops

Following-up on FRDC project recommendations

Few respondents specifically referred to these projects, although several noted their importance in informing and keeping fishers abreast of developments in bycatch reduction. They also noted the importance of outreach activity, and that industry workshops are a core component.

Notable, many recommendations from **FRDC Project No. 2006/308** were followed up, as evidenced by subsequent bycatch reduction efforts in the NPF and QECTF. Opportunities for further testing of BRDs occurred, both at sea and in the flume tank, and efforts with the BRD enhancer continued and contributed to the development of the FishEX 70, Tom's and Kon's fisheyes, both of which included industry knowledge in their development because they were developed by industry. Opportunities to test BRDs in other locations has also been available to fishers for many years. Notably, it seems that little attempt has been made to understand the behaviour of bycatch species to acoustic signals, or to convert bycatch into byproduct.

FRDC Project No. 2016/057 was an attempt to share knowledge of latest developments in bycatch reduction and fuel efficiency with industry from around the country. A core recommendation was a travelling roadshow to reach as many prawn fisheries and fishers as possible around the country, and this recommendation resulted in **FRDC Project No. 2017/065**. There has been little follow-up activity since the conclusion of this project, primarily because it concluded only recently.

Reluctance to reduce bycatch

According to respondents, fishers are most concerned that further bycatch reduction efforts will be costly or painful, e.g., difficult to handle and maintain (Table 12). Respondents across all four fisheries consistently ranked this the most or one of the most important reasons why fishers are reluctant to voluntarily reduce bycatch. Other very important reasons include concerns that pressure to reduce bycatch will never end, perceived lack of incentives to offset any catch loss, and perceived lack of opportunity, benefit, or reward from further reducing bycatch. Least important reasons for the reluctance of fishers to voluntarily reduce bycatch include concerns that fishers will be unevenly affected, that they will appear incompetent, and that there is insufficient time to become adjusted to the idea of additional bycatch reduction efforts. Respondents across all four fisheries consistently ranked these reasons the most or one of the most least important reasons why fishers are reluctant to voluntarily reduce bycatch.

Readiness to voluntarily reduce bycatch

Respondents were asked to score multiple statements regarding the readiness of fishers to further reduce bycatch on a voluntary basis (Table 13). The Northern Prawn Fishery (NPF) scored higher than remaining fisheries across all six categories, while the Commonwealth Trawl Sector (CTS) scored lowest, in part due to low sample size.

According to respondents, all fishers in the CTS have what it takes to modify their fishing gear to reduce bycatch (efficacy) and their affection for being a fisher will not diminish as a result of any bycatch reduction efforts (affection). However, apparently not all fishers agree there is a need to reduce bycatch (discrepancy), accept that reducing bycatch is appropriate (appropriateness) or there is intrinsic benefit from doing so (valence), and recognise that they have support from authorities, peers, and public to reduce bycatch (principal support).

Based on respondent scores all fishers in the NSW Oceanic and Estuarine Prawn Trawl Fisheries (NSWPTF) agree that a need to reduce bycatch exists (discrepancy), that there is intrinsic benefit from doing so (valence), that they have what it takes to make it happen (efficacy), and that their affection for being a fisher will not diminish as a result of efforts to reduce bycatch (affection). However, apparently not all fishers accept that the mortality of bycatch is unacceptable and that they should all play a leading role in reducing bycatch mortality (appropriateness). They also do not believe it is morally important to reduce bycatch mortality (valence) or recognise that they have support from authorities, peers, and public to reduce bycatch (principal support).

In the Queensland East Coast Otter Trawl Fishery (QECOTF), fishers are apparently not ready to voluntarily reduce bycatch mortality, with respondents indicating not all fishers agree that a need to reduce bycatch exists (discrepancy), that reducing bycatch is appropriate (appropriateness), or that they recognise support is available from authorities, peers, and the public to reduce bycatch (principal support). Respondents did however recognise the efficacy of all fishers in reducing bycatch mortality (efficacy), their unchanged affection for being a fisher as a result of efforts to reduce bycatch (affection), and that they all find some intrinsic benefit in reducing bycatch (valence).

NPF scores for each category suggest a high level of readiness to voluntarily reduce bycatch, although all fishers apparently do not accept that the mortality of bycatch is not acceptable (appropriateness) or are dedicated to changing fishing practice to reduce bycatch mortality (principal support).

Table 12. Perceived reasons why fishers are reluctant to further reduce bycatch, by weighted average. Score and ranking: 1 - Very important, 2 - Important, and 3 - Not important. CTS - Commonwealth Trawl Sector, NSWPTF - NSW Prawn Trawl Fishery, QECOTF - Queensland.

Reason	**Weighted average**				
	CTS (n = 2)	**NSWPTF (n = 4)**	**QECOTF (n = 4)**	**NPF (n = 6)**	**All (n = 16)**
Concerns that further bycatch reduction efforts will be costly or painful	1.00	1.25	1.50	1.33	**1.31**
Concerns that pressure to further bycatch will never end	1.00	1.75	1.75	1.33	**1.50**
Perceived lack of incentives to offset any catch loss from additional bycatch reduction efforts	1.00	1.75	1.50	1.67	**1.56**
Perceived lack of opportunity, benefit, or reward from further bycatch reduction efforts	1.50	1.50	1.50	1.83	**1.63**
Perception that bycatch reduction using their current trawl gear is sufficient/adequate	2.00	1.75	2.00	1.33	**1.69**
Disinterest or apathy regarding additional bycatch reduction efforts	2.00	2.00	2.00	1.17	**1.69**
Uncertainty about how they might be affected by additional bycatch reduction efforts	1.00	1.50	2.00	1.83	**1.69**
Perceived loss of control over their fishing operation/business as a result of additional bycatch reduction efforts	2.50	1.75	2.25	2.00	**2.06**
Fundamental, pathological, or ideological resistance to additional bycatch reduction efforts	2.00	1.75	2.25	2.17	**2.06**
Mistrust of individuals responsible for promoting a need to further reduce bycatch, including their motives	1.50	1.75	2.00	2.50	**2.06**
Perceived lack of understanding of the need/reason for additional bycatch reduction efforts	2.50	2.00	2.25	2.50	**2.31**
Perceived lack of consultation regarding a need for additional bycatch reduction efforts	2.00	2.25	1.75	2.83	**2.31**
Concerns that past efforts to reduce bycatch will be ignored or dishonored	2.00	2.75	2.00	2.33	**2.31**
Perception there is insufficient time to become adjusted to the idea of additional bycatch reduction efforts	2.00	2.50	2.25	2.67	**2.44**
Concerns they will appear incompetent in the face of additional bycatch reduction efforts	3.00	2.50	2.50	2.67	**2.63**
Perceived concerns that further bycatch reduction efforts will unevenly affect other fishers in the fishery	2.50	3.00	2.25	3.00	**2.75**

Table 13. Respondent scores (weighted average) regarding the perceived readiness of fishers to further reduce bycatch, by fishery. Readiness statements were grouped into six categories: Discrepancy, appropriateness, valence, efficacy, principal support, and affection. Respondents were asked to score each statement: 1 - strongly disagree, 2 - disagree, 3 - unsure, 4 - agree, 5 - strongly agree. Scores < 3 pinpoint why or where readiness to reduce bycatch is low and in need of future consideration. n = sample size.

Category/Statement	**Fishery (Weighted avg.)**			
	CTS (n=2)	**NSWPTF (n=4)**	**QECOTF (n=6)**	**NPF (n=7)**
Discrepancy				
All fishers in this fishery agree that ***additional*** steps are necessary to change or modify their fishing gear to further reduce their impact on bycatch species	2.50	3.25	2.83	3.43
All fishers in this fishery ***agree*** that minimising their impact on bycatch species is important for the health of their fishery	2.50	3.00	2.83	4.00
All fishers in this fishery agree that it is ***important*** to respond to government authorities and public concerns regarding their impacts on bycatch species	1.50	3.00	2.50	3.71
All fishers in this fishery ***agree*** that reducing bycatch can potentially result in improved fishing gear performance, new marketing opportunities, or increased product value.	1.50	3.25	3.17	3.43
Wt. avg.	**2.00**	**3.13**	**2.83**	**3.64**
Appropriateness				
All fishers in this fishery ***accept*** that the mortality of bycatch species in commercial fishing activity is not acceptable	2.50	2.25	2.00	2.71
All fishers in this fishery ***accept*** that it is reasonable for government authorities and the public to disapprove of the mortality of bycatch species due to commercial fishing activity	2.50	3.25	2.67	3.14
All fishers in this fishery ***accept*** that they should play a leading role in reducing the mortality of bycatch species	2.50	2.50	2.83	3.43
All fishers in this fishery ***accept*** that using modified fishing gear is an important step to reduce the mortality of bycatch species	2.50	3.75	3.17	4.00
Wt. avg.	**2.50**	**2.94**	**2.67**	**3.32**
Valence				
All fishers in this fishery agree that it is ***morally*** important to reduce the mortality of bycatch species in their fishery	1.50	2.50	2.67	3.43
All fishers in this fishery are ***happy*** to reduce bycatch in their fishery to the greatest extent practicable	1.50	3.00	3.33	3.71
All fishers in this fishery ***understand*** that government authorities and the public have a right to be concerned about the mortality of bycatch in their fishery	2.50	3.50	3.00	3.14
All fishers in this fishery feel ***pride*** in their efforts to reduce bycatch in their fishery	1.50	3.00	3.00	3.71
Wt. avg.	**1.75**	**3.00**	**3.00**	**3.50**

Efficacy				
All fishers in this fishery have the ***authority*** to implement changes to their fishing gear to reduce the mortality of bycatch species	3.50	4.00	4.17	3.29
All fishers in this fishery have the ***skill*** to implement any necessary changes to their fishing gear to reduce the mortality of bycatch species	4.50	3.00	3.50	3.43
All fishers in this fishery have the ***experience*** to implement any necessary changes to their fishing gear to reduce the mortality of bycatch species	4.50	3.00	2.67	3.14
All fishers in this fishery have the ***capability*** to make the necessary changes to their fishing gear to reduce the mortality of bycatch species and minimise catch loss	3.50	4.00	3.17	3.57
Wt. avg.	4.00	**3.50**	**3.38**	**3.36**
Principal support				
All fishers in this fishery are aware the ***public*** supports their efforts to reduce the mortality of bycatch species in their fishery to the greatest extent practicable	2.00	2.50	2.83	3.57
All fishers in this fishery are aware that ***fishery managers*** and other government authorities support their efforts to reduce the mortality of bycatch species in their fishery to the greatest extent practicable	4.00	3.00	3.50	4.29
All fishers in this fishery are ***supportive*** of the idea to reduce the mortality of bycatch species in their fishery to the greatest extent practicable	2.00	2.50	2.67	4.29
All fishers in this fishery are ***dedicated*** to changing their fishing practices to reduce the mortality of bycatch species in their fishery to the greatest extent practicable	2.00	2.50	2.00	2.57
Wt. avg.	**2.50**	**2.63**	**2.75**	**3.68**
Affection				
All fishers in this fishery will still feel ***respected by other fishers*** in the fishery as a result of their efforts to reduce the mortality of bycatch species	3.00	3.00	2.50	3.57
All fishers in this fishery will still feel a ***sense of belonging*** in the fishery despite taking steps to reduce the mortality of bycatch species	3.00	3.50	3.33	3.57
All fishers in this fishery will still feel a ***sense of pride*** in being a fisher, despite taking steps to reduce the mortality of bycatch species	4.00	3.75	3.33	3.86
All fishers in this fishery will still feel ***devoted*** to the fishery, despite taking steps to reduce the mortality of bycatch species	3.00	3.50	3.83	4.00
Wt. avg.	**3.25**	**3.44**	**3.25**	**3.75**

Discussion

The findings of this project are based on review of FRDC-funded project reports describing efforts to reduce bycatch as well as responses to a survey that investigated if cited recommendations from these projects were followed-up with or otherwise. Respondents were also asked to describe circumstances and conditions that contributed to any follow-up activity, and impediments and bottlenecks if there had been little or no such activity. They were also asked to comment on perceived readiness of fishers to reduce bycatch voluntarily, as this information can potentially be used to guide future collaborative bycatch reduction efforts.

The number of survey respondents was seven or less for each fishery although this reflected a significant proportion of the population of suitable qualified respondents. Respondents were deemed qualified if they had been a principal investigator in one or more relevant FRDC-funded projects, had played an active role in one or more these projects, in any capacity including follow-up activity, or had been a manager in the fishery during or after the time of the project. Only a small number of individuals met these criteria and were therefore qualified to respond to the survey. In almost all instances these individuals had also been involved in the fishery for several decades and were aware of any other bycatch reduction developments and the attitudes of fishers to bycatch reduction. It should be noted, however, that responses from these individuals may not necessarily reflect the prevailing views and attitudes of all fishers and others engaged in the fishery, despite their history and experience.

In some instances, there had been considerable activity following up on cited project recommendations to further reduce bycatch. This was sometimes evidenced by subsequent projects, funded by FRDC or others, and sometimes by voluntary efforts by fishers. Several projects had only recently been completed, leaving little time for individuals to follow-up on project recommendations, although recent fisheye development in the NPF and the ongoing research in the CTS (**FRDC Project No. 2019/027**) are notable exceptions. Respondents provided little insight into why cited recommendations from some of the older projects may not have been followed up with, although several suggested it was because FRDC funding priorities had changed and were focussed elsewhere. Other possible reasons for lack of follow up include disinterest by researchers, fishers, or others, or their distraction by other interests.

Impediments and bottlenecks to voluntary or non-FRDC funded attempts to reduce bycatch

Each survey respondent typically provided multiple reasons they believe impede or prevent fishers from making voluntary attempts to further reduce bycatch. Several respondents noted that these challenges could be overcome quickly and efficiently through legislation, that voluntary attempts to make progress are often disappointing and that legislation can fast-track changes in the fishery. Others, however, noted that voluntary efforts by fishers have occurred when catch loss or potential financial gain are the desired outcomes, and that legislation can take many years to introduce following the completion of research.

Impediments and bottlenecks to voluntary efforts to reduce bycatch were attributed to fishery managers, fishers, and researchers. In each of the four trawl fisheries, fishery managers permit fishers to voluntarily modify their fishing gear to reduce bycatch, for example, relocating the position of a BRD in the codend, providing they are not counter to legislated limits. In several of these fisheries, fishers can also follow gear testing protocols to rigorously test and seek regulatory approval for their gear. Several respondents cited these opportunities as evidence there are no impediments to fishers further reducing bycatch, although others noted that gear testing protocols

are too limiting or take too long to follow to their conclusion. In the NPF, for example, a new BRD tested voluntarily by a fisher during the tiger prawn season cannot usually be tested independently by a researcher until the subsequent tiger prawn season, meaning that at least two years will pass before the BRD is fully evaluated, let alone introduced for legislation. Reducing this period is not usually an option because researchers are not usually available to test the device at short notice, and the testing program requires careful consideration, planning, and resourcing. Another cited impediment was a requirement for BRDs to be tested during the fishing season, which means the financial risk associated with any lost fishing time or catch loss is borne by the fisher, with no chance to recover this loss. As a result, this process requires a significant level of dedication and risk-taking by the fisher, to remain enthusiastic about the new gear over a period of several years or more.

Respondents from several fisheries noted that some fishery managers seemed little interested in reducing bycatch. In NSW, for example, the introduction of regulations based on the findings of peer-reviewed BRD research often took many years to develop and introduce, sometimes close to a decade later. Such an approach does little to inspire fishers and researchers, who question why they should show interest when the regulatory process takes so long. Exacerbating this concern, respondents noted that regulators are often challenged in their ability to develop regulations that are iron-clad and effective, in part because they are not trained in fishing technology, and because they are not closely engaged in the relevant projects. It was also noted that the political environment was sometimes not receptive to such regulation, that strong personalities can sometimes have undue sway on proceedings. Finally, compliance officers are sometimes insufficiently trained to effectively measure BRDs and identify non-compliance, and therefore challenged in their ability to effectively police and enforce regulations.

The comments by respondents suggest that fishery managers need to streamline and fast-track their processes to facilitate voluntary efforts to reduce bycatch and to introduce effective regulations. Most respondents also suggested fishers need to take greater responsibility and be more proactive in BRD development. Several noted that while there are some fishers that are enthusiastic and proactive, there are many who will not test a BRD unless forced to by regulation, even when the economic impact has been shown to be low or non-existent. Respondents were sympathetic to the economic concerns of fishers - three of the four most important perceived reasons why fishers are reluctant to reduce bycatch are underpinned by economic and operational concerns - but also felt that fishers must be active and part of any efforts to optimise BRD performance. This combined with the findings indicating fishers are reluctant to further reduce bycatch because they do not see the need or deem it appropriate, are signposts that should be a focus of any future bycatch reduction effort. This also improves their sense of principal support, and increases the likelihood that voluntary efforts can increasingly become the norm across an entire fishery, rather than the exception.

Many respondents suggested that project extension activity was frequently inadequate and that fishers were often unaware of project outcomes and recommendations. This assumes all fishers were available and receptive to project messaging, but it does raise questions regarding the efficacy of such activity. To a large extent this outcome is the fault of the principal investigator and others involved in the project. Part of the problem is that extension activity often occurs towards the end of a project when there is a risk that planned activity is compromised due to insufficient remaining time or funds. Project researchers are responsible for ensuring this does not occur, although sometimes this cannot be avoided, particularly if fieldwork problems or delays were experienced. Exacerbating this issue, the professional development of some researchers is incumbent upon them publishing project results in a scientific journal, not sharing them at an industry meeting or workshop, or publishing them online or in an industry periodical. This potentially undermines or serves as a

distraction from industry extension activity, the outcomes of which are difficult to quantify and are a seldom considered metric of personal development. Finally, some researchers are financially unable to continue extension activity upon project completion (even if they wanted to), and quickly redirect their interests elsewhere, perhaps seeking funding for new project activity.

What worked, should have been done differently, and should be done in the future

According to respondents the FRDC has played an essential role in bycatch reduction in trawl fisheries around the country, and without their funding support little progress would have been made. There are few other funding sources with a strong history of funding research in the fishing industry. Respondents also noted the essential role that fishers have played in this research, which amongst other things, helps ensure a level of pragmatism in the design, operation, and management of BRDs.

Several respondents lauded the FRDC for their multi-year funded projects, noting that it takes several years to get started, engage and complete fieldwork, evaluate results, arrive at a conclusion, and extend the findings to fishers and others. Others, however, were critical that recommendations from completed projects could not be pursued immediately because no further funding from FRDC was available. This typically resulting in a substantial loss of momentum, while some project recommendations were put on hold for many years before funding from FRDC or elsewhere could be found. In other instances, some project recommendations were never followed-up, despite still being relevant today.

A significant responsibility for the voluntary adoption of project recommendations, including reducing bycatch, rests with commercial fishers. They are the ones who can conceivably extend testing of a BRD beyond the life of the project, modify or adjust it accordingly, and test it under a variety of operating conditions without project funding. However, concerns by fishers regarding the economic and operational impact of such testing remains a significant impediment that hampers their enthusiasm and readiness. Researchers also have significant responsibility, to ensure fishers and others are aware of project outcomes, including fishery managers where regulation is an intended outcome. They must also provide fishers adequate information to they can respond to project outcomes and recommendations, including voluntary testing, if desired. This is also important if a project recommendation is to regulate the new BRD, so that fishers have an opportunity to test the device and prepare themselves for regulation. According to respondents, the delivery of this information is frequently inadequate, which suggests that greater efforts are required to extend such information to fishers, repeatedly and persistently.

In the future, consideration should be given to exploring the extent to which fishers are ready to voluntarily build on project outcomes and further reduce bycatch. While their concerns regarding the economic impact of such efforts are widely appreciated, other potential barriers to reducing bycatch are less well known yet they provide broader insight into their resolve and why they may or may not be ready to pursue this outcome. In this study, respondents scored the perceived readiness of fishers to reduce bycatch based on a study of change readiness adapted from Rafferty *et al*. (2013). Accordingly, their readiness to voluntarily reduce bycatch will be influenced by their attitudes towards bycatch and the perceived readiness of their environment to operationalise their bycatch reduction efforts. In this project, respondents indicated that fishers in the CTS and QECOTF do not agree there is a discrepancy (need) for additional bycatch reduction efforts or that it is appropriate. This is obviously not a strong foundation for encouraging future bycatch reduction efforts by fishers, and armed with this information, researchers, fishery managers, and others can take remedial steps to address these issues. This might include a long and extensive extension

campaign that articulates clearly why further efforts to reduce bycatch are necessary and appropriate, perhaps including a workshop approach similar to **FRDC Project No. 2017/065** at regular intervals and regular articles in industry literature and social media. Demonstrable progress in addressing catch loss and other concerns by fishers should also be a highlight of such a campaign.

Low discrepancy and appropriateness scores in these two fisheries may also be a signal flagging the limited success of previous extension programs, perhaps because such efforts did not adequately engage or interest fishers, and/or they were discontinued once the projects were completed. Across all four fisheries, respondents indicated fishers have what it takes to further reduce bycatch and their affection for the fishery would remain unchanged, although respondents in several fisheries indicated that fishers lacked principal support to do so. Opportunities to improve principal support include building a closer relationship between the fishing industry and the public. This could involve raising public awareness of progress in bycatch reduction efforts to date, the economic and other impacts such efforts have had on fishers, and the challenges faced by fishers to make further progress. It also includes helping fishers support each other in reducing bycatch, by building their awareness of the need, appropriateness, and benefits of doing so, and it includes facilitating dedicated attempts to reduce bycatch to the greatest extent practicable, such as streamlining testing protocols so that dedicated and timely testing and review of BRDs can be completed. Finally, it also includes tackling issues of concern to fishers such as catch loss, as this recognises and validates their concerns and demonstrates that such concerns are also important features of a bycatch reduction program.

In conclusion, there are many reasons why project outcomes and recommendations may not have been followed up although the end result is that project momentum has stalled or ceased entirely. Researchers cite project recommendations because they believe further development in bycatch reduction is required, yet frequently there is no funding to do so. This project made no effort to question the validity or appropriateness of these recommendations, but failure to maintain momentum risks producing less than optimal outcomes in bycatch reduction, despite substantial historical success around the country. Suggestions for improvement, by the FRDC, researchers, fishery managers, and fishers have been made in an attempt to reduce the risk that project recommendations gather dust. However, as a primary funding provider in bycatch reduction, the FRDC should consider all suggestions in this project and take steps to facilitate, guide, or require their introduction.

Recommendations

Based on the outcomes of this project the following recommendations are made:

- The cited recommendations from **FRDC Project No. 2017/065** should be pursued. These recommendations were based on the outcomes of multiple recent industry workshops around the country and comments from many fishers and others. Many of these recommendations were further validated by respondent comments in this project.
- Strengthen extension activity to fishers. A common message from respondents was a call to improve fisher understanding and knowledge of bycatch reduction efforts, both during the life of individual projects and beyond; change takes time but is unlikely to occur if fishers have poor understanding and knowledge. Implicit in these calls is that current extension practices are inadequate or insufficient and that important project messages are not resonating with fishers. While many researchers do an excellent job communicating project results, such communication often ceases once the project concludes. Communication needs to be ongoing and repeated to enhance understanding and knowledge, including BRD developments in their fishery and elsewhere. Questions also need to asked regarding the efficacy of various forms of communication and information transfer, from industry workshops, newsletters, to videos, including their timing and frequency. Similarly, questions regarding the efficacy of the FRDC, researchers, and others engaged in these activities need to be asked, and the potential for alternatives such as dedicated champions of project activity should be explored. Such champions could ensure that communication and information transfer is appropriate, consistent, and persistent beyond the life of individual projects. Additional extension activity could also include the following, cited in Kennelly (2017);

  > *"….the next steps in the implementation of the sorts of modifications described in this project* [**FRDC Project No. 2017/065**] *throughout prawn-trawl fleets in Australia would see gear technicians working on multiple boats in multiple fisheries, showing as many fishers as possible how to use chosen modifications whilst also developing novel concepts. Such work should include scientifically rigorous trials that demonstrate the fleet-wide utility of modifications and so supply defensible evidence of the value of the modifications."*

  While the idea of industry champions and gear technicians working at sea is not new and has been successfully applied previously (e.g., **FRDC Project No. 1996/254)**, an early step for consideration is how they should be funded, noting that similar efforts by the now defunct SeaNET program also attempted to overcome this impediment several years ago.
- Strengthen extension activity to fishery managers, researchers, and the public. Respondents suggested that fishers perceive they do not have principal support from these groups to further reduce bycatch. Steps should therefore be taken to improve principal support, primarily by recognising and addressing their concerns and reporting demonstrated progress through targeted and repeated communication. Fisher concerns regarding a lack of principal support should not be taken lightly because evidence from **FRDC Project No. 2017-046** suggests that poor support is detrimental to the mental health of fishers (Brooks *et al*., 2019).
- Simplify the protocols that allow fishers to voluntarily test and evaluate the performance of new BRDs. Multiple respondents noted these protocols are inefficient and take too long to complete, usually two years or longer. Fishery managers should therefore consider how to streamline gear-testing protocols. To build enthusiasm and maintain momentum, testing of a

new BRD should ideally be completed within one year or fishing season. An annual BRD testing program in the Gulf of Mexico allows fishers to nominate new BRDs for testing by NMFS gear technologists over a period of a few weeks, and consideration for how such an approach might be applied in each fishery here is a useful starting point. Furthermore, if testing cannot be timed to coincide with the off season, consideration of a cost recovery model is necessary to offset any catch loss associated with testing during the season. This could be achieved by comparing catches between multiple nets or boats during the period of testing, and providing recompense for any shortfall in landings.

- Develop specific bycatch targets and ensure industry engagement from the onset. The model applied by NPFI to achieve a 30% reduction in bycatch serves as a clear demonstration how an engaged industry with a clear target can voluntarily achieve a significant improvement. Regulation of new BRDs that achieve this target must also be introduced as quickly as possible to maintain progress and capture momentum.
- Fishery managers should take steps to shorten the regulatory process, improve their understanding of fishing gear to develop regulations that cannot be circumvented by fishers, and improve policing and enforcement of regulations. Fishery managers should also take an active role in bycatch reduction projects, to better understand project developments and contribute insight into regulatory challenges, which may help guide BRD testing and data collection. They should also consider modelling various management scenarios with the new BRD in mind. This includes the economic and operational impact of each scenario, and the likely impacts on fisher safety, with concerns regarding the impact of management decisions on fisher safety reported in **FRDC Project 2017-046**.
- FRDC should take the lead driving and facilitating the recommendations cited above because they have a national focus that includes all commercial fisheries and are the primary funding provider in bycatch reduction research. This includes the following:
    - A stronger push for researchers to share their results with all stakeholders. Notwithstanding current FRDC requirements for an outreach and extension program in funded research projects, greater efforts are required to ensure fishers are aware of project outcomes and the need and appropriateness of further bycatch reduction. This is particularly important in the fishery where the research was completed, but also in similar fisheries where similar fishing gear is used and/or similar bycatch species are encountered. Consideration should be given to establishing industry champions dedicated to sharing bycatch reduction findings and other information with fishers and gear technicians working at sea with fishers to test and develop new bycatch reduction devices. Improving principal support for bycatch reduction means other stakeholders including the public should also be considered in such outreach and extension programs.
    - FRDC should identify and facilitate the development of mechanisms to ensure ongoing extension activity to all stakeholders once a project has concluded. This too will help ensure fishers are aware of project outcomes and reminded of the need and appropriateness of further bycatch reduction efforts. Indirectly, this will further encourage voluntary efforts to refine the performance of bycatch reduction devices, and it will help improve principal support by other stakeholders for further bycatch reduction efforts.
    - A stronger push for fishery managers to be engaged in bycatch reduction projects from the onset, to increase their awareness of project developments and encourage their early consideration of regulatory change as a result of project outcomes. Consideration should be given to requiring that all such projects include a fishery manager as a collaborator, with project proposals clearly describing their active participation, for example, in project design and development of potential regulations.

- Facilitating review of existing bycatch reduction testing protocols and potential streamlining, including consideration of mechanisms to offset the economic risk to fishers of such testing. This may require the development of a working group specific to each fishery, with fishers, fishery managers, and fishing technologists working together to seek solutions to this issue.
- FRDC should increase monitoring of project recommendations and any subsequent related activity, and facilitate consideration of next steps that build on project outcomes. This will help minimise loss of momentum in bycatch reduction within a fishery, which hampers progress and potentially increases costs as momentum is rebuilt. Lost momentum also undermines fisher perceptions regarding the need and appropriateness of further bycatch reduction efforts.
- FRDC should consider developing a committee of key individuals dedicated to discussing the abovementioned recommendations and exploring how FRDC can lead or facilitate further development in bycatch reduction. In the first instance this might take the form of an online workshop, to not only discuss these recommendations but also the merits of developing such a committee and future steps.

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Appendices

Appendix 1. The East Coast Otter Trawl Fishery survey. The survey was identical between fisheries with the exception of the introductory pages.

FRDC Project survey.

This survey is designed to evaluate progress in bycatch reduction in the East Coast Otter Trawl Fishery, and in particular, since 2000. Of particular interest is progress since the conclusion of the following FRDC-funded research:

- FRDC Project No. 2015/014. *Estimating the impacts of management changes on bycatch reduction and sustainability of high-risk bycatch species in the Queensland East Coast Otter Trawl Fishery,*
- FRDC Project No. 2008/101. *Extension of Fisheries Research and Development Corporation funded research results in improved bycatch reduction devices to the Queensland East Coast Otter Trawl Fishery,*
- FRDC Project No. 2005/054. *A collaborative extension program by the Queensland Department of Primary Industries and Fisheries, SeaNet and Ecofish for the development and adoption of square mesh codends in select prawn and scallop trawl fisheries In Queeensland,* and
- FRDC Project No. 2005/053. *Reducing the impact of Queensland's trawl fisheries in protected sea snakes*,

noting that in 2000 turtle excluder devices and bycatch reduction devices became mandatory in this fishery.

This survey is funded by FRDC Project 2019/082. *Progress in bycatch reduction in trawl fisheries: Are the findings, outcomes, and recommendations from FRDC funded bycatch reduction projects acted upon?*

The objectives of FRDC 2019/082 are:

2. Review the findings, outcomes, and recommendations of bycatch reduction research in multiple trawl fisheries around Australia, based on review of FRDC project final reports and other literature
3. Assess if the findings and outcomes of this research have translated into changes in fishing practice or behaviour
4. Assess if the recommendations of this research have been acted upon subsequently, and if not, identify reasons why not to the extent practicable
5. Identify impediments to the adoption of bycatch reduction devices or other options to reduce bycatch in these fisheries, and recommend remedial solutions.

FRDC-funded research in this fishery has included efforts to evaluate the effect of bar spacing and other modifications on TED performance, and the efficacy of square-mesh codends and other codend modifications designed to reduce bycatch. Cited recommendations from all FRDC-funded projects in this fishery are presented in Table 1.

Your responses to this survey are confidential, and will only be reported in aggregate with names and any identifiable comments removed.

Table 1. Cited recommendations FRDC funded projects related to the East Coast Otter Trawl Fishery.

Project No.	Recommendations (specific to bycatch reduction)
2015/014	6. Efforts should be made to quantify the effect of reduced bar spacing in TEDs on elasmobranchs.
	7. Fishers should facilitate further research to determine the post-trawl survival of elasmobranchs
2008/101	2. No specific recommendations were provided
2005/054	5. There is a need to review the minimum acceptable mesh size that used in the construction of square-mesh codends
	6. There is also a need to investigate the application of knotless material in codend construction
	7. Investigate the potential biomass increase as a result of using square-mesh codends, particularly in the shallow water king prawn fishery
	8. Investigate the effect of square-mesh codends on net drag and fuel consumption
2005/053	5. Seek legislation requiring the mandatory use of selective codends such as T90 selector panels and T90 lengtheners
	6. Investigate the post-capture survival of escaping fish
2000/170	2. No specific recommendations were provided
1996/254	4. Monitor the ongoing development of TEDs and BRDs to ensure they achieve stated goals, and document changes in bycatch composition and quantity.
	5. Continue to support opportunities for fishers, researchers, and others to build relationships and exchange information and expertise.
	6. Support industry interest in further trawl modification to reduce environmental impact, for example, alternative ground gear designs
1993/229	3. Further monitoring the incidence of turtle bycatch in trawl nets is required off the QLD coast
	4. The impact of prawn trawling on the post-release survival of turtles should be studied

Survey Questions

Section 1.

- What is your name? _____
- What is your current position and affiliation? _____

  _____
- Which FRDC projects were you engaged in? (include relevant project number/s)?_____

  _____

  When answering <u>the following</u> questions, only consider the projects you listed in the previous question

- To your knowledge were there any attempts by fishers or others to actively follow up on any of the cited project recommendations in Table 1 (Yes/No/Uncertain)? _____
  - If yes, what were they **<u>and</u>** what were the motivators or drivers that supported this follow-up activity? _____

    _____

    _____

    _____
  - If yes, was this follow-up activity ultimately successful (Yes/No/Uncertain)? _____
    - If yes/no, why was this follow-up activity successful/unsuccessful? _____

    _____

    _____

    _____

    _____
  - If no attempt was made to follow-up on cited project recommendations, why do you think this was the case? _____

    _____

    _____

    _____
  - If no attempt was made to follow up on cited project recommendations, do you think the relevant fishers/individuals/organisations were aware of these recommendations (Yes/No/Uncertain)? _____

- If no attempt was made to follow up on cited project recommendations, what do you think was needed to enable or encourage follow-up activity? _____
  _____
  _____
  _____
- If no attempt was made to follow up on cited project recommendations, what do you now think the next steps should be? _____
  _____
  _____
  _____

- Ultimately, this research contributed to the introduction of regulations requiring the mandatory use of specified gear modifications to reduce bycatch.
  - Why do you think these regulations came about? _____
    _____
    _____
    _____
  - What were the attitudes of fishing companies/boat owners to these regulations at the time? Why did they have these concerns? _____
    _____
    _____
    _____
  - What were the attitudes of skippers to these regulations at the time? Why did they have these concerns? _____
    _____
    _____
    _____

- To your knowledge have there been any voluntary or non-FRDC funded attempts, during or since the periods of FRDC funding, to modify bycatch reduction devices (grids, etc.), change fishing gear, or fishing practice to:
  - Reduce capture of dolphins, seals, or other cetaceans (Yes/No/Uncertain)? _____
  - Reduce capture of sharks? (Yes/No/Uncertain)_____
  - Reduce capture of sawfish? (Yes/No/Uncertain)_____
  - Reduce capture of seahorses/pipefish? (Yes/No/Uncertain)_____
  - Reduce capture of sea snakes? (Yes/No/Uncertain) _____

- Reduce capture of other bycatch? (Yes/No/Uncertain)_____
- Reduce catch loss associated with a bycatch reduction device, improve handling of the device, or for any other reason?_____

- If yes, what has been attempted and what was the outcome?

_____

_____

_____

_____

- If yes, who was involved in this research (fishers/researchers/etc.)? _____

_____

_____

- Do you think there are any impediments or bottle necks to fishers further reducing bycatch in this fishery on a voluntary basis (Yes/No/Uncertain)? _____
  - If no, what were/are the motivators that encouraged/encourage fishers to further reduce bycatch? _____

    _____

    _____

    _____
  - If yes, place a number between 1 – 3 in the space provided to indicate why **<u>you think</u>** some fishers in this fishery are reluctant to further reduce bycatch. Please score/rank your reasons - 1 (very important), 2 (important), or 3 (not important).

Question	**Score**
Perceived loss of control over their fishing operation or business as a result of additional bycatch reduction efforts.	
Perceived lack of understanding of the need/reason for additional bycatch reduction efforts.	
Perception that bycatch reduction using their current trawl gear is sufficient/adequate.	
Perceived lack of consultation regarding a need for additional bycatch reduction efforts.	
Disinterest or apathy regarding additional bycatch reduction efforts.	
Uncertainty about how they might be affected by additional bycatch reduction efforts.	
Perceived concerns that further bycatch reduction efforts will unevenly affect other fishers in the fishery.	
Perception there is insufficient time to become adjusted to the idea of additional bycatch reduction efforts.	
Concerns that past efforts to reduce bycatch will be ignored or dishonored.	

Fundamental, pathological, or ideological resistance to additional bycatch reduction efforts.	
Concerns they will appear incompetent in the face of additional bycatch reduction efforts.	
Perceived lack of incentives to offset any catch loss from additional bycatch reduction efforts.	
Concerns that pressure to further bycatch will never end.	
Concerns that further bycatch reduction efforts will be costly or painful.	
Mistrust of individuals responsible for promoting a need to further reduce bycatch, including their motives.	
Perceived lack of opportunity, benefit, or reward from further bycatch reduction efforts.	
Other (please explain below)	

- If yes, what do you think are the next-steps to overcoming these impediments or bottlenecks?_____

  _____

  _____

  _____

- If you or anyone else was to repeat any bycatch reduction effort in this fishery, should anything be done differently (Yes/No/Uncertain)? _____
  - If yes, what would should be done differently? _____

    _____

    _____

    _____
  - If not, why do you think this is the case? _____

    _____

    _____

    _____

- Regarding changes to date by fishers to reduce bycatch in this fishery, what motivators, conditions, or circumstances do you think were important to facilitate their change? _____

  _____

  _____

  _____

- What are some of the key lessons you have learnt from bycatch reduction efforts with this fleet that others could/should apply to similar bycatch reduction efforts in other fisheries?

_____

_____

_____

_____

- Would you have expected a different outcome from your bycatch reduction efforts with a substantially different fleet size, ie. tenfold increase or decrease in boat numbers (Yes/No/Uncertain)? _____
  - If yes/no, why would you expect/not expect a different outcome?

_____

_____

_____

_____

- If the mix of owner-operated vessels and company-owned vessels changed in this fleet would you have expected a different outcome from your bycatch reduction efforts (Yes/No/Uncertain)? _____
  - If yes/no, why do you think the outcome would have/would not have been different?

_____

_____

_____

_____

- Tick the box that you think best describes the attitude of most commercial fishers around Australia to voluntary change in their fishery? In this context, voluntary change can be in response to a crisis, problem, or an identified opportunity for themselves and/or the fishery.

☐ *They readily/enthusiastically embrace and accept voluntary change in their fishery*

☐ *They sometimes embrace and accept voluntary change in their fishery*

☐ *They occasionally embrace and accept voluntary change in their fishery*

☐ *They rarely embrace and accept voluntary change in their fishery*

☐ *They never embrace and accept voluntary change in their fishery*

- With respect to bycatch reduction efforts to date in the fishery you are most familiar with, is there anything the FRDC should have done differently (Yes/No/Uncertain)? _____

- If yes/no, what did they get right/wrong?

_____

_____

_____

_____

- With respect to bycatch reduction efforts in a fishery you are most familiar with, is there anything that the FRDC should/must do in the future (Yes/No/Uncertain)? _____
- If yes, what should/must they be do?

_____

_____

_____

_____

- With respect to bycatch reduction efforts in the fishery you are most familiar with, is there anything that anyone else (fisher/s, industry bodies, others) should/must do in the future (Yes/No/Uncertain)? _____
- If yes, what must they do?

_____

_____

_____

_____

End of Section 1.

Section 2.

This section explores your perception regarding the readiness of fishers to further reduce bycatch. Using the 5-point scale below, and **only considering the fisheries relevant to your responses in Section 1**, please score each of the following statements.

Please use the scoring scale below from 1 to 5 to indicate how strongly you agree with each of the following statements.

Score	Response
1	I strongly disagree
2	I disagree
3	I am unsure
4	I agree
5	I strongly agree

Discrepancy - perceived level of agreement that a need to change exists

Statement	Score
All fishers in this fishery agree that ***additional*** steps are necessary to change or modify their fishing gear to further reduce their impact on bycatch species (e.g., non-commercial fish, undersized species, protected species)	
All fishers in this fishery ***agree*** that minimising their impact on bycatch species is important for the health of their fishery	
All fishers in this fishery agree that it is ***important*** to respond to government authorities and public concerns regarding their impacts on bycatch species	
All fishers in this fishery ***agree*** that reducing bycatch can potentially result in improved fishing gear performance, new marketing opportunities, or increased product value.	

Appropriateness - perceived level of acceptability, relevance, aptness of a proposed change

Statement	Score
All fishers in this fishery ***accept*** that the mortality of bycatch species (e.g., non-commercial fish, undersized species, protected species) in commercial fishing activity is not acceptable	
All fishers in this fishery ***accept*** that it is reasonable for government authorities and the public to disapprove of the mortality of bycatch species due to commercial fishing activity	
All fishers in this fishery ***accept*** that they should play a leading role in reducing the mortality of bycatch species	
All fishers in this fishery ***accept*** that using modified fishing gear is an important step to reduce the mortality of bycatch species	

Please use the scoring scale below from 1 to 5 to indicate how strongly you agree with each of the following statements.

Score	Response
1	I strongly disagree
2	I disagree
3	I am unsure
4	I agree
5	I strongly agree

Valence - intrinsic attractiveness or otherwise, e.g., happiness, fear, joy, anger, surprise, pride, fear

Statement	Score
All fishers in this fishery agree that it is ***morally*** important to reduce the mortality of bycatch species (e.g., non-commercial fish, undersized species, protected species) in their fishery	
All fishers in this fishery are ***happy*** to reduce bycatch in their fishery to the greatest extent practicable	
All fishers in this fishery ***understand*** that the government authorities and the public have a right to be concerned about the mortality of bycatch in their fishery	
All fishers in this fishery feel ***pride*** in their efforts to reduce bycatch in their fishery	

Efficacy - perceived personal ability to produce a desired outcome

Statement	Score
All fishers in this fishery have the ***authority*** to implement changes to their fishing gear to reduce the mortality of bycatch species (e.g., non-commercial fish, undersized species, protected species)	
All fishers in this fishery have the ***skill*** to implement any necessary changes to their fishing gear to reduce the mortality of bycatch species	
All fishers in this fishery have the ***experience*** to implement any necessary changes to their fishing gear to reduce the mortality of bycatch species	
All fishers in this fishery have the ***capability*** to make the necessary changes to their fishing gear to reduce the mortality of bycatch species and minimise catch loss	

Please use the scoring scale below from 1 to 5 to indicate how strongly you agree with each of the following statements.

Score	Response
1	I strongly disagree
2	I disagree
3	I am unsure
4	I agree
5	I strongly agree

Principal Support - by authorities, peers, family, etc.

Statement	Score
All fishers in this fishery are aware that the ***public*** supports their efforts to reduce the mortality of bycatch species (e.g., non-commercial fish, undersized species, protected species) in their fishery to the greatest extent practicable	
All fishers in this fishery are aware that ***fishery managers*** and other government authorities support their efforts to reduce the mortality of bycatch species in their fishery to the greatest extent practicable	
All fishers in this fishery are ***supportive*** of the idea to reduce the mortality of bycatch species in their fishery to the greatest extent practicable	
All fishers in this fishery are ***dedicated*** to changing their fishing practices to reduce the mortality of bycatch species in their fishery to the greatest extent practicable	

Affection - a sense of belonging to the fishery

Statement	Score
All fishers in this fishery will still feel ***respected by other fishers*** in the fishery as a result of their efforts to reduce the mortality of bycatch species (e.g., non-commercial fish, undersized species, protected species)	
All fishers in this fishery will still feel a ***sense of belonging*** in the fishery despite taking steps to reduce the mortality of bycatch species	
All fishers in this fishery will still feel a ***sense of pride*** in being a fisher, despite taking steps to reduce the mortality of bycatch species	
All fishers in this fishery will still feel ***devoted*** to the fishery, despite taking steps to reduce the mortality of bycatch species	

End of Section 2.