
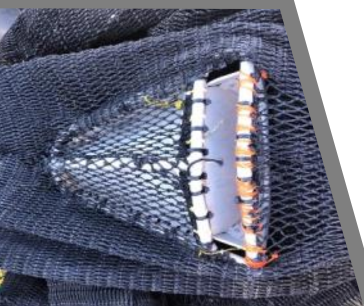



Industry gear innovations achieve bycatch reduction target in the Northern Prawn Fishery

NPF Industry Pty Ltd

Producing the finest quality prawns from a sustainable marine ecosystem

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Contents

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- The Kon's Covered Fisheyes BRD on board the *FV Xanadu* with Jamie Ball (skipper) and his crew members Jamie Charlier, Rhett Mckay, Jessie Hall, Bryce Wolfe, Kris Dixon and Krystal Moreton.
- The Tom's Fisheye BRD onboard the *FV Ocean Producer* with Steve Coe (skipper) and his crew members Josh Cooper, Jo Donges and Dylan Bykiw and onboard the *FV Eylandt Pearl* with Mark Robson and his crew members Mandy Blackburn, Annaleise Cherpilllod, Iwan Setiawan, Yayat Hidayat and Richard Clifford.
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2 List of Figures

3 List of Tables

4 Summary

In 2015, NPF Industry Pty Ltd launched the Northern Prawn Fishery's Bycatch Strategy 2015-2018 with the vision to reduce capture of small bycatch by 30% within three years. A key component of the Bycatch Strategy was industry innovation and through this process, several Bycatch Reduction Devices (BRD) were developed.

From 2015 to 2017, industry developed a number of BRDs which were initially tested by commercial vessel crews during the fishing seasons. Through this process, the Kon's Covered Fisheyes (KCF), Tom's Fisheye, and the FishEX 70 were selected for at-sea scientific testing in the Northern Prawn Fishery, primarily in the Gulf of Carpentaria, during commercial operations in 2016 and 2018. Scientific trials were designed to (1) determine their effectiveness in reducing capture of small bycatch and (2) determine any commercial prawn losses compared to a currently legislated BRD (Square Mesh panel) when used in the tiger prawn fishery. The three devices were found to significantly reduce capture of small bycatch by approximately 23.25 to 43.73%, with average commercial prawn losses ranging from -3.33% to +0.5% compared to a Square Mesh Panel BRD.

5 Aims

The aim of the trials was to assess the performance of three industry-developed BRDs (Kon's Covered Fisheyes, Tom's Fisheye and FishEX 70 BRDs) in reducing the capture of small bycatch and maintaining retention of commercial prawns compared to the current legislated Square Mesh Panel BRD during at-sea trials.

6 Introduction

The Northern Prawn Fishery (NPF) is located off Australia's northern coast, extending from the low water mark to the outer edge of the Australian fishing zone in the area between Cape York in Queensland and Cape Londonderry in Western Australia. The NPF targets seven commercial species of prawns including White Banana (*Penaeus merguiensis*), Redleg Banana (*Penaus indicus*), Brown Tiger (*Penaeus esculentus*), Grooved Tiger (*Penaus semisulcatus*), Blue Endeavour (*Metapenaeus endeavouri*), and Red Endeavour (*Metapenaeus ensis*). There are minor catches of other prawns species and scampi, squid, cuttlefish, scallops and bugs are also taken as byproduct. Since 2012, the fishery has been certified as sustainable under the Marine Stewardship Council (MSC).

The NPF is a tropical prawn-trawl fishery where operators can tow twin, triple or quad-rigged otter trawl nets. Typical of other tropical trawl fisheries, the volume and species diversity of bycatch caught in the NPF is high (Pender et al. 1992, Courtney et al. 2006, Dell et al. 2009, White et al. 2019). The NPF Industry has been progressively working with the Australian Fisheries Management Authority (AFMA), researchers and gear technologists to develop and implement new ways to reduce bycatch in the fishery. Through the implementation of permanent and seasonal closures, gear reductions, fleet reductions and the introduction of Turtle Excluder Devices (TEDs) and BRDs, the NPF has achieved significant reductions in total bycatch capture over the past 30 years. To assist with the development and implementation of new devices, the NPF Management Advisory

Committee (NORMAC) Bycatch Subcommittee developed the TED and BRD Testing Protocol which requires a new device to reduce bycatch by at least 10% with an associated commercial prawn loss less than 2.5% during an at-sea scientific trial of any device.

BRDs were made mandatory in the NPF in 2001. There are currently nine BRDs approved for use in the NPF: the Square Mesh Codend, Square Mesh Panel, Radial Escape Section, Fisheye, Yarrow Fisheye, Popeye Fishbox, Modified Turtle Excluder Device, the Kon's Covered Fisheyes, FishEX 70 and the Toms Fisheye. From electronic logbook records, 83% of vessel operators were using Square Mesh Panel BRDs and the remaining vessels using the Fisheye BRD (source: 2014 NPF logbook data).

In 2015, NPF Industry Pty Ltd launched its Bycatch Strategy 2015-2018 with a vision to voluntarily reduce capture of small bycatch by 30% within three years in the fishery. The initial phase of the strategy was to encourage industry innovation to develop and test new or modified BRDs or gear to achieve this goal.

In order to compare differences in bycatch volumes and species compositions, three new BRD designs were tested against the current BRD design used by the majority of vessels in the fishery; a Square Mesh Panel BRD. This approach provided real time comparisons of the effectiveness of the new BRDs during typical commercial fishing operations across variables including trawl net position (quad-gear), geographical region, fishing season and environmental conditions. The approach was taken after considerable discussion with the Northern Prawn Resource Assessment Group (NPRAG) in early 2015. It was determined that the complexity of the fishery (i.e. different species, areas, seasons, gear) made establishing a baseline very challenging.

7 Bycatch Reduction Devices Tested

Kon's Covered Fisheyes

The KCF BRD was developed by Kon Triantopoulos, net maker for A. Raptis & Sons Pty Ltd, and was initially trialled by Raptis in November 2015 with preliminary results of 19% bycatch reduction and minimal prawn loss (<2.5%) compared to a Square Mesh Panel BRD located at 120 meshes from the codend drawstrings. As such, it was agreed by NPF Industry that the device should undergo a scientific trial to determine its effectiveness in reducing capture of small bycatch without losing catch of target species.

The KCF BRD was modelled on the existing Fisheye BRD but encompassed a cone-shaped insert designed to create an area of reduced water flow in which small teleost fishes might take shelter and escape (Figure 1). The KCF BRD is comprised of two of these modified fisheyes in each net, positioned in line with each other. Following the successful at-sea testing of the KCF BRD in June and November 2016 and subsequent approval for use in the fishery, it was agreed by NPF Industry in February 2018 that further testing of the device as a single covered fisheye would be beneficial to determine its effectiveness. Industry members were also concerned with the workplace safety aspect of two additional metal objects in the codends, particularly in rough weather. For full specifications of the devices see Table 1 and Appendix 4.

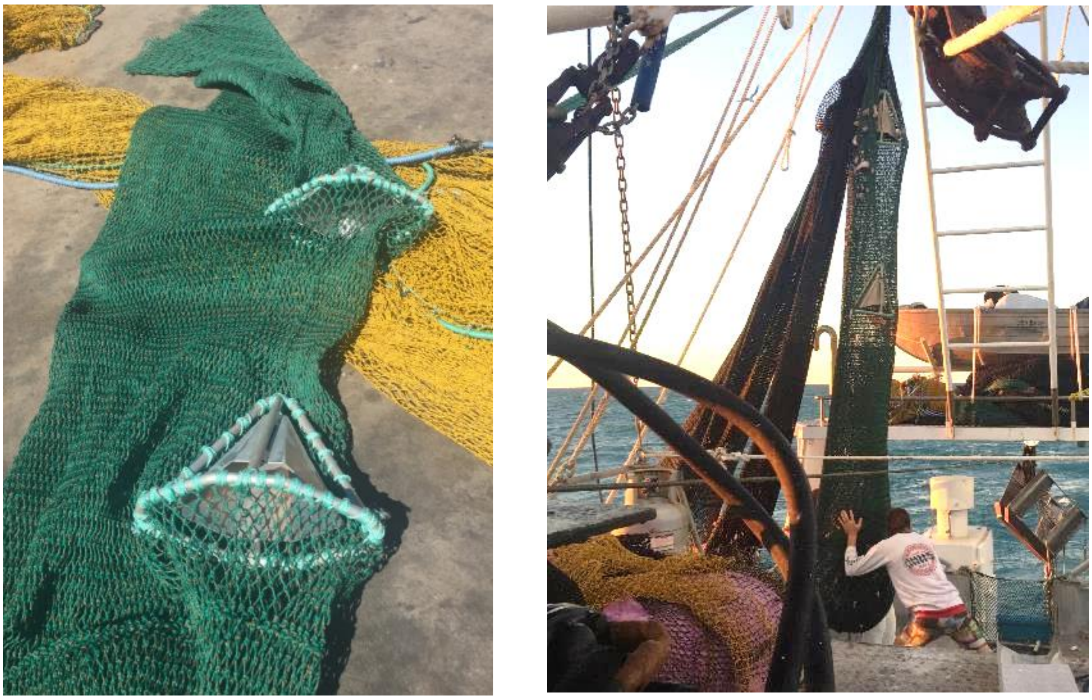

Figure 1: The Kon's Covered Fisheyes BRD (source: AFMA).

Tom's Fisheye

The Tom's Fisheye is essentially a single KCF. It was modified by A. Raptis & Sons Pty Ltd to have a larger escape gap (from 55 mm to 75mm) and smaller frame than the fisheyes used in the KCF. After trialling of the Tom's Fisheye in June 2018, further refinements were made including closing the base of the cone with a welded plate and another increase in the width of the escape opening (from 75mm to 94mm) and retested. For full specifications of the devices see Table 1 and Appendix 4.

Figure 2: Tom's Fisheye without cone back plate (left) and modified with cone back plate (right) (source: A. Raptis & Sons P/L).

FishEX 70

The FishEX 70 BRD (Figure 3) was developed by Austral Fisheries Pty Ltd. It is based on the same design principles of the KCF, utilising the cone shape to create areas of low water pressure to attract the fish to the escape gap. The FishEX 70 is used as a single device rather than the double set up of the KCF. For full specifications of the devices see Table 1 and Appendix 4.

Figure 3: The FishEX 70 BRD (source: Austral Fisheries).

Table 1: Specifications for the Kon's Covered Fisheyes, Tom's Fisheye, FishEX 70 and Square Mesh Panel BRDs.

Device	Total length (mm)	Width & height at opening (mm)	Escape gap (mm)	Position in codend*
Kon's Covered Fisheyes	360	430/205	55	55 &78
Tom's Fisheye (June)	350	360/185	75	65
Tom's Fisheye (November)	350	350/185	94	60
FishEX 70	550	460/275	70	65
Square Mesh Panel	600	400	101	120

*number of meshes from codend drawstrings.

The devices were trialled under normal commercial fishing operations in the Gulf of Carpentaria and off the Arnhem Land coast. The KCF BRD was trialled on *FV Xanadu I* from 2 to 10 June 2016 (Trial 1: 24 shots) and 31 October to 15 November 2016 (Trial 2: 45 shots). The Tom's Fisheye was trialled on the *FV Ocean Producer* from 25 May to 7 June 2018 (Trial 3: 29 shots). Modifications were then made to the device and it was retested on the *FV Eylandt Pearl* from 27 October to 12 November 2018 (Trial 4: 68 shots). The FishEX 70 was trialled on the *FV Newfish II* from 26 May to 7 June 2018 (Trial 5: 38 shots). AFMA scientific observers were deployed on the vessels to measure the performance of the new BRDs (Treatment) compared to a standard Square Mesh Panel BRD measuring 650mm x 450mm (Control) and collect catch composition data.

8 Gear Specifications

All vessels conducting the scientific trials of the new BRDs used quad-rigged tiger prawn nets with 51 - 56mm diamond mesh codends (measured from knot to knot), with the exception of the *FV Ocean Producer* which had quad-rigged banana prawn nets with 46mm diamond mesh codends. On average headline length was 14m and groundrope length was 16m. Nets were fished using number 7 bison boards (300kg in weight, 183cm length, 20cm width and 112cm height) or number 8 bison boards (350kg weight, 180cm in length, 22cm in width, 123cm in height) and skids of 300kg (170cm length, 18cm width, 112 cm height) were also used. All nets used during the trials were also fitted with standard TEDs.

9 Experimental Design

NPF Industry Pty Ltd developed a BRD testing guide, in consultation with CSIRO, to provide a standardised methodology for skippers to collect data when undertaking preliminary trials at sea of a new BRD. A rigorous experimental design for the formal scientific trials was also developed in consultation with CSIRO (Appendix 1), with two experimental designs developed and implemented. It was essential in the scientific trials, to ensure statistically robust data, that each BRD type was tested in each of the four quad-gear net positions (i.e. port outside, port inside, starboard inside, starboard outside) to account for possible differences in the fishing efficiency between the four nets.

9.1 Experimental Design 1

For scientific trials 1 and 2, the KCF BRD was tested against the control Square Mesh Panel (SMP) BRD. Two of the quad-gear nets were fitted with the SMP BRD located at 115 meshes from the codend drawstring. The other two quad-gear nets were fitted with the KCF BRD located at 55 and 78 meshes from the codend drawstring, in each of the two nets. This spacing between the two fisheye devices was determined by the manufacturer of the KCF BRD. During the trial, the BRDs were moved across quad-gear net positions to ensure each BRD was tested in each of the four quad-gear nets (Table 2).

Table 2: The schedule of BRD placements for the June 2016 trial of the Kon's Covered Fisheyes.

Trial Number	Nights	Port Outside	Port Inside	Starboard Inside	Starboard Outside
1	1, 2, 3	SMP2	KCF2	SMP1	KCF1
1	4, 5, 6	KCF2	SMP1	KCF1	SMP2
1	7, 8, 9	SMP1	KCF1	SMP2	KCF2
1*	10, 11, 12	KCF1	SMP2	KCF2	SMP1

*Nights lost due to bad weather; trial continued in November 2016

9.2 Experimental Design 2

For scientific trials 3 and 5, the Tom's Fisheye BRD was tested against the control SMP BRD. All four of the quad-gear nets were fitted with the control SMP BRD located at 115 meshes from the codend drawstrings and the Tom's Fisheye BRD located at 65 (Trial 3) and 60 meshes (Trial 5) from the codend drawstrings.

For trial 4, the FishEX 70 was also tested against the control Square Mesh Panel BRD with the SMP BRD again located at 115 meshes from the codend drawstring and the FishEX 70 BRD located at 65 meshes from the codend drawstring. According to the testing schedule, the control and treatment BRDs would be opened and closed using a standard mesh panel to simulate moving the BRDs across the four quad-gear nets. This change was made from the first experimental design to reduce the workload for the crew by eliminating the need to physically move codends or BRDs to the different net positions. The first four trials were undertaken for 12 sampling nights, with each of the control and treatment BRDs being trialled in a quad-gear net for three consecutive nights. The fifth trial was carried out over 16 nights, to allow an additional night of trialling of each BRD in each of the four quad-gear net positions. This design ensured that in all trials, each of the BRD types were tested in each of the quad-gear nets and always with two control BRD nets and two treatment BRD nets operating at any one time.

9.3 Data Collection

Data collection methods varied slightly after Trials 1 and 2 with knowledge gained from these trials on more effective and efficient ways to collect the required data. It should be noted that while catch composition data was collected during all trials, the analysis between the control and treatment BRDs has not been undertaken for this report as the main objective of the trials was to assess the effectiveness of the treatment BRDs in reducing small bycatch, rather than identifying exclusion of specific species. All Threatened, Endangered and Protected (TEP) species and potentially 'at-risk' bycatch species (identified through the CSIRO Environmental Risk Assessment and Sustainability Assessment of Fishing Effect (SAFE) analysis) caught in the trawls were also identified, measured and recorded as per standard AFMA observer protocols.

9.3.1 Trials 1 and 2 – Kon's Covered Fisheyes

Shots averaged four hours in duration, with three shots being undertaken each night between the hours of 18:00 and 07:30. The four codends were spilled into separated areas of the sorting tray to keep the catches split (Figure 4), so the performance of the KCF BRD could be analysed against the control SMP BRD nets.

To obtain accurate bycatch weights for each codend, the bycatch was diverted via chute into 60 L lug baskets and the contents of each lug basket weighed, before discarding. The commercial prawn component of each of the four codends was also processed separately to measure any prawn loss or gain between the treatment and control BRDs. Although weights for each prawn group (Tiger, Banana, Endeavour and King) were recorded, only total commercial prawn weight for each codend was used for the BRD comparisons.

Catch composition analysis was undertaken for every shot, with a 10kg sub sample of bycatch being collected from one control BRD net and one KCF BRD net. The bycatch in the sub samples were identified to species level, and weights for each species recorded.

Underwater video footage was also collected to provide insights into how the device functioned, fish behaviour, and whether any potential improvements could be made to the BRD design. No lighting system was used in conjunction with the camera, so footage was only able to be collected during the first shot of the evening. The decision was made not to pursue any form of independent lighting source for the camera as this may have impacted the efficacy of the KCF BRD and added another variable to the data.

Figure 4: Catch from the net with the Kon's Covered Fisheyes BRD (left) compared to a control net with a Square Mesh Panel BRD (right side), excluding the catch on the conveyer in the center. When compared, these two codends had the same quantity of prawns but significantly less bycatch in the net with the Kon's Covered Fisheyes BRD.

9.3.2 Trials 3, 4 and 5 – Tom's Fisheye and FishEX 70

Shot duration averaged 3.5 hours for the FishEX 70 and 3 hours for the Tom's Fisheye trials and was between the hours of 18:00 and 07:50.

To obtain accurate weights of the bycatch, crane scales were set up to weigh each codend individually. This method was used to reduce the intensity of the workload and improve accuracy when weighing individual lug baskets.

A lifting strap or 'snotter' was wrapped around the codend at a set distance from the drawstrings (approx. 40 meshes). The crane scales were secured to the snotter and lifting gear. Suspended codend gross weights were recorded after the scales stabilised. An empty, wet codend weight of 25kg was subtracted from the recorded gross weight to give a total catch weight for each codend. Retained catch weight was subtracted from total catch weight, which provided the total discard weight for each codend. Several calibrations/comparisons were made between 50kg hanging scales and the crane scales. Several baskets (under 50kg) were weighed with both scale types. The crane scale weights were more precise than the hanging scales in this range as they remained stable (very little weight change with vessel movement).

The catch was then spilt into separated areas of the sorting tray or into lug baskets and the catch from each of the four quad-gear nets processed separately to obtain weights of commercial prawns. Similar to the other two trials, weights for each prawn group (Tiger, Banana, Endeavour and King) were summed to give a total commercial prawn weight for each codend which was used for the BRD comparisons.

Catch composition data was collected for one shot per night, with a 10kg sub sample of bycatch being collected from one control BRD net and one treatment BRD net. The bycatch in the sub samples were identified to species level, and weights for each species recorded.

9.4 Bycatch Recapture

Prior to the start of Trial 1, the possibility of discarded bycatch being recaptured during typical commercial fishing operations was tested by carrying out a mark-recapture experiment.

As vessels operating in the NPF use a technique referred to as 'line fishing' whereby a vessel will conduct multiple shots along the same trawl line over a relatively short period of time, there was a possibility that discards may be recaptured during the subsequent shots. The likelihood of this occurring is anecdotally much higher in areas with little tidal or current movement and when trawls are carried out in shallower water depths. In order to ascertain whether bycatch recapture was occurring during this trip, 40kg of randomly selected bycatch was dyed using a concentrated methylene blue bath on the first and second nights of fishing and discarded as per standard fishing operations.

The following shots of the night were monitored for stained bycatch recaptures. On the first night, one dyed crab was recaptured (alive) on the third shot and on the second night no dyed bycatch was recaptured. Fishing was carried out between 16 and 18m water depths on both nights.

During Trial 2, 40kg of randomly selected bycatch was stained and discarded on the second night of fishing in approximately 24-26m depths. None of the stained bycatch was recaptured during subsequent shots. Fishing was conducted at this depth range throughout the entire November trial.

Concentrations used for the dying of bycatch were: 10g of methylene blue concentrate powder to 10L of seawater. In addition, 500ml of 'Blue Planet Multi Cure' water treatment for aquarium fish, containing Malachite Green 0.40mg/ml and Methylene Blue 4.00mg/ml was added to another10 L of seawater. It should also be noted that once mixed, the solution was only effective for staining biological material for approximately 12 hours.

9.5 Data Analysis

Total bycatch and total commercial prawn weights were recorded separately for each of the four quad-gear nets for each shot. This data was given to CSIRO for statistical analysis (see Appendices 2 and 3 for details). The bycatch volume and commercial prawn catch data from the two KCF BRD trials was combined for analysis as the trials were conducted on the same vessel with the same gear.

The bycatch and commercial prawn catch data for Trials 1 and 2 (combined) and Trials 3, 4 and 5 (separately) were assessed using a generalised linear mixed model (GLMM). After trying various model forms, a GLMM with a Gamma distribution was fitted to the bycatch data to determine the effectiveness of the treatment BRD net after removing the effect of time trawled, position in the quad gear, Trial Number and random effect of shot. Standard model diagnostics were checked and showed that the model fit was adequate. A similar model was then fitted to the commercial prawn catch data and determined to be a good fit for the prawn data.

The frequency of the differences between Control and Treatment BRDs for commercial prawn catch and bycatch (kgs caught per hour of trawling) were plotted using histograms for Trials 1, 2 and 5.

However, the histograms could not be produced for Trials 3 and 4 due to the unbalanced sampling that occurred.

10 Results

The modelled results for each new BRD tested are shown in Table 3 and further expanded in Sections 10.1 – 10.3.

Table 3: Modelled results from the scientific trails of the Kon's Covered Fisheyes, Tom's Fisheye and FishEX 70 BRDs.

Trial	***Device***	***Position***	***Trial Location***	***No. of shots (n)***	***Bycatch reduction (%)***	***Prawn catch (%)***
1 & 2	Kon's Covered Fisheyes	55 & 78 meshes	Weipa Karumba Mornington Vanderlins Sth Groote Nth Groote	69	**36.7** (C.I: 33.6% to 39.6%)	**+0.5** (C.I: -4% to +5%)
3	Tom's Fisheye (no back plate)	65 meshes (codends 46mm)	Vanderlins Gove Wessels Coburg	29	**23%** (C.I: 19% to 27%)	**-3.3%** (C.I: -11% to +5%
4	FishEX 70	65 meshes	Vanderlins	38	**41.82%** (C.I: 34.62 to 48.23%	**+0.13%** (C.I: -12.68 to +14.83%
5	Tom's Fisheye (with back plate)	60 meshes (codends 57mm)	North Groote Weipa	64	**43.73%** (C.I: 41.68 to 45.70	**-0.01%** (CI: -2.77% to +2.72%)

10.1 Kon's Covered Fisheye Trials

Due to deteriorating weather conditions during Trial 1 (June 2016), the trial was stopped after 9 nights of trawling. The sampling design schedule of BRD position in the second at-sea trial in November 2016 continued from where the first trial in June ceased to account for these three lost sampling days. This was followed by another full rotation of the BRD types across the four quad-gear net positions over the next 12 nights of trawling. The first trial was carried out within the Karumba and Mornington Island regions, while the second trial started at Weipa for the first night and then moved to north Vanderlins, followed by the Groote Eylandt region (Figure 5).

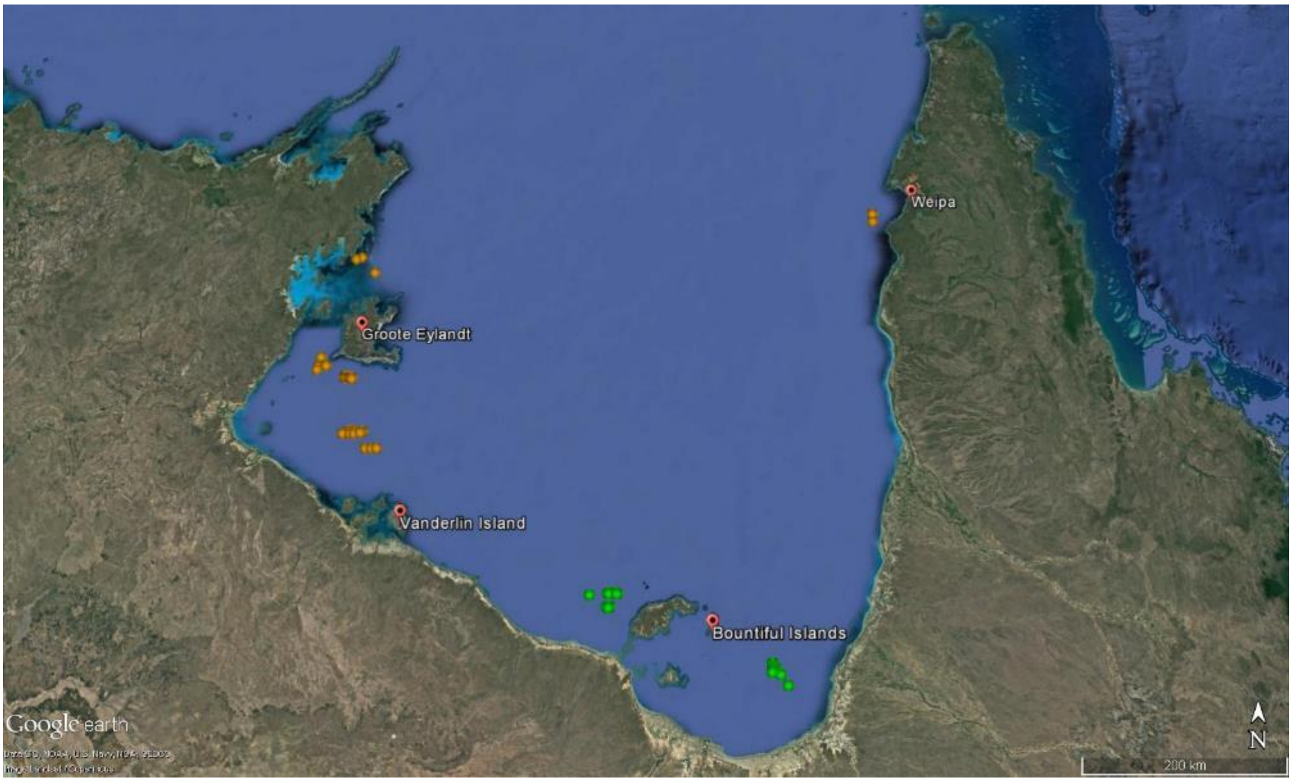

Figure 5: Area fished, showing show locations, during the 2016 scientific trials of the Kon's Covered Fisheyes BRD in June (green) and November (orange) in the Northern Prawn Fishery (source: Google Earth).

Analysis of the data showed significantly less bycatch was caught (p<0.0001) in the nets with the KCF BRDs installed compared to the nets with the standard Square Mesh Panel BRD installed. Mean bycatch reduction by weight achieved by the KCF BRD was 36.7% (95% Confidence Interval: 33.6 – 39.6%), when compared to the Square Mesh Panel across the 69 shots. The difference in commercial prawn catches between the treatment and control BRD nets was not significantly different (p=0.815).

There were large variations in both the total bycatch caught and the commercial prawns retained between each of the four quad-gear nets for most shots during the two trials (Table 2). While the commercial prawn catch was similar across the two trials (approximately 6.5kg per hour of trawling for one main quad-gear net), the bycatch caught during the second trial (34.51kg per hour) was about half that of the first trial (71.39kg per hour) (Table 4). This may be due to either differences in bycatch communities across the Gulf of Carpentaria and/or the different time of year the trials were undertaken.

Table 4: Comparison of the average bycatch caught and commercial prawns retained (kgs/hr) during the two at-sea trials of the Kon's Covered Fisheyes (see Appendix 2 for details).

	Trial 1 (June)	Trial 2 (November)
Bycatch Weight	71.39kg	34.51kg
Commercial Prawns	6.53kg	6.76kg

Bycatch reduction

There was almost always more bycatch caught in the nets with the control SMP BRD compared to the nets with the treatment KCF BRD (Figure 6). There were only 10 trawls where one of the KCF

BRD nets caught more bycatch than the adjacent Square Mesh Panel BRD net and eight of these occurred during one rotation (for three nights; Trawls 52 to 59) on only one side.

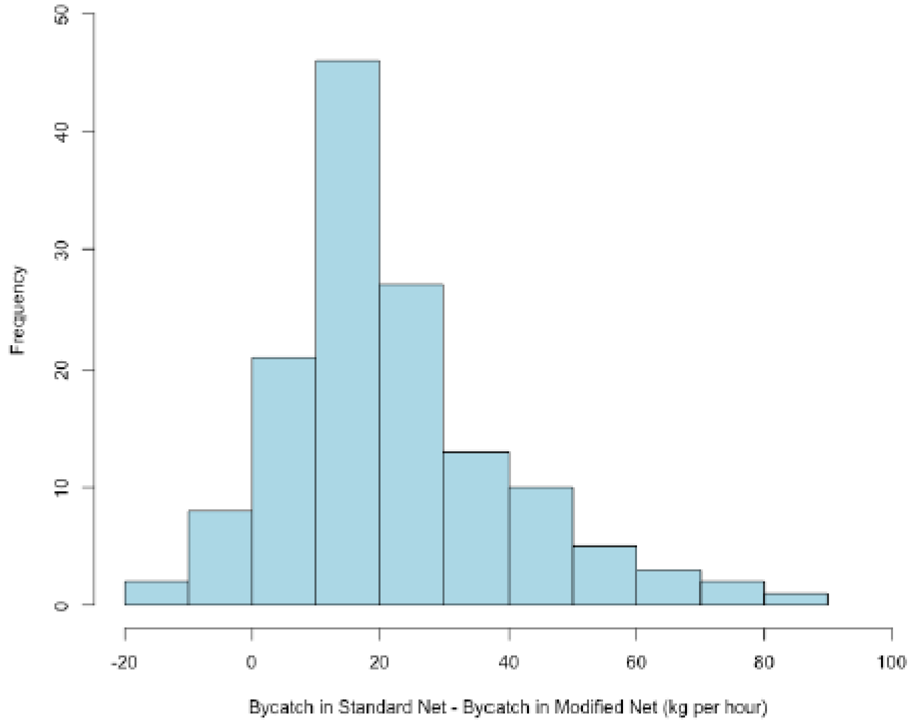

Figure 6: The frequency of the differences in total bycatch (kgs caught per hour of trawling) caught between the Kon's Covered Fisheyes BRD net and Square Mesh Panel BRD net on each side during the two at-sea trials (Appendix 2).

The results indicate that a large amount of the variability in the catches of bycatch is accounted for by the random effect. For example, the correlation between nets within a shot is very high (see Appendix 2) whereas the fixed net effect shows significantly less bycatch was caught in the KCF BRD nets compared to the Square Mesh Panel BRD nets. The transformed model coefficients indicate a reduction of approximately 36.7% in bycatch weights in the KCF BRD nets (95% Confidence Interval: -33.6 to -39.6%) compared to the Square Mesh Panel BRD nets. The catch rates in the different main quad gear positions were compared against the Port Inside and some significant differences were detected. The highest catch rates of bycatch were in the Port Outside and the lowest was in the Port Inside nets.

Prawn catch

For the commercial prawn catches, there was a more even distribution around 0 than the bycatch weights between the KCF BRD and Square Mesh Panel BRD nets (i.e.no difference between the treatment and control) during the two at-sea trials (Figure 7).

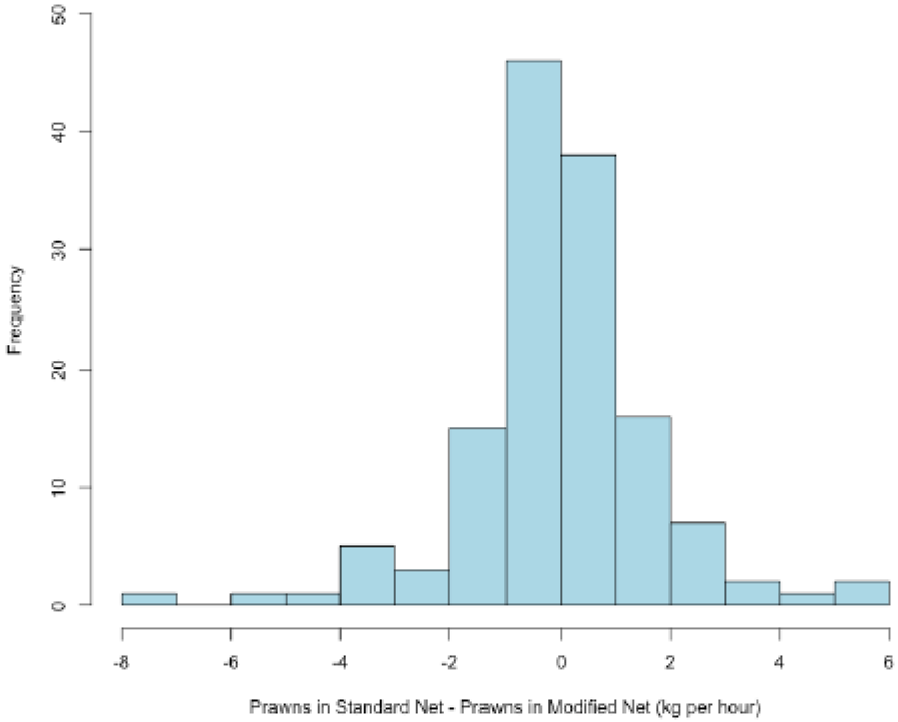

Figure 7: The frequency of the differences in commercial prawn catch (kgs caught per hour of trawling) between the Kon's Covered Fisheyes BRD net and Square Mesh Panel BRD net on each side during the two at-sea trials (Appendix 2).

As seen with the bycatch, most of the variability in commercial prawn catches is described by shot to shot variability (see Appendix 2). There were significantly more commercial prawns caught on the Port Outside net compared to the other main quad-gear nets. The net fixed effect shows negligible difference between the commercial prawns caught in the KCF BRD nets (Treatment) compared to the Square Mesh Panel BRD nets (Control) with 0.5% more commercial prawns caught using the KCF BRD nets (Confidence Interval: -3.8 – 5.1%).

10.2 Tom's Fisheye Trials

The Tom's Fisheye was first scientifically tested in June 2018 (Trial 3) in the Mornington and Vanderlins regions, then across the coast of Arnhem Land between Gove and the Coburg Peninsula. After modifications were made to the device, it was retested during October to November 2018 in the north Groote and Weipa regions (Trial 5; see Figure 8).

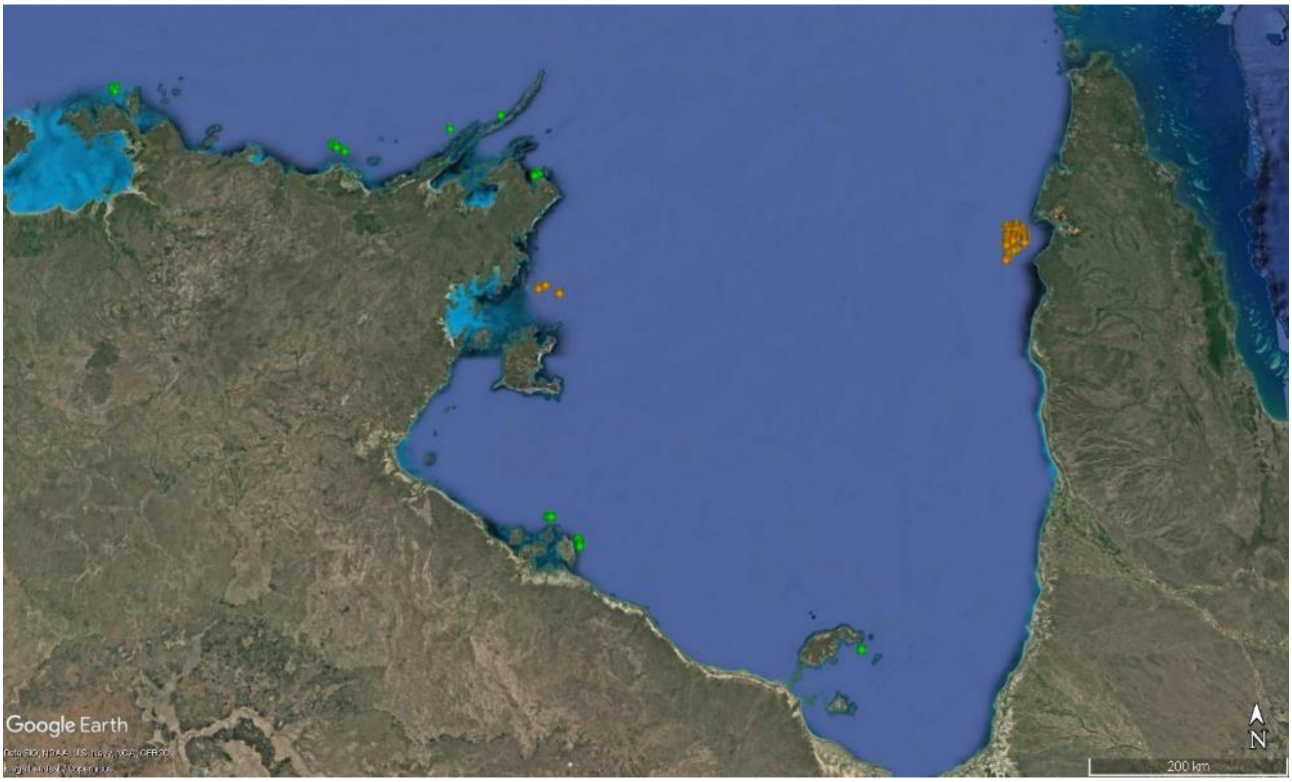

Figure 8: Area fished, showing show locations, during the 2018 scientific trials of the Tom's Fisheye BRD in June (green) and October/November (orange) in the Northern Prawn Fishery (source: Google Earth).

As the device was modified between trials and tested on different boats for each trial, the data was analysed separately. There were large variations in both the total bycatch caught and the commercial prawns retained between each of the four quad-gear nets for most shots during Trial 3 (Appendix 3). The nets with the SMP BRD caught, on average, both more bycatch and more commercial prawns (Table 5). In Trial 5, there were also large variations in both the total bycatch caught and the commercial prawns retained between each of the four-quad gear nets for most shots (Appendix 3). The nets with the SMP BRD caught, on average, more bycatch but a very similar amount of commercial prawns when compared to the Tom's Fisheye BRD (Table 5).

Table 5: Comparison of the average bycatch caught and commercial prawns retained (kgs/hr) during the two at-sea trials of the Tom's Fisheye (Appendix 3).

	Trial 3		Trial 5	
	Tom's FE	**SMP**	**Tom's FE**	**SMP**
Bycatch Volume	56.38	72.63	57.46	103.35
Commercial Prawns	4.73	5.17	8.23	8.28

Bycatch Reduction

Trial 3 (June 2018)

The results indicate that a large amount of the variability in the catches of bycatch is accounted for by the random effect i.e. the correlation between nets within a shot is very high. The net fixed effect shows a substantially lower mean bycatch rate in the Tom's Fisheye BRD nets compared to the Square Mesh Panel BRD nets ($p<0.0001$). Applying the exponential transformation to the model coefficients allows us to estimate the difference in bycatch in the two net types. The transformed model coefficients indicate a reduction of approximately 23.25% in bycatch weights in the Tom's Fisheye BRD nets (95% Confidence Interval: -19.25 to -27.05%) compared to the Square Mesh Panel BRD nets. The catch rates in the different main quad gear positions are compared against the Port Inside and some significant differences were detected. The highest catch rates of bycatch were in the Port Outside and least in the Starboard Outside.

Trial 5 (October/ November 2018)

The results indicate that a large amount of the variability in the catches of bycatch is accounted for by the random effect i.e. the correlation between nets within a shot is very high. The net fixed effect shows a significantly lower mean bycatch rate in the Tom's Fisheye BRD nets compared to the Square Mesh Panel BRD nets ($p<0.0001$) (Figure 9). Applying the exponential transformation to the model coefficients allows us to estimate the difference in bycatch for the two net types. The transformed model coefficients indicate a reduction of approximately 43.73% in bycatch weights in the Tom's Fisheye BRD nets (95% Confidence Interval: -41.68 to -45.70%) compared to the Square Mesh Panel BRD nets. The catch rates in the different main quad gear positions are compared against the Port Inside and some significant differences were detected. The highest catch rates of bycatch were in the Port Inside and least in the Starboard Inside.

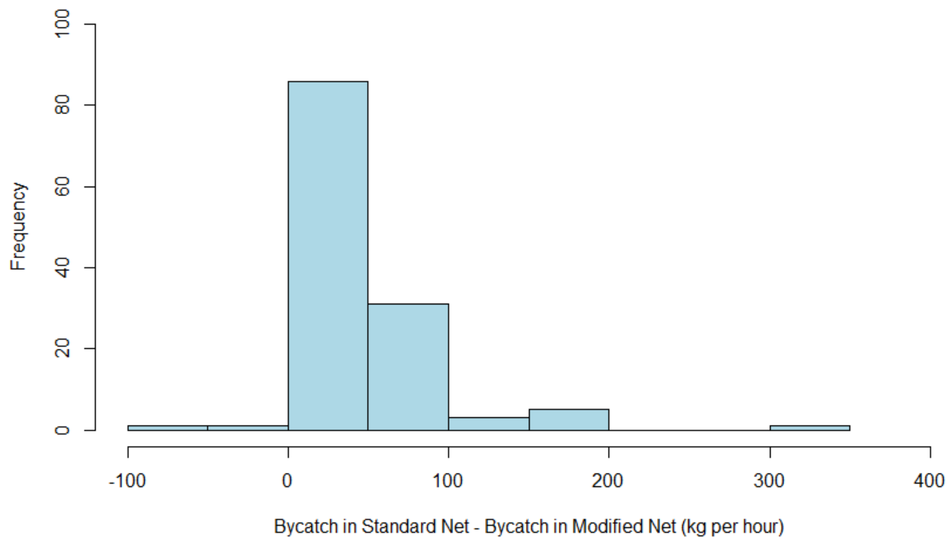

Figure 9: The frequency of the differences in total bycatch (kgs caught per hour of trawling) caught between the Tom's Fisheye BRD net and Square Mesh Panel BRD net on each side during the two at-sea trials (Appendix 3).

Prawn Catch

Trial 3 (June)

Most of the variability in commercial prawn catches is described by shot-to-shot variability. There were significantly more commercial prawns caught on the Port Inside net compared to the Starboard Outside and Starboard Inside. There is no evidence of a significant difference between the mean catch rate of commercial prawns caught in the Tom's Fisheye BRD nets compared to the Square Mesh Panel BRD nets. The model indicates a reduction in commercial prawn catch of 3.33% using the Tom's Fisheye BRD nets (Confidence Interval: -11.06% to +5.07%). This 95% confidence interval is quite wide indicating that the loss could be as high as 11% or conversely, there could be a mean increase of up to 5%.

Trial 5 (October/ November)

A lot of the variability in commercial prawn catches is described by shot-to-shot variability. There is no evidence of a significant difference in commercial prawn catch between the different net positions. There is also no evidence of a significant difference between the mean catch rate of commercial prawns caught in the Tom's Fisheye BRD nets compared to the Square Mesh Panel BRD nets. The model indicates a reduction in commercial prawn catch of 0.01% using the Tom's Fisheye BRD nets (Confidence Interval: -2.72 to +2.77%). This 95% confidence interval fairly evenly spreads 0 so there is high certainty that the difference in prawn catch between the two net types was minimal.

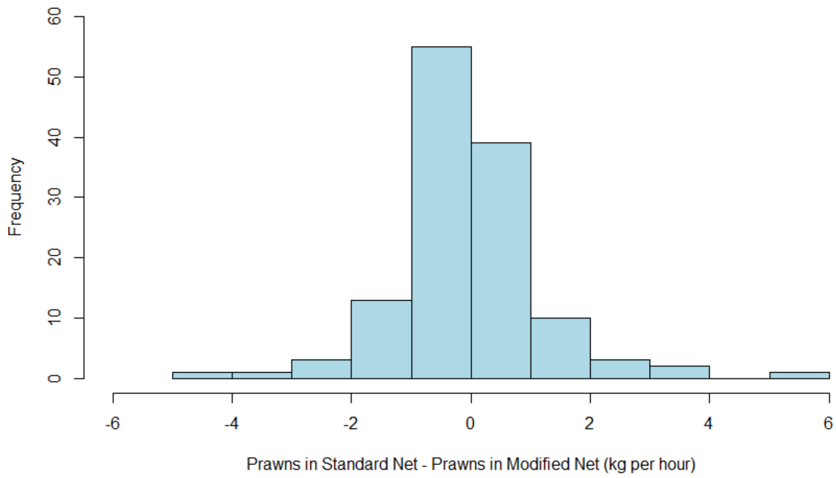

Figure 10: The frequency of the differences in commercial prawn catch (kgs caught per hour of trawling) between the Tom's Fisheye BRD net and Square Mesh Panel BRD net on each side during the two at-sea trials (Appendix 3).

10.3 FishEX 70

The FishEX 70 BRD was scientifically trialled in June 2018 in the Mornington Island region of the Gulf of Carpentaria (Trial 4; see Figure 11). During the trial, damage occurred to the Portside nets causing the sampling regime to become unbalanced. Further modelling was conducted on the data for the FishEX 70 to determine the sensitivity of the unbalanced data on the overall result.

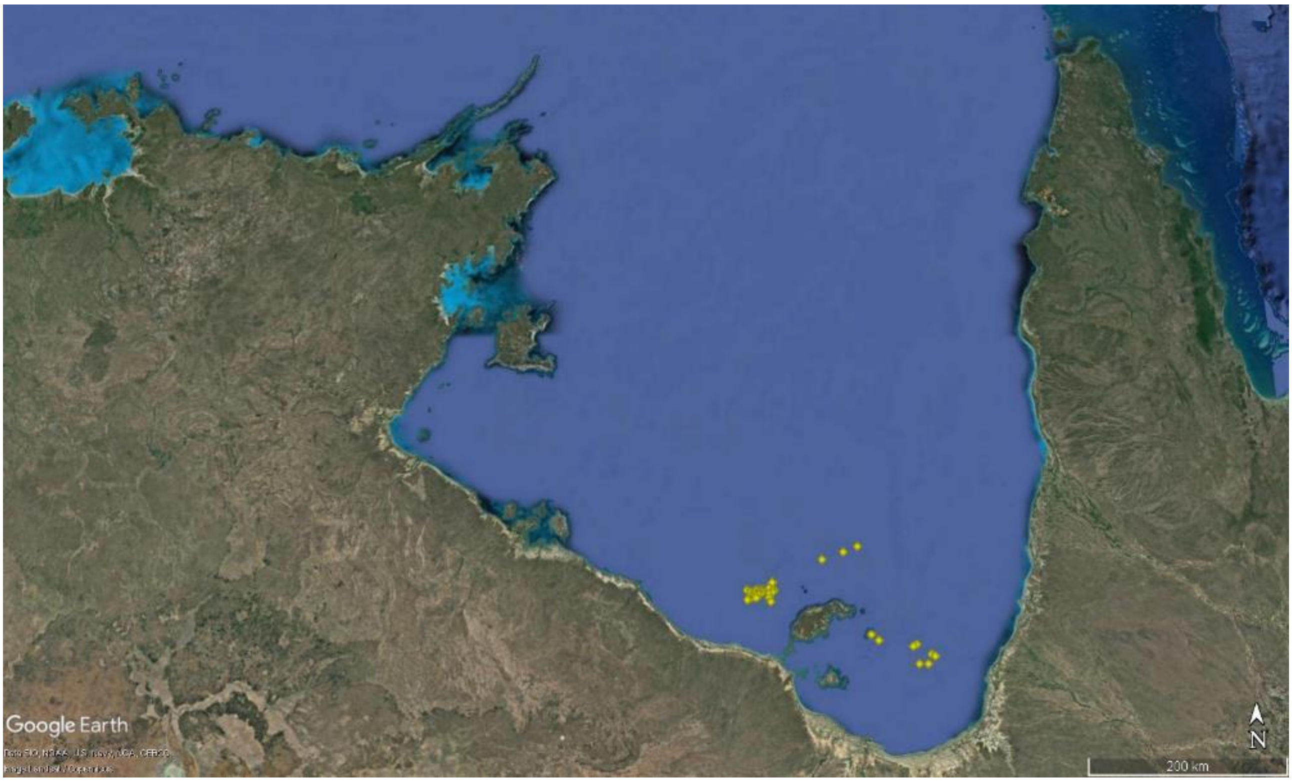

Figure 11: Area fished, showing shot locations, during the 2018 scientific trial of the FishEX 70 BRD in June in the Northern Prawn Fishery (source: Google Earth).

There were large variations in both the total bycatch caught and the commercial prawns retained between each of the four quad-gear nets for most shots (Appendix 3). The nets with the Square Mesh Panel BRD caught, on average, both more bycatch and commercial prawns (**Error! Reference source not found.**). The catch rates on the Square Mesh Panel BRD were comparable between this trial and the trial conducted at the same time using the Tom's Fisheye BRD (Trial 3).

Table 6: Comparison of the average bycatch caught and commercial prawns retained (kgs/hour) during the at-sea trial of the FishEX 70.

	FishEX70	Square Mesh Panel
Bycatch Volume	58.80	110.98
Commercial Prawns	3.78	5.04

Of particular concern in the analysis was the low catch rate of commercial prawns using the FishEX 70 BRD. We removed all records from the analysis where gear failure had occurred (either 'TEDed' (where the TED is blocked by a large organism forcing the catch out of the TED escape hole) or following the repair of the Portside nets) and recalculated the mean catch rates (**Error! Reference source not found.**). The difference in prawn catches between the two nets are less, indicating that the effect of the FishEX 70 BRD will most likely be exaggerated if these records were not removed from the analysis.

Table 7: Comparison of the average bycatch caught and commercial prawns retained (kgs/hour) during the at-sea trial of the FishEX 70, after removing records where the gear failed.

	FishEX70	Square Mesh Panel
Bycatch Volume	66.37	119.38
Commercial Prawns	4.38	5.18

Sensitivity Test

Removing the nets which were affected by gear failure reduced the dataset from 152 to 105 observations and made the data much less balanced with respect to net position (see Appendix 2). All but one of the nets on the Port Outside, in the remaining dataset, were Square Mesh Panel BRDs.

To test the sensitivity of the model to this lack of balance in the data, we removed all of the Port Outside records and refitted the bycatch model. The Reduction in bycatch was estimated as 41.01%, a value very close to that estimated by the model fitted to the broader data (41.82%). Similarly, the estimate in mean prawn catch was a reduction of 0.6%, a value close to the broader model (increase of 0.13%). Given the similarity between the models, we have confidence that the model can handle the unbalanced data and see no reason to remove all of the Port Outside nets from the analysis.

Bycatch Reduction

The fixed effects show the mean bycatch volumes caught was significantly less in the FishEX 70 BRD nets compared to the SMP BRD nets ($p<0.0001$). The transformed model coefficients indicate a reduction of approximately 41.82% in bycatch weights in the FishEX 70 BRD nets (95% Confidence Interval: 34.62 to 48.23%) compared to the SMP BRD nets. The catch rates in the different main quad-gear positions when compared against the Port Inside net showed no significant differences were detected.

Prawn Catch

There is no evidence of a significant difference between the mean commercial prawn catch rate for the FishEX 70 BRD nets compared to the Square Mesh Panel BRD nets. The model indicates an increase in commercial prawn catch of 0.13% using the FishEX 70 BRD nets (Confidence Interval: -12.68 – 14.83%). This 95% confidence interval is wide indicating that the loss could be as high as 12.6%, or conversely, there could be a mean increase of up to 14.8%.

11 Discussion

There is sufficient data from the scientific trials to demonstrate that the KCF, FishEX 70 and Tom's Fisheye BRD significantly reduce small fish bycatch from between 23.25% to 43.73% with no significant difference in the commercial prawn catch compared to a Square Mesh Panel BRD at 115 meshes from the codend drawstrings.

Based on analysis of underwater video footage taken during the trials of the KCF, modifications were made to the device including a larger escape gap and testing it as a single fisheye – the Tom's Fisheye. The footage and design of the KCF also led to the design of the FishEX 70 which utilised a back plate to close off the cone section. The back plate aimed to guide fish toward the escape gap and stop them from hiding in the cone rather than exiting the net (as was observed in video footage taken during preliminary trials of the FishEX 70). The modifications and redesign proved successful with the FishEX 70 achieving almost 42% bycatch reduction with no prawn loss and was subsequently approved for use in the NPF from August 2018. The initial version of the Tom's Fisheye BRD was also effective at reducing bycatch with minimal prawn loss but did not obtain the 30% reduction in small bycatch industry was seeking. The skipper for the June 2018 trial of the Tom's Fisheye continued to work with it in August 2018 during the tiger prawn season and discovered that the codend mesh size may influence results. The device appeared to work better with a larger mesh size (51 mm compared to 46 mm used in the June 2018 trial) which allowed better water flow through the codend. This reduced the 'flow-back' where the catch is pushed forward during winch up and prawns can be lost through the BRD escape opening. After discussions with the designers (A. Raptis & Sons P/L), the Tom's Fisheye was modified again to increase the escape gap and weld a back plate onto the cone. The modifications, combined with the larger mesh size, proved very effective at reducing small bycatch with almost 44% reduction and no prawn loss. This well exceeded the industry target of 30% bycatch reduction and the Tom's Fisheye was approved for use in the NPF from 1 April 2019.

In addition to the ecological benefit of reducing bycatch in the NPF, there may be a number of other significant benefits of using these new devices. The reduction in volume of bycatch may reduce net drag thereby having a fuel-saving effect. The reduced catch volume in the codends and reduced net drag also has the potential to increase the swept area of the trawls due to trawl doors being maintained at the optimal distance apart. Furthermore, with significantly less bycatch to sort, shorter processing times (from hopper to freezer) and the potential of reduced prawn damage from the smaller volumes of bycatch in the codend, these new BRDs could improve the quality of commercial prawns for the NPF.

These devices are most suited to tiger prawn fishing where there are generally lower volumes of total catch caught in each shot and a greater proportion of small bycatch caught compared to banana prawn fishing. It is possible that during very large shots (i.e. banana prawn fishing), product could be lost through the escape opening of the BRD which is located further down the codend towards the drawstring, but trials of the devices in this sub-fishery have not been undertaken.

Due to the location and shape of the devices and the need for small animals to swim through an escape opening, it is highly unlikely that these BRDs would be an effective mitigation device for some benthic or demersal species with poor swimming capabilities such as crabs, seahorses and pipefish. The ability of other marine species, such as sea snakes (Threatened, Endangered and Protected) to escape through these new BRDs is still unknown as only a small number of interactions were recorded during the trials. However, the number of sea snakes recorded during the trials of the KCF indicate these fisheye designs and their placement could enhance sea snake escapement (28 sea snakes in nets with KCF BRD compared to 49 in nets with a Square Mesh Panel BRD).

12 Industry Adoption

To achieve the voluntary industry target of a 30% bycatch reduction by mid-2018, skippers were encouraged to start using the KCF BRD in the tiger prawn season of 2017. However, there was minimal uptake during this season.

To assist fishers with the transition from the Square Mesh Panel or standard Fisheye BRDs to the new BRDs, an implementation plan was developed where vessels were required to operate with 50% of the vessels nets fitted with the new BRDs and the remaining 50% with the current BRD used. In August 2018, NPF Industry Pty Ltd and AFMA implemented the phase-in approach as a means of demonstrating to the fishers the effect of the new BRDs on significantly reducing small bycatch and at the same time maintaining their commercial prawn catches. As there would be significantly less bycatch volumes in their nets with the new BRDs compared to what skippers are used to, comparing their catches between the new device and what they previously used could alleviate concerns of prawn losses and show commercial prawn catch is not being compromised.

Initially, the majority of skippers tried the FishEX 70 with several opting for or changing to the KCF BRD during the 2018 phase-in. With the approval of the Tom's Fisheye in 2019, the phase-in approach continued with most of the fleet opting for the Tom's Fisheye BRD and several skippers installing them in all their nets in operation. The new BRDs will be fully implemented in the tiger prawn sub-fishery in 2020.

13 Further Research

The three new BRDs; Kons Covered Fisheyes, FishEX 70 and Tom's Fisheye, were all tested in the tiger prawn sub-fishery of the NPF. In the 2018 tiger prawn season, several skippers were fishing in the redleg banana prawn sub-fishery (a sub-fishery within the Joseph Bonaparte Gulf) using the KCF or FishEX 70. In this region of the fishery, skippers noted some possible commercial prawn loss but this was not quantified. As a result, while an AFMA scientific observer was onboard, an evaluation of the commercial prawn catches between the new BRDs and the control BRDs was carried out. There were no significant losses in commercial prawn catches detected. During the 2018 phase-in, particularly for the first month, operational issues were encountered with the FishEX 70 such as trawl bogging, prawn loss when catches were large and BRD floatation issues. Further work may be required to streamline this device and make it easier for operators to use if this BRD is to be used in the fishery. Due to the large volumes of catch generally encountered in the white and redleg banana prawn sub-fisheries, further research is required to determine the effectiveness of these new BRDs. These may need to be tested at different locations within the codend that would be more suitable to the levels of prawn catch and still be effective at reducing small bycatch (noting that the level of small bycatch in the white banana prawn sub-fishery is significantly lower than in the tiger prawn sub-fishery). Fishers have also indicated that sea snake catches have been much reduced when using these new BRDs, an area requiring further research to minimise impacts on Threatened, Endangered and Protected marine species. In 2020, NPF Industry Pty Ltd will have the Toms Fisheye BRD tested in a flume tank to better understand the water flow dynamics of the device and determine if further improvements in performance could be made.

The selectivity of these new BRDs on the bycatch species of the NPF may warrant further investigation to determine which species are most likely to benefit from the implementation of these BRDs into the fishery. The catch composition data collected could show any species-specific differences in the bycatch escapement rates and to provide additional information for further fine-tuning of the devices.

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Appendix 1: BRD Scientific Trial Design Example - Kon's Covered Fisheyes BRD trial.

Purpose:

To trial methods for reducing bycatch in the Northern Prawn Fishery using the industry developed double fisheye BRD (Kon's Covered Fisheyes or KCF) in accordance the objectives of the NPF Bycatch Strategy 2015-18 to reduce the capture of small bycatch by 30% in three years.

Methods:

<u>Phase 1: Arrival and Calibration</u>

A. Field team travel to Karumba to rendezvous with vessel.

B. Consult with skipper about the experimental design including:
  - separating each net when dumped on top of the hopper
  - processing each net separately through the hopper
  - discarding of bycatch to eliminate recapture
  - prawn loss strategy
  - any additional ways to manage the process

C. Prepare lug baskets with colour-coded surveyor tape for sea snakes (1 lug basket per net). Close handle gaps with tape (or plywood and cable ties) to stop snakes escaping through the holes and/or fingers being put through the handles.

D. Mark sections of the hopper for each net using colour-coded surveyor tape (see Fig 1)

E. Undertake initial trawls (approx. 4) with normal fishing gear to become familiar with sampling protocols and evaluate relative fishing performance of quad gear:
  - Weighing total bycatch in each net separately for each shot.
  - Sort prawn catch from each net separately for each shot.
  - Record number and lengths of TEP and at-risk species from each net for every shot.
  - Photograph all TEP and at-risk species with colour-coded scale tag.

F. Refine fishing performance to ensure equal fishing efficiency of nets to the extent possible, or document variance to enable this to be accounted for in analysis.

<u>NOTE:</u> the nets should already be fishing efficiently and comparably as the crew would have adjusted the chains at the start of the season. However, once the trial begins, there should be no fine-tuning or adjusting of the gears. The direct comparison to standard BRDs during each shot and the rotation schedule for nets will account for any fishing efficiency differences.

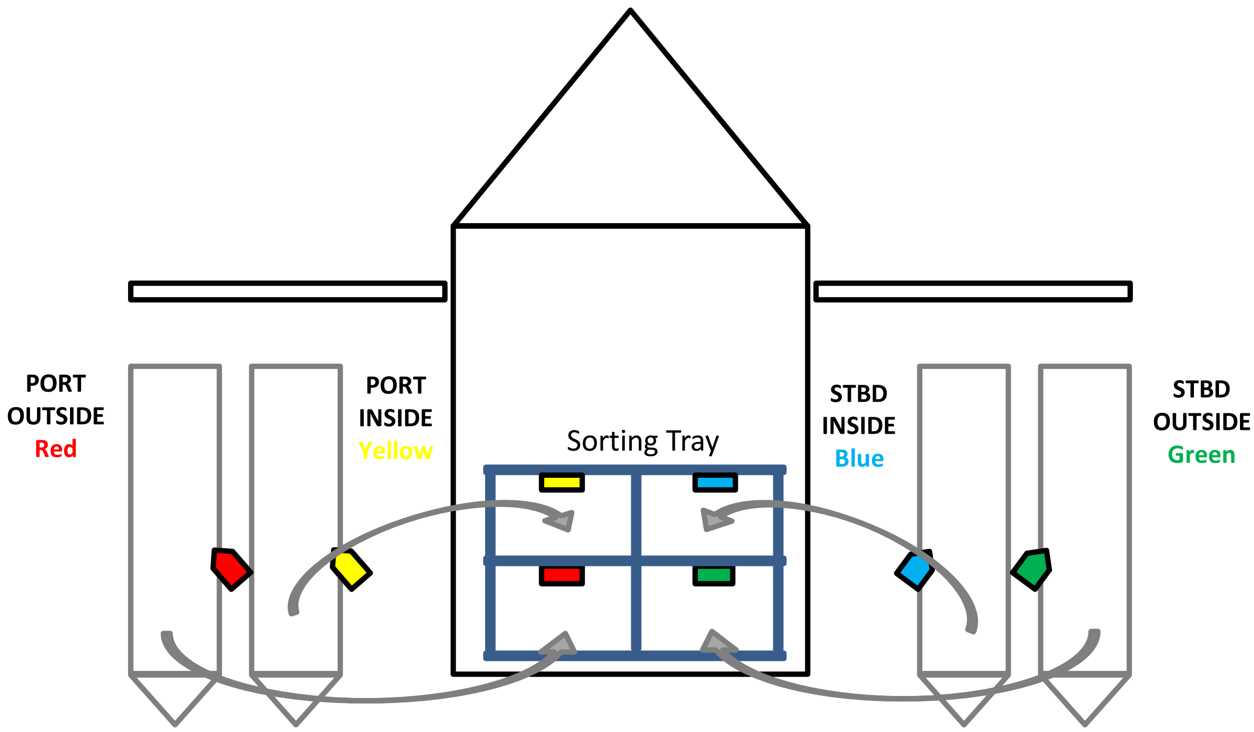

Figure 1: Diagrammatic representation of the colour coding to set up on back deck to facilitate separate codend catch processing. Diagram courtesy of CSIRO

One issue will be discarded bycatch being caught in the next shot. To test if this is happening, soak 40+kg of bycatch in methylene blue for the duration of one shot. Discard when the gear is next fully deployed. This is to test if the bycatch is recaptured; bycatch recaptures are more likely to occur in shallow water trawling. Therefore, it should be carried out in the depths likely to be fished by the vessel during the trial.

*If blue bycatch is recaptured, run the blue test again discarding the bycatch from the stern of the vessel. The bycatch chute is generally on the starboard side of the vessel, it may be possible that by discarding the bycatch over the stern of the vessel it is pushed past the open nets before it descends**

*NOTE: turning the vessel is not likely to counteract the recapture issue; weighing bycatch from quad gear will take up to an hour, too long for a vessel to be carrying out a turning manoeuvre; bycatch will most likely be sucked into the whirlpool created behind the vessel in a turn and be pushed out, and possibly down, by the propeller wash; having a vessel in a turn for that duration will also change the fishing efficiency of each of the four nets differently.

Phase 2: Installation and trial of KCF BRD

G. Install one KCF in the Port Outside net and one KCF in the Starboard Inside net. Cover up existing SMP BRD in these two nets. Colour code each of the codend nets using the colour-coded surveyor tape supplied so crew will know where to dump the catch. Data collection to include:

- Weighing total bycatch in each net separately for each shot.
- Sort prawn catch from each net separately for each shot. Get species, weights and grades from crew for each net.
- Record number and lengths of TEP and at-risk species from each net for every shot.
- Photograph all TEP and at-risk species with colour-coded scale tag.
- Take a 10kg subsample from one Experimental BRD (KCF) net and one control BRD (SMP) net for each shot and ID, where possible, to species level.
- Collect video footage on one shot during the night and last (dawn) shot to further evaluate performance.

H. At the end of the night's fishing, calculate the percentage of prawns for the Experimental BRDs versus control BRDs for each shot and averaged across the night. This will show any possible prawn loss per shot and per night between the Experimental and control BRDs. If possible, do this by prawn grade. If there is a loss, knowing the grade will help determine what size class might be escaping or being excluded. At the end of the three nights, average across all nights.

I. At the end of three fishing nights of the BRD trial, move codends as detailed in Table 1. This will require unstitching the whole codend and re-stitching it onto another trawl net throat as described in Table 1. <u>Ensure the surveyor tape is removed from each net before relocating and put tape on the new net in the positions as detailed in Table 1.</u>

J. Repeat data collection as described at H with codends in new positions.

K. Repeat H and I according to nights and BRD configuration in Table 1.

Rotating the BRDs is essential to ensure a statistically robust data collection by accounting for possible differences in the fishing efficiency between the four nets. If a problem occurs and a night of fishing is missed, continue with this schedule of rotation.

Table 1: BRD placements for trial

Nights	Port Outside	Port Inside	Starboard Inside	Starboard Outside
1, 2, 3	SMP2	KCF2	SMP1	KCF1
4, 5, 6	KCF2	SMP1	KCF1	SMP2
7, 8, 9	SMP1	KCF1	SMP2	KCF2
10, 11, 12	KCF1	SMP2	KCF2	SMP1

Prawn Loss/Gain

It is important to evaluate the nights prawn catch to determine if there's any loss or gain of product. There is an industry agreement that a <2.5% prawn loss is acceptable. This is the acceptable percentage of prawn loss specified in the NPF TED and BRD testing protocol.

After six nights of fishing, if the average prawn loss is greater than 2.5% for the KCFs then move the KCFs to 90 or 100 meshes from the codend drawstrings (in consultation with skipper and crew). Ensure you note on the datasheets that this has occurred. Fish for another one to two nights collecting data as detailed in Phase 2. After each night's fishing, calculate prawn loss or gain again.

Bycatch Loss/Gain

Calculate bycatch in the same manner as the prawn catch. This will give an indication of the effectiveness of the trialled BRD compared to the control BRD. Note: this is only an indication, scientific analysis of the data after the trial will be required to determine any significant changes and factoring in differences in the fishing efficiency of each net.

Appendix 2: CSIRO Final Analysis of the Kon's Covered Fisheyes BRD trial data

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Final Analysis of NPFI 'Kon's Covered Fisheyes' BRD Trial Data

Emma Lawrence and Gary Fry

19 December 2016

Contents

1 Background

The Northern Prawn Fishery Industry (NPFI) initiated a bycatch reduction program in 2015 with a target of 30% bycatch reduction across the fleet by 2018. The NPF currently has eight Bycatch Reduction Devices (BRDs) approved for use in the NPF. Whilst some of these devices may reduce bycatch, potential prawn loss from the use of these devices continues to be of major concern for the fishing industry. As gear technology and understanding of fish behaviour improves, scientists and commercial fishers are able to better design and tailor BRDs to retain target species and allow bycatch species to escape.

In 2016, scientific data was collected by AFMA scientific observers during two industry-led trials to test a new BRDs; 'Kons Covered Fisheyes' developed by Kon Triantopoulos from A. Raptis & Sons Pty Ltd, against a currently approved BRD; ‘Square Mesh Panel’. Prior to the first at-sea trial, NPFI contacted CSIRO to request expert opinion on the sampling design of the trial. Once the data was collected, NPFI and AFMA requested CSIRO's expertise in statistically assessing the data for bycatch reduction levels and commercial prawn retention rates. This analysis will be used in a peer-reviewed report published by NPFI and AFMA.

2 Objective

To assess the performance of the ‘Kons Covered Fisheyes’ BRD against a currently used bycatch reduction device, ‘Square Mesh Panel’ BRD, using a Generalized Linear Mixed Model analysis of the at-sea trial data.

3 Methods

The data was collected during two at-sea trials by AFMA scientific observers onboard the ‘*FV Xanadu*’ during the two industry-led trials between 2nd June – 10th June 2016 and 31st October – 15th November 2016. The at-sea trials used two ‘Kon’s Covered Fisheyes’ and two ‘Square Mesh Panel’ BRDs, where each BRD was placed in one of the four main nets of the quad gear configuration. At the commencement of the first trial, the ‘Kon’s Covered Fisheyes’ BRDs were placed in the Port Inside and Starboard Outside nets and the ‘Square Mesh Panel’ BRDs were placed in the Port Outside and Starboard Inside nets. After every three nights fishing, the BRDs were rotated into a different quad gear position so each specific BRD was tested in each of the four main quad gear nets. Due to deterioration of weather and shortening of the first trial by three days, each BRD was only tested in three of the four positions. At the commencement of the second trial, the BRDs were placed in the positions of the main quad gear nets that were missed in the first trial and trialled for three nights before another full rotation was completed.

Total bycatch and total commercial prawn weights were recorded separately for each of the nets for each shot. This data was given to CSIRO for further analysis.

After trying various model forms we fitted a generalized liner mixed model (glmm) with a Gamma distribution to the bycatch data to determine the effectiveness of the treatment net after removing the effect of time trawled, position in the main quad gear, Trial Number (1 or 2) and accounting for correlation within a shot. Standard model diagnostics were checked and showed that the model fit was adequate.

A similar model was then fitted to the prawn catch data. Model diagnostics were checked and this model was shown to also be a good fit for the prawn data.

4 Results

There were nine nights of trawling completed during the first at-sea BRD trial and 15 nights of trawling during the second at-sea trial. The first trial was carried out within the Bountiful Island and Mornington Island region while the second trial started at Weipa for the first night then moved to the north Vanderlins region followed by the Groote Eylandt region (see Appendix 1).

There were large variations in both the total bycatch caught (Table 1) and the commercial prawns retained between each of the four quad gear nets for most shots (Table 2) during the two trials. While the prawn catch was similar across the two trials, approximately 6.5kg per hour of trawling for one main quad gear net, the bycatch caught during the second trial (34.51kg) was about half that of the first trial (71.39kg) (Table 3). This may be due to either differences in bycatch communities across the Gulf of Carpentaria or the different time of year the trials were undertaken.

The bycatch volume and commercial prawn data from the two trials was then combined for analysis. As there was always a control and treatment on the port and starboard side at any one time, the differences in the bycatch volumes and prawn catch (kg per hour) between the two nets for each side for each shot was compared. There was almost always more bycatch caught in the main quad gear nets with the 'Square Mesh Panel' (Control BRD) compared to the nets with the 'Kon's Covered Fisheyes' (Treatment BRD) (Figure 1). There was only 10 trawls where one of the 'Kons' Covered Fisheyes' BRD nets caught more bycatch than the adjacent 'Square Mesh Panel' BRD net and eight of these occurred during one rotation (for three nights; Trawls 52 to 59) on only one side. For the commercial prawn catches, there was a more even distribution of catch between the 'Kon's Covered Fisheyes' BRD and 'Square Mesh Panel' BRD nets during the two at-sea trials (Figure 2).

Table 1. Comparison of the total bycatch (kgs) caught in each of the quad gear nets using the 'Kons Covered Fisheyes' (KCF) and 'Square Mesh Panel' (SMP) Bycatch Reduction Devices during the two at-sea trials. (BRDs: KCF1 – light green; KCF2 – dark green; SMP1 – light blue; SMP2 – dark blue).

Trip	Night Start Date	Shot Number	Port Outside	Port Inside	Starboard Inside	Starboard Outside
1	02-Jun-16	1	551	367	476	310
1	02-Jun-16	2	426	175	372	141
1	03-Jun-16	3	311	89	255	117
1	03-Jun-16	4	237	82	183	99
1	03-Jun-16	5	119	90	127	70
1	03-Jun-16	6	229	71	182	60
1	04-Jun-16	7	207	85	213	67
1	04-Jun-16	8	344	200	264	215
1	04-Jun-16	9	259	102	195	118
1	04-Jun-16	10	223	142	177	110
1	05-Jun-16	11	255	354	256	318
1	06-Jun-16	12	407	645	518	595
1	06-Jun-16	13	318	480	306	471
1	06-Jun-16	14	268	440	314	337
1	07-Jun-16	15	196	287	236	300
1	07-Jun-16	16	265	357	189	399
1	07-Jun-16	17	143	232	146	265
1	08-Jun-16	18	364	234	342	283
1	08-Jun-16	19	298	185	254	214
1	09-Jun-16	20	188	93	169	115
1	09-Jun-16	21	530	286	503	326
1	09-Jun-16	22	375	157	401	213
1	10-Jun-16	23	329	145	335	152
1	10-Jun-16	24	229	159	178	180
2	31-Oct-16	25	151	280	107	231
2	31-Oct-16	26	130	225	71	148
2	31-Oct-16	27	86	165	63	127
2	02-Nov-16	28	152	225	160	221
2	02-Nov-16	29	68	114	69	103
2	02-Nov-16	30	188	234	137	261
2	03-Nov-16	31	187	230	151	226
2	03-Nov-16	32	91	113	79	130
2	03-Nov-16	33	82	157	100	188
2	04-Nov-16	34	267	355	261	405
2	04-Nov-16	35	62	126	84	140
2	04-Nov-16	36	175	253	98	201
2	05-Nov-16	37	144	215	104	164
2	05-Nov-16	38	56	77	82	121
2	05-Nov-16	39	83	145	83	122
2	06-Nov-16	40	110	186	79	169
2	06-Nov-16	41	52	75	48	80
2	06-Nov-16	42	102	127	92	47

2	07-Nov-16	43	245	151	180	138
2	07-Nov-16	44	159	80	136	85
2	07-Nov-16	45	131	90	161	104
2	08-Nov-16	46	223	121	179	108
2	08-Nov-16	47	136	54	99	66
2	08-Nov-16	48	176	88	117	71
2	09-Nov-16	49	219	130	176	125
2	09-Nov-16	50	105	58	91	75
2	09-Nov-16	51	162	116	135	98
2	10-Nov-16	52	140	123	90	190
2	10-Nov-16	53	89	60	56	71
2	10-Nov-16	54	119	95	63	119
2	11-Nov-16	55	150	127	88	206
2	11-Nov-16	56	74	53	52	82
2	11-Nov-16	57	107	66	58	108
2	12-Nov-16	58	120	97	96	169
2	12-Nov-16	59	58	43	45	78
2	12-Nov-16	60	139	155	65	160
2	13-Nov-16	61	164	135	217	166
2	13-Nov-16	62	115	81	121	109
2	13-Nov-16	63	162	96	218	171
2	14-Nov-16	64	147	98	175	107
2	14-Nov-16	65	178	125	217	132
2	14-Nov-16	66	178	90	230	134
2	15-Nov-16	67	95	60	150	70
2	15-Nov-16	68	180	100	250	160
2	15-Nov-16	69	280	190	350	200

Table 2. Comparison of the commercial prawns retained (kgs) in each of the quad gear nets using the 'Kons Covered Fisheyes' (KCF) and 'Square Mesh Panel' (SMP) Bycatch Reduction Devices during the two at-sea trials. (BRDs: KCF1 – light green; KCF2 – dark green; SMP1 – light blue; SMP2 – dark blue).

Trip	Night Start Date	Shot Number	Port Outside	Port Inside	Starboard Inside	Starboard Outside
1	02-Jun-16	1	21.32	29.15	16.6	19.81
1	02-Jun-16	2	29.5	27.8	27.6	21.3
1	03-Jun-16	3	26.8	26.95	25.44	27.6
1	03-Jun-16	4	14.01	9.06	10.7	11.6
1	03-Jun-16	5	12.11	16.65	12.89	15.91
1	03-Jun-16	6	44.23	31.19	35.54	29.39
1	04-Jun-16	7	22.55	17	17.95	19.72
1	04-Jun-16	8	60.4	36.82	40.4	44
1	04-Jun-16	9	38.9	19.1	24	45
1	04-Jun-16	10	12.08	16.5	11.6	20.1
1	05-Jun-16	11	45	44.6	41.5	51.4
1	06-Jun-16	12	25.9	23.1	19.2	22.8
1	06-Jun-16	13	23.9	21.7	18.8	28.8
1	06-Jun-16	14	12.3	12.5	12.3	11.7
1	07-Jun-16	15	16.72	16.2	17.5	17.4
1	07-Jun-16	16	41	36.7	47.4	45.7
1	07-Jun-16	17	44.7	37.2	45.8	42
1	08-Jun-16	18	6.4	7.5	5.8	5.5
1	08-Jun-16	19	29.5	33.6	31.4	34.2
1	09-Jun-16	20	31.2	31.65	31.1	27.3
1	09-Jun-16	21	22.2	19.7	15.4	20.4
1	09-Jun-16	22	38.6	29.8	52.5	51.4
1	10-Jun-16	23	3.8	4.1	4	3.7
1	10-Jun-16	24	0.6	0.4	0.9	0.2
2	31-Oct-16	25	9.9	11	6.5	8.4
2	31-Oct-16	26	34.2	39.1	25.4	17.8
2	31-Oct-16	27	16.2	16.7	12.7	16
2	02-Nov-16	28	19.7	18.5	17.5	16.5
2	02-Nov-16	29	32.4	32.8	29.7	25.1
2	02-Nov-16	30	16	15.9	14.8	14.9
2	03-Nov-16	31	21.3	19.7	17.2	24.3
2	03-Nov-16	32	36.3	37	30.3	33.1
2	03-Nov-16	33	22.4	20.7	15.9	21.6
2	04-Nov-16	34	23.8	19.6	17.3	20.5
2	04-Nov-16	35	24	37.5	36.1	34
2	04-Nov-16	36	26.7	21.5	15.7	16.9
2	05-Nov-16	37	40.1	41.5	29.3	33
2	05-Nov-16	38	31.1	37.2	50	44.1
2	05-Nov-16	39	20.9	27.7	22.6	28.3
2	06-Nov-16	40	25.5	24.5	19.1	23.8
2	06-Nov-16	41	23.3	29	24.2	22.3
2	06-Nov-16	42	15.9	11.6	14.3	0.8

2	07-Nov-16	43	33.1	32.2	27.3	27.8
2	07-Nov-16	44	34	28.7	27.4	24.1
2	07-Nov-16	45	27.2	24.3	26.6	23.7
2	08-Nov-16	46	32.5	31.1	27.1	26.5
2	08-Nov-16	47	34	28.9	33.3	24.5
2	08-Nov-16	48	36.7	31.1	30.6	20.5
2	09-Nov-16	49	45.1	43.5	34.5	36
2	09-Nov-16	50	87.6	71.1	62.9	64.6
2	09-Nov-16	51	33.4	33.2	24.7	30.1
2	10-Nov-16	52	37.9	33.6	31.8	36
2	10-Nov-16	53	76.5	45.6	50.6	32.7
2	10-Nov-16	54	29.9	24.7	27.4	29
2	11-Nov-16	55	41.6	32.5	29.5	34.4
2	11-Nov-16	56	63.5	50.9	56.7	54
2	11-Nov-16	57	33.3	18.7	24	24
2	12-Nov-16	58	40.5	29.5	32.5	36.3
2	12-Nov-16	59	60.1	44.7	52.8	57.4
2	12-Nov-16	60	23.9	22.6	21.2	20.6
2	13-Nov-16	61	17.3	20.1	19.7	19.7
2	13-Nov-16	62	15.4	16.4	16.6	19.3
2	13-Nov-16	63	8.3	6.4	8.3	8.7
2	14-Nov-16	64	13.5	12.1	16	16.1
2	14-Nov-16	65	21.7	18.1	21.5	22.1
2	14-Nov-16	66	14.8	12.4	17.6	17.2
2	15-Nov-16	67	17.1	13.6	16.8	18.9
2	15-Nov-16	68	10.7	11.4	12.8	16
2	15-Nov-16	69	5.4	6.4	6.2	8.2

Table 3. Comparison of the average bycatch caught and commercial prawns retained (kgs) during the two at-sea trials.

	Trial 1	Trial 2
Bycatch Volume	71.39kg	34.51kg
Commercial Prawns	6.53kg	6.76kg

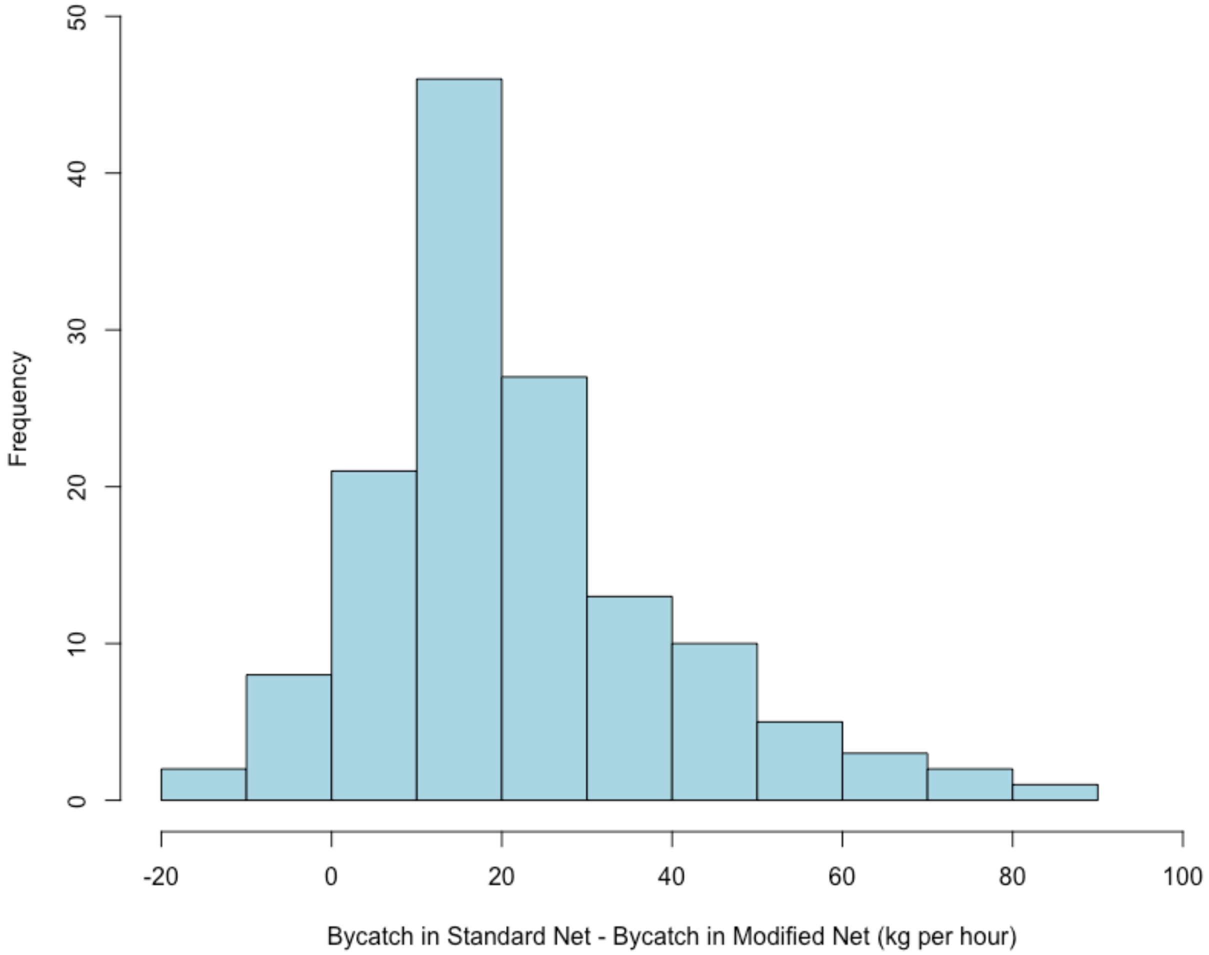

Figure 1. The frequency of the differences in total bycatch (kgs caught per hour of trawling) caught between the 'Kons Covered Fisheyes' BRD net and 'Square Mesh Panel' BRD net on each side during the two at-sea trials.

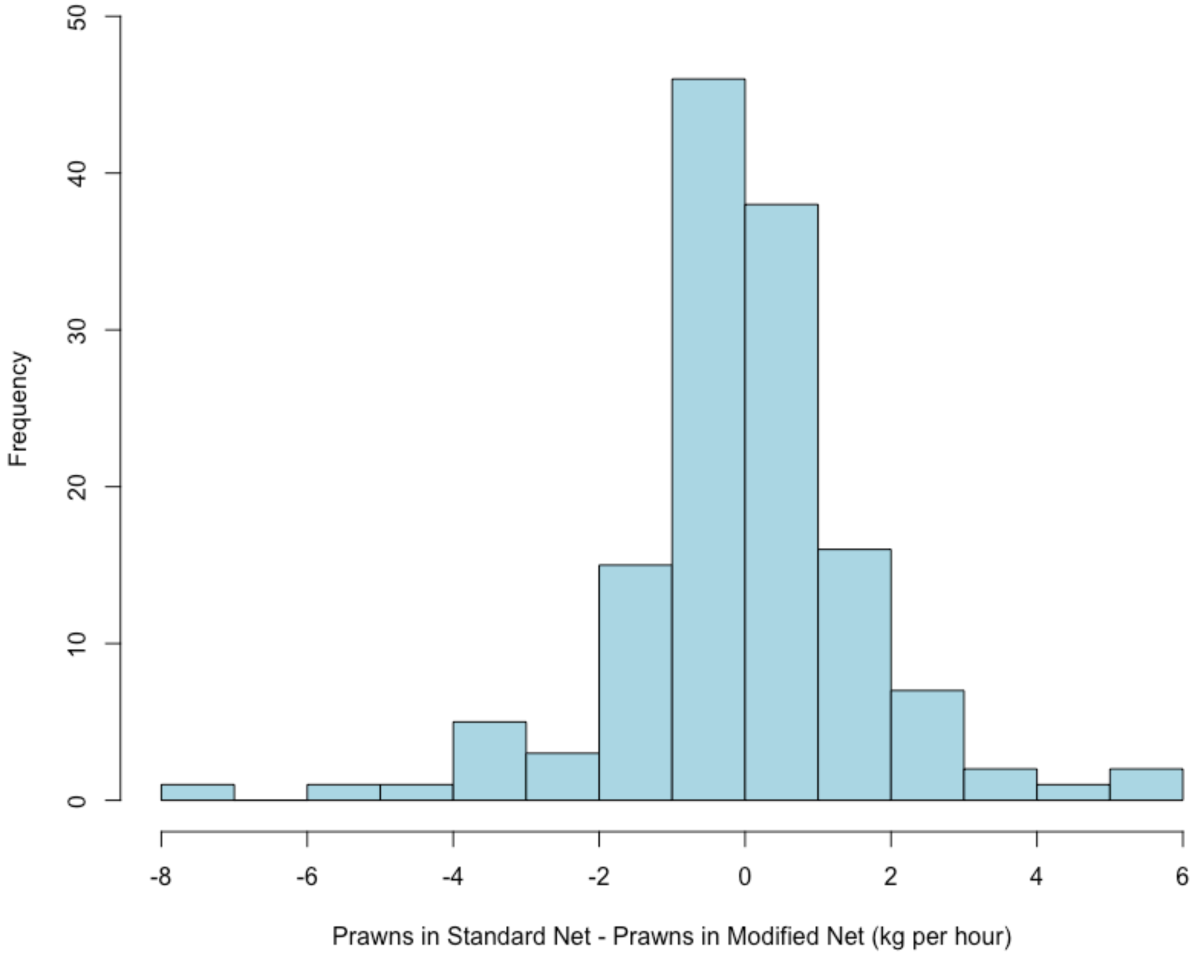

Figure 2. The frequency of the differences in commercial prawn catch (kgs caught per hour of trawling) between the 'Kons Covered Fisheyes' BRD net and 'Square Mesh Panel' BRD net on each side during the two at-sea trials.

4.1 Bycatch

The model for the bycatch data was fitted in R using the glmmPQL package in R and was of the form:

glmmPQL(Bycatch~offset(Duration)+Net+Position+Trial Number, random=~1|Shot, family=Gamma(link=log), data=AFMA_trial, maxit=100)

A summary of the fitted model is:

Random effects:

	Formula: ~1 |	Shot
	(Intercept)	Residual
StdDev:	0.4063487	0.1960974

Fixed effects: Bycatch ~ offset(Duration) + Net + Position + Trial Number

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.1652787	0.08940809	203	1.848588	0.0660
NetF	-0.4572924	0.02424490	203	-18.861384	0.0000
PositionPO	0.1774058	0.03375658	203	5.255445	0.0000
PositionSI	0.0574370	0.03375658	203	1.701506	0.0904
PositionSO	0.0200215	0.03384424	203	0.591576	0.5548
Trial 2	-0.6529772	0.10683954	67	-6.111756	0.0000

The results indicate that a large amount of the variability in the catches of bycatch is accounted for by the random effect i.e. the correlation between nets within a shot is very high. The fixed effects show significantly less bycatch was caught in the Treatment (F) nets ('Kon's Covered Fisheyes' BRD nets) compared to the control nets ('Square Mesh Panel' BRD nets). The transformed model coefficients indicate a reduction of approximately 36.7% in bycatch weights in the 'Kon's Covered Fisheyes' BRD nets (95% Confidence Interval: -33.6 to -39.6%) compared to the 'Square Mesh Panel' BRD nets. The catch rates in the different main quad gear positions are compared against the Port Inside and some significant differences were detected. The highest catch rates of bycatch were in the Port Outside and least in the Port Inside.

4.2 Commercial Prawns

The model for the commercial prawn data fitted was of the form:

glmmPQL(Prawns~offset(Duration)+Net+Position+Trial Number, random=~1|Shot, family=Gamma(link=log), data=AFMA_trial, maxit=100)

A summary of the fitted model is:

Random effects:

	Formula: ~1 |	Shot
	(Intercept)	Residual
StdDev:	0.6720651	0.1815889

Fixed effects: Prawns ~ offset(Duration) + Net + Position + Trial Number

	Value	Std.Error	DF	t-value	p-value
(Intercept)	-2.4763864	0.14164021	203	-17.483640	0.0000
NetF	0.0052603	0.02245884	203	0.234218	0.8151
PositionPO	0.0846957	0.03125906	203	2.709476	0.0073
PositionSI	-0.0227372	0.03125906	203	-0.727379	0.4678
PositionSO	-0.0044679	0.03134030	203	-0.142560	0.8868
Trial 2	0.1650870	0.17331795	67	0.952509	0.3443

Again, most of the variability in commercial prawn catches is described by shot to shot variability. There were significantly more commercial prawns caught on the Port Outside net compared to the other main quad gear net positions. The fixed effects show negligible difference between the commercial prawns caught in the Treatment nets ('Kon's Covered Fisheyes' BRD nets) compared to the Control nets ('Square Mesh Panel' BRD nets) with 0.5% more commercial prawns caught using the 'Kon's Covered Fisheyes' BRD nets (Confidence Interval: -3.8 to +5.1%). This shows that there is a mean percentage increase of 0.5% in commercial prawn catches when using the 'Kon's Covered Fisheyes' BRD with 95% confidence that any reduction in commercial prawn catch will be no more than 3.8% for any one trawl and an increase of 5.1% for any one trawl.

5 Interpretation

There is sufficient data to clearly show that there is significantly less bycatch caught in the nets with ‘Kons Covered Fisheyes’ BRDs installed compared to the nets with the standard ‘Square Mesh Panel’ BRD installed. This was mainly due to the quite notable and consistent reduction, around 36.7%, in bycatch volumes in these Treatment nets.

There was also no significant difference in commercial prawn catches between the nets fitted with ‘Kons Covered Fisheyes’ BRD compared to nets with the standard ‘Square Mesh Panel’ BRD. The initial analysis of the data from first trial showed that due to the complexity of the model fitted for this size sample and the large standard errors associated with the data, it was not possible to state that there no difference with any statistical confidence in commercial prawn catches between the Treatment and Control BRD nets.

By undertaking the second trial and increasing sample numbers, it was possible to demonstrate that was an overall mean increase in commercial prawn catches of 0.5% by weight. There is 95% certainty that the loss of commercial prawns using the ‘Kon’s Covered Fisheyes’ BRD is less than 3.8% in any one trawl and an increase in catch of up to 5.1% for any one trawl.

It was not possible to examine other variables such as dawn/dusk and bycatch volume effects on bycatch volumes and commercial prawn catches due to the small sample sizes and highly variable data from the two at-sea trials.

6 Appendix 1

The raw data from the two at-sea trials comparing the 'Kons Covered Fisheyes' BRD net and 'Square Mesh Panel' BRD net on total bycatch volumes and commercial prawn caught.

									Starboard Outside			Starboard Inside			Port Inside			Port Outside		
Trip	Shot	Date	Shot Start Time	Shot Finish Time	Start Latitude	Start Longitude	Finish Latitude	Finish Longitude	Net	Bycatch (kg)	Prawn Catch (kg)	Net	Bycatch (kgs)	Prawn Catch (kgs)	Net	Bycatch (kgs)	Prawn Catch (kgs)	Net	Bycatch (kgs)	Prawn Catch (kgs)
1	1	2/06/2016	18:15	21:15	17° 01 . 41'	140° 24 . 11'	16° 57 . 93'	140° 24 . 09'	F1	310	19.81	C1	476	16.6	F2	367	29.15	C2	551	21.32
1	2	2/06/2016	21:40	0:35	16° 58 . 12'	140° 23 . 79'	17° 01 . 52'	140° 23 . 79'	F1	141	21.3	C1	372	27.6	F2	175	27.8	C2	426	29.5
1	3	3/06/2016	0:50	3:55	17° 01 . 78'	140° 24 . 11'	16° 58 . 27'	140° 24 . 09'	F1	117	27.6	C1	255	25.44	F2	89	26.95	C2	311	26.8
1	4	3/06/2016	4:10	6:50	16° 58 . 02'	140° 23 . 78'	16° 59 . 77'	140° 23 . 80'	F1	99	11.6	C1	183	10.7	F2	82	9.06	C2	237	14.01
1	5	3/06/2016	18:35	22:25	17° 01 . 32'	140° 24 . 96'	17° 00 . 04'	140° 24 . 63'	F1	70	15.91	C1	127	12.89	F2	90	16.65	C2	119	12.11
1	6	3/06/2016	22:35	2:25	17° 00 . 56'	140° 24 . 64'	16° 58 . 70'	140° 24 . 63'	F1	60	29.39	C1	182	35.54	F2	71	31.19	C2	229	44.23
1	7	4/06/2016	2:35	6:25	16° 59 . 23'	140° 24 . 63'	16° 54 . 18'	140° 24 . 92'	F1	67	19.72	C1	213	17.95	F2	85	17	C2	207	22.55
1	8	4/06/2016	19:15	23:25	16° 22 . 79'	139° 01 . 04'	16° 22 . 78'	140° 56 . 15'	F1	215	44	C1	264	40.4	F2	200	36.82	C2	344	60.4
1	9	4/06/2016	23:35	3:30	16° 22 . 75'	138° 56 . 53'	16° 22 . 77'	139° 00 . 55'	F1	118	45	C1	195	24	F2	102	19.1	C2	259	38.9
1	10	5/06/2016	3:45	6:25	16° 22 . 78'	139° 00 . 95'	16° 25 . 52'	139° 00 . 27'	F1	110	20.1	C1	177	11.6	F2	142	16.5	C2	223	12.08
1	11	5/06/2016	22:40	2:55	16° 22 . 60'	138° 55 . 76'	16° 22 . 58'	138° 59 . 39'	C2	318	51.4	F1	256	41.5	C1	354	44.6	F2	255	45
1	12	6/06/2016	3:10	7:25	16° 22 . 57'	138° 58 . 76'	16° 22 . 59'	138° 57 . 62'	C2	595	22.8	F1	518	19.2	C1	645	23.1	F2	407	25.9
1	13	6/06/2016	18:15	22:25	16° 22 . 46'	139° 00 . 30'	16° 22 . 46'	138° 56 . 33'	C2	471	28.8	F1	306	18.8	C1	480	21.7	F2	318	23.9
1	14	6/06/2016	22:40	2:55	16° 22 . 44'	138° 56 . 83'	16° 23 . 14'	138° 45 . 34'	C2	337	11.7	F1	314	12.3	C1	440	12.5	F2	268	12.3
1	15	7/06/2016	3:05	6:55	16° 23 . 52'	138° 45 . 89'	16° 22 . 44'	139° 00 . 87'	C2	300	17.4	F1	236	17.5	C1	287	16.2	F2	196	16.72
1	16	7/06/2016	20:05	23:55	16° 29 . 56'	138° 57 . 21'	16° 29 . 85'	138° 56 . 63'	C2	399	45.7	F1	189	47.4	C1	357	36.7	F2	265	41
1	17	8/06/2016	0:10	4:25	16° 29 . 85'	138° 56 . 37'	16° 29 . 57'	138° 56 . 73'	C2	265	42	F1	146	45.8	C1	232	37.2	F2	143	44.7
1	18	8/06/2016	17:45	19:40	16° 29 . 51'	138° 57 . 07'	16° 29 . 79'	138° 56 . 76'	F2	283	5.5	C2	342	5.8	F1	234	7.5	C1	364	6.4
1	19	8/06/2016	19:55	0:30	16° 29 . 47'	138° 57 . 20'	16° 29 . 49'	138° 55 . 38'	F2	214	34.2	C2	254	31.4	F1	185	33.6	C1	298	29.5
1	20	9/06/2016	0:40	4:55	16° 29 . 50'	138° 54 . 88'	16° 29 . 58'	138° 53 . 59'	F2	115	27.3	C2	169	31.1	F1	93	31.65	C1	188	31.2

									Starboard Outside			Starboard Inside			Port Inside			Port Outside		
Trip	**Shot**	**Date**	**Shot Start Time**	**Shot Finish Time**	**Start Latitude**	**Start Longitude**	**Finish Latitude**	**Finish Longitude**	**Net**	**Bycatch (kg)**	**Prawn Catch (kg)**	**Net**	**Bycatch (kgs)**	**Prawn Catch (kgs)**	**Net**	**Bycatch (kgs)**	**Prawn Catch (kgs)**	**Net**	**Bycatch (kgs)**	**Prawn Catch (kgs)**
1	21	9/06/2016	18:55	22:55	17° 02 . 88'	140° 28 . 41'	16° 57 . 14'	140° 24 . 74'	F2	326	20.4	C2	503	15.4	F1	286	19.7	C1	530	22.2
1	22	9/06/2016	23:05	2:55	16° 56 . 95'	140° 24 . 21'	16° 59 . 59'	140° 25 . 78'	F2	213	51.4	C2	401	52.5	F1	157	29.8	C1	375	38.6
1	23	10/06/2016	3:05	7:00	17° 00 . 06'	140° 26 . 12'	17° 12 . 73'	140° 34 . 55'	F2	152	3.7	C2	335	4	F1	145	4.1	C1	329	3.8
1	24	10/06/2016	18:20	22:25	17° 07 . 98'	140° 31 . 93'	17° 14 . 84'	140° 35 . 66'	F2	180	0.2	C2	178	0.9	F1	159	0.4	C1	229	0.6
2	25	31/10/2016	18:05	20:45	12° 50 . 76'	141° 27 . 31'	12° 50 . 83'	141° 27 . 32'	SM1	231	8.4	FE1	107	6.5	SM2	280	11	FE2	151	9.9
2	26	31/10/2016	21:00	1:10	12° 50 . 39'	141° 27 . 35'	12° 55 . 15'	141° 27 . 32'	SM1	148	17.8	FE1	71	25.4	SM2	225	39.1	FE2	130	34.2
2	27	31/10/2016	1:25	5:20	12° 55 . 49'	141° 27 . 34'	12° 51 . 12'	141° 27 . 32'	SM1	127	16	FE1	63	12.7	SM2	165	16.7	FE2	86	16.2
2	28	2/11/2016	18:35	22:30	15° 05 . 55'	136° 46 . 95'	15° 05 . 59'	136° 41 . 77'	SM1	221	16.5	FE1	160	17.5	SM2	225	18.5	FE2	152	19.7
2	29	2/11/2016	22:40	2:45	15° 05 . 55'	136° 41 . 23'	15° 05 . 58'	136° 44 . 96'	SM1	103	25.1	FE1	69	29.7	SM2	114	32.8	FE2	68	32.4
2	30	2/11/2016	2:55	7:00	15° 05 . 59'	136° 44 . 42'	15° 05 . 55'	136° 44 . 35'	SM1	261	14.9	FE1	137	14.8	SM2	234	15.9	FE2	188	16
2	31	3/11/2016	18:40	22:35	14° 57 . 48'	136° 33 . 98'	14° 57 . 39'	136° 28 . 57'	SM1	226	24.3	FE1	151	17.2	SM2	230	19.7	FE2	187	21.3
2	32	3/11/2016	22:45	2:45	14° 57 . 37'	136° 28 . 04'	14° 57 . 38'	136° 31 . 69'	SM1	130	33.1	FE1	79	30.3	SM2	113	37	FE2	91	36.3
2	33	3/11/2016	2:55	7:10	14° 57 . 40'	136° 32 . 17'	14° 57 . 37'	136° 31 . 24'	SM1	188	21.6	FE1	100	15.9	SM2	157	20.7	FE2	82	22.4
2	34	4/11/2016	18:40	22:35	14° 56 . 27'	136° 33 . 70'	14° 56 . 29'	136° 31 . 19'	SM1	405	20.5	FE1	261	17.3	SM2	355	19.6	FE2	267	23.8
2	35	4/11/2016	22:45	2:45	14° 56 . 30'	136° 30 . 57'	14° 56 . 29'	136° 30 . 25'	SM1	140	34	FE1	84	36.1	SM2	126	37.5	FE2	62	24
2	36	4/11/2016	2:55	7:05	14° 56 . 31'	136° 30 . 73'	14° 56 . 30'	136° 31 . 49'	SM1	201	16.9	FE1	98	15.7	SM2	253	21.5	FE2	175	26.7
2	37	5/11/2016	18:35	22:30	14° 56 . 01'	136° 33 . 34'	14° 56 . 01'	136° 31 . 71'	SM1	164	33	FE1	104	29.3	SM2	215	41.5	FE2	144	40.1
2	38	5/11/2016	22:40	3:25	14° 56 . 04'	136° 32 . 29'	14° 55 . 99'	136° 31 . 26'	SM1	121	44.1	FE1	82	50	SM2	77	37.2	FE2	56	31.1
2	39	5/11/2016	3:40	7:00	14° 56 . 01'	136° 31 . 91'	14° 56 . 00'	136° 30 . 16'	SM1	122	28.3	FE1	83	22.6	SM2	145	27.7	FE2	83	20.9
2	40	6/11/2016	18:35	22:25	14° 55 . 95'	136° 33 . 31'	14° 55 . 93'	136° 30 . 99'	SM1	169	23.8	FE1	79	19.1	SM2	186	24.5	FE2	110	25.5
2	41	6/11/2016	22:40	2:40	14° 55 . 95'	136° 30 . 74'	14° 55 . 93'	136° 29 . 43'	SM1	80	22.3	FE1	48	24.2	SM2	75	29	FE2	52	23.3
2	42	6/11/2016	2:50	7:00	14° 55 . 96'	136° 28 . 96'	14° 55 . 93'	136° 30 . 67'	SM1	47	0.8	FE1	92	14.3	SM2	127	11.6	FE2	102	15.9
2	43	7/11/2016	18:50	22:30	14° 56 . 26'	136° 34 . 95'	14° 56 . 42'	136° 39 . 84'	FE2	138	27.8	SM1	180	27.3	FE1	151	32.2	SM2	245	33.1
2	44	7/11/2016	22:45	2:45	14° 56 . 40'	136° 39 . 32'	14° 56 . 79'	136° 37 . 07'	FE2	85	24.1	SM1	136	27.4	FE1	80	28.7	SM2	159	34
2	45	7/11/2016	3:00	7:00	14° 56 . 81'	136° 37 . 58'	14° 56 . 26'	136° 34 . 89'	FE2	104	23.7	SM1	161	26.6	FE1	90	24.3	SM2	131	27.2
2	46	8/11/2016	18:40	22:25	14° 56 . 17'	136° 34 . 99'	14° 56 . 53'	136° 38 . 15'	FE2	108	26.5	SM1	179	27.1	FE1	121	31.1	SM2	223	32.5
2	47	8/11/2016	22:40	2:40	14° 56 . 54'	136° 37 . 64'	14° 56 . 18'	136° 38 . 83'	FE2	66	24.5	SM1	99	33.3	FE1	54	28.9	SM2	136	34

									Starboard Outside			Starboard Inside			Port Inside			Port Outside		
Trip	Shot	Date	Shot Start Time	Shot Finish Time	Start Latitude	Start Longitude	Finish Latitude	Finish Longitude	Net	Bycatch (kg)	Prawn Catch (kg)	Net	Bycatch (kgs)	Prawn Catch (kgs)	Net	Bycatch (kgs)	Prawn Catch (kgs)	Net	Bycatch (kgs)	Prawn Catch (kgs)
2	48	8/11/2016	2:55	7:00	14° 56 . 52'	136° 38 . 68'	14° 56 . 18'	136° 38 . 27'	FE2	71	20.5	SM1	117	30.6	FE1	88	31.1	SM2	176	36.7
2	49	9/11/2016	18:35	22:25	14° 25 . 40'	136° 27 . 44'	14° 26 . 41'	136° 31 . 84'	FE2	125	36	SM1	176	34.5	FE1	130	43.5	SM2	219	45.1
2	50	9/11/2016	22:40	2:45	14° 26 . 30'	136° 31 . 46'	14° 25 . 85'	136° 29 . 44'	FE2	75	64.6	SM1	91	62.9	FE1	58	71.1	SM2	105	87.6
2	51	9/11/2016	2:55	7:05	14° 25 . 94'	136° 29 . 87'	14° 25 . 69'	136° 27 . 85'	FE2	98	30.1	SM1	135	24.7	FE1	116	33.2	SM2	162	33.4
2	52	10/11/2016	18:35	22:25	14° 25 . 32'	136° 27 . 41'	14° 26 . 32'	136° 31 . 88'	SM2	190	36	FE2	90	31.8	SM1	123	33.6	FE1	140	37.9
2	53	10/11/2016	22:40	2:45	14° 26 . 25'	136° 31 . 47'	14° 25 . 75'	136° 29 . 31'	SM2	71	32.7	FE2	56	50.6	SM1	60	45.6	FE1	89	76.5
2	54	10/11/2016	2:55	6:45	14° 25 . 87'	136° 29 . 80'	14° 25 . 96'	136° 28 . 53'	SM2	119	29	FE2	63	27.4	SM1	95	24.7	FE1	119	29.9
2	55	11/11/2016	18:35	22:25	14° 26 . 57'	136° 31 . 05'	14° 26 . 03'	136° 28 . 62'	SM2	206	34.4	FE2	88	29.5	SM1	127	32.5	FE1	150	41.6
2	56	11/11/2016	22:40	2:50	14° 26 . 14'	136° 29 . 07'	14° 25 . 82'	136° 27 . 71'	SM2	82	54	FE2	52	56.7	SM1	53	50.9	FE1	74	63.5
2	57	11/11/2016	3:00	7:00	14° 25 . 90'	136° 28 . 02'	14° 26 . 16'	136° 29 . 20'	SM2	108	24	FE2	58	24	SM1	66	18.7	FE1	107	33.3
2	58	12/11/2016	18:30	22:25	14° 26 . 71'	136° 31 . 35'	14° 26 . 05'	136° 28 . 37'	SM2	169	36.3	FE2	96	32.5	SM1	97	29.5	FE1	120	40.5
2	59	12/11/2016	22:40	2:45	14° 26 . 17'	136° 28 . 91'	14° 25 . 93'	136° 27 . 86'	SM2	78	57.4	FE2	45	52.8	SM1	43	44.7	FE1	58	60.1
2	60	12/11/2016	3:00	6:55	14° 25 . 83'	136° 27 . 41'	14° 26 . 35'	136° 29 . 65'	SM2	160	20.6	FE2	65	21.2	SM1	155	22.6	FE1	139	23.9
2	61	13/11/2016	18:40	22:25	14° 25 . 84'	136° 27 . 17'	14° 19 . 72'	136° 16 . 42'	FE1	166	19.7	SM2	217	19.7	FE2	135	20.1	SM1	164	17.3
2	62	13/11/2016	22:40	2:45	14° 19 . 25'	136° 16 . 31'	14° 19 . 65'	136° 16 . 43'	FE1	109	19.3	SM2	121	16.6	FE2	81	16.4	SM1	115	15.4
2	63	13/11/2016	2:55	7:00	14° 19 . 15'	136° 16 . 35'	14° 14 . 14'	136° 14 . 57'	FE1	171	8.7	SM2	218	8.3	FE2	96	6.4	SM1	162	8.3
2	64	14/11/2016	18:35	22:30	14° 14 . 32'	136° 12 . 79'	14° 19 . 41'	136° 12 . 06'	FE1	107	16.1	SM2	175	16	FE2	98	12.1	SM1	147	13.5
2	65	14/11/2016	22:40	2:45	14° 19 . 54'	136° 11 . 63'	14° 21 . 38'	136° 10 . 69'	FE1	132	22.1	SM2	217	21.5	FE2	125	18.1	SM1	178	21.7
2	66	14/11/2016	2:55	7:05	14° 20 . 97'	136° 10 . 86'	14° 15 . 98'	136° 11 . 79'	FE1	134	17.2	SM2	230	17.6	FE2	90	12.4	SM1	178	14.8
2	67	15/11/2016	18:35	22:30	13° 16 . 50'	136° 32 . 85'	13° 17 . 17'	136° 30 . 00'	FE1	70	18.9	SM2	150	16.8	FE2	60	13.6	SM1	95	17.1
2	68	15/11/2016	22:40	2:45	13° 17 . 48'	136° 29 . 67'	13° 25 . 30'	136° 40 . 82'	FE1	160	16	SM2	250	12.8	FE2	100	11.4	SM1	180	10.7
2	69	15/11/2016	3:00	7:00	13° 25 . 71'	136° 40 . 86'	13° 30 . 88'	136° 41 . 60'	FE1	200	8.2	SM2	350	6.2	FE2	190	6.4	SM1	280	5.4

Appendix 3: CSIRO Final Analysis of the FishEX 70 and Tom's Fisheye BRDs Trial Data

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Analysis of NPFI BRD Trial Data 2018

Emma Lawrence and Gary Fry

December 2018

Contents

1 Introduction

The Northern Prawn Fishery conducted trials of two new Bycatch Reduction Devices (BRDs) in May-June 2018 and, after further modifications were made, one of these was retested in November 2018 against a currently approved BRD; the Square Mesh Panel BRD. The two new devices were based on the approved Kon's Covered Fisheye device and both were tested as single 'fisheyes' positioned at 60 or 65 meshes from the codend drawstrings while the control Square Mesh Panel BRD was positioned at 120 meshes from the codend drawstring. The trials were done in accordance with the objectives of the NPF Bycatch Strategy 2015-18 to reduce the capture of small bycatch by 30% in 3 years. The Tom's Fisheye BRD was first trialled on the vessel Ocean Producer, and the FishEX70 BRD trialled on the vessel Newfish II, in May-June 2018 with the new devices positioned at 65 meshes from the codend drawstrings. The Tom's Fisheye BRD was trialled again on the vessel Eylandt Pearl in November 2018 and was positioned at 60 meshes from the codend drawstrings. The data was collected by AFMA scientific observers and given to CSIRO for analysis.

2 Methods

2.1 Sample Design

Due to time constraints in repeatedly installing and removing the control Square Mesh Panel BRDs and test BRDs (either the FishEX70 or Tom's Fisheye BRD) in the four codends, both of the control and test BRDs were installed in each of the four nets. Using standard codend mesh pieces, one of the control or test BRDs in a codend was covered up in turn to trial each BRD type in each of the four net positions in the quad gear to achieve a balanced design. The control and test BRD types were trialled in each of the four net positions for three consecutive nights. The experimental design used in the May-June 2018 trial is shown in Table 1.

Table 1. The experimental design of BRD net position across the quad gear during the May-June 2018 trial using the Ocean Producer to test the Single Kon's Covered Fisheye BRD and the Newfish II to test the FishEX70 BRD against the control Square Mesh Panel BRD.

Night	Port Outside (Net1)	Port Inside (Net2)	Starboard Inside (Net3)	Starboard Outside (Net4)
1	Calibration of standard nets (Square Mesh Panel @ 120 meshes)			
2-4	Test	Test	Control	Control
5-7	Test	Control	Control	Test
8-10	Control	Control	Test	Test
11-13	control	Test	Test	Control

The Ocean Producer did not undertake the final rotation of nets (see Appendix 1). While the Newfish II completed all rotations, a damaged net in the middle of the trial meant that the Port side nets did not perform correctly for the remainder of the trial (even though they were repaired). There were also ten instances of the nets being TED'd (blockage at the TED causing loss of catch) on this vessel.

The experimental design for the trial in November 2018 differed slightly from the May-June 2018 trial. The control and test BRD types were trialled in each of the four net positions for four consecutive nights and the BRD net position configuration differed by having, at any one time, one control Square Mesh Panel BRD and one test Tom's Fisheye BRD in the Port or Starboard side. The experimental design used in the November 2018 trial is shown in Table 2.

Table 2. The experimental design of BRD net position across the quad gear during the November 2018 trial using the Eylandt Pearl to test the Tom's Fisheye BRD against the control Square Mesh Panel BRD.

Night	Port Outside (Net1)	Port Inside (Net2)	Starboard Inside (Net3)	Starboard Outside (Net4)
1	Calibration of standard nets (Square Mesh Panel @ 120 meshes)			
2-5	Test	Control	Test	Control
6-9	Control	Test	Control	Test
10-13	Test	Control	Test	Control
14-17	Control	Test	Control	Test

Total bycatch and total commercial prawn weights were recorded separately for each of the nets for each shot. We first looked at the mean catch of prawns and bycatch per hour for each net type on each vessel. We then removed any data that was not indicative of usual fishing practices (gear failure, TED blockage), before fitting models to the data.

After trying various model forms we fitted a generalized liner mixed model (GLMM) with a Gamma distribution to the bycatch data to determine the effectiveness of the treatment net after removing the effect of time trawled (model offset), position in the main quad gear (main effect) and accounting for correlation within a shot (random effect). The models were fitted separately for each of the vessels. Standard model diagnostics were checked and showed that the model fits were adequate.

Similar models were then fitted to the commercial prawn catch data. Model diagnostics were checked and these models were shown to also be a good fit for the prawn data.

3 Results

3.1 Tom's Fisheye BRD (June trial)

The Ocean Producer completed twelve nights trawling. Each BRD was used at least nine times in each net position on the vessel (Table 3). The trawl duration was mostly between two and three and a half hours.

Table 3. Number of times each BRD was used in each position in the quad gear on the Ocean Producer

Position	Tom's Fisheye	Square Mesh Panel
Starboard Outside	11	18
Starboard Inside	20	9
Port Inside	18	11
Port Outside	9	20

There were large variations in both the total bycatch caught and the commercial prawns retained between each of the four quad gear nets for most shots (Appendix 1). The nets with the Square Mesh Panel BRD caught, on average, both more bycatch and commercial prawns (Table 4).

Table 4. Comparison of the average bycatch caught and commercial prawns retained (kgs/hour) during the at-sea trial on the Ocean Producer.

	Tom's Fisheye	Square Mesh Panel
Bycatch Volume	56.38	72.63
Commercial Prawns	4.73	5.17

3.1.1 Bycatch

We initially tried to fit the model for the bycatch data using the glmer function (lme4 package) in R, however due to convergence problems we used the glmmPQL function (MASS package) in R. While glmer offers a slightly more accurate statistical approximation, we expect the differences would be minor and so we are satisfied that the modelled estimates are accurate.

The model for the bycatch data was fitted in R using the glmmPQL package in R and was of the form:

glmmPQL(Bycatch~offset(Duration)+Net+Position, random=~1|Shot, family=Gamma(link=log))

A summary of the model output is:

Random effects:

	Formula: ~1 | Shot	
	(Intercept)	Residual
StdDev:	0.4344056	0.1293628

Fixed effects: Bycatch ~ offset(log(Duration)) + Net + Position

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.12299597	0.08753173	83	1.405159	0.1637
NetTomFE	-0.26459378	0.02590091	83	-10.215616	0.0000
PositionPO	0.00737341	0.03564716	83	0.206844	0.8366
PositionSI	-0.01230708	0.03477496	83	-0.353906	0.7243

PositionSO	-0.10858524	0.03528731	83	-3.077175	0.0028

The results indicate that a large amount of the variability in the catches of bycatch is accounted for by the random effect i.e. the correlation between nets within a shot is very high. The fixed effects show a significantly lower mean bycatch rate in the Tom's Fisheye BRD nets compared to the Square Mesh Panel BRD nets (p<0.0001). Applying the exponential transformation to the model coefficients allows us to estimate the difference in bycatch in the two net types. The transformed model coefficients indicate a reduction of approximately 23.25% in bycatch weights in the Tom's Fisheye BRD nets (95% Confidence Interval: -19.25 to -27.05%) compared to the Square Mesh Panel BRD nets. The catch rates in the different main quad gear positions are compared against the Port Inside and some significant differences were detected. The highest catch rates of bycatch were in the Port Outside and least in the Starboard Outside.

3.1.2 Commercial prawn catch

We again initially tried to fit the model for the commercial prawn data using the glmer function (lme4 package) in R, however due to convergence problems we used the glmmPQL function (MASS package) in R.

The model for the commercial prawn data was fitted in R using the glmmPQL package in R and was of the form:

glmmPQL(Prawns~offset(Duration)+Net+Position, random=~1|Shot, family=Gamma(link=log))

A summary of the model output is:

Random effects:

	Formula: ~1 | Shot	
	(Intercept)	Residual
StdDev:	0.9983746	0.2080645

Fixed effects: Prawns ~ offset(log(Duration)) + Net + Position

	Value	Std.Error	DF	t-value	p-value
(Intercept)	-2.7227073	0.19906539	80	-13.677452	0.0000
NetTomFE	-0.0338933	0.04251337	80	-0.797239	0.4277
PositionPO	-0.0923199	0.05851009	80	-1.577846	0.1185
PositionSI	-0.1143642	0.05691224	80	-2.009484	0.0479
PositionSO	-0.1657935	0.05817422	80	-2.849949	0.0056

Again, most of the variability in commercial prawn catches is described by shot to shot variability. There were significantly more commercial prawns caught on the Port Inside net compared to the Starboard Outside and Starboard Inside. There is no evidence of a significant difference between the mean catch rate of commercial prawns caught in the Tom's Fisheye BRD nets compared to the Square Mesh Panel BRD nets. The model indicates a reduction in commercial prawn catch of

3.33% using the Tom's Fisheye BRD nets (95% Confidence Interval: -11.06% to +5.07). This 95% confidence interval is quite wide indicating that the loss could be as high as 11% or conversely, there could be a mean increase of up to 5%.

3.2 FishEX70 BRD

The Newfish II completed twelve nights of at-sea trawling. Each BRD was used at least sixteen times in each net position on the vessel (Table 5). The trawl duration was mostly between three and four hours.

Table 5. Number of times each BRD was used in each position in the quad gear on the Newfish II

Position	FishEX70	Square Mesh Panel
Starboard Outside	16	22
Starboard Inside	20	18
Port Inside	20	18
Port Outside	20	28

There were large variations in both the total bycatch caught and the commercial prawns retained between each of the four quad gear nets for most shots (Appendix 1). The nets with the Square Mesh Panel BRD caught, on average, both more bycatch and commercial prawns (Table 6). The catch rates on the Square Mesh Panel BRD are comparable between this trial and the trial conducted using the Single Kon's Covered Fisheye BRD on the Ocean Producer.

Table 6. Comparison of the average bycatch caught and commercial prawns retained (kgs/hour) during the at-sea trial on the Newfish II.

	FishEX70	Square Mesh Panel
Bycatch Volume	58.80	110.98
Commercial Prawns	3.78	5.04

Of particular concern is the low catch rate of commercial prawns using the FishEX70 BRD. We removed all records from the analysis where gear failure had occurred (either TED'd or following the repair of the Port side nets) and recalculated the mean catch rates (Table 7). The difference in prawn catches between the two nets are less, indicating that the effect of the FishEX70 BRD will most likely be exacerbated if we do not remove these records from the analysis.

Table 7. Comparison of the average bycatch caught and commercial prawns retained (kgs/hour) during the at-sea trial on the Newfish II, after removing records where the gear failed.

	FishEX70	Square Mesh Panel
Bycatch Volume	66.37	119.38
Commercial Prawns	4.38	5.18

3.2.1 Bycatch

We initially tried to fit the model for the bycatch data using the glmer function (lme4 package) in R based on only the data where the gear performed correctly, however due to convergence problems we used the glmmPQL function (MASS package) in R.

The model for the bycatch data was fitted in R using the glmmPQL package in R and was of the form:

glmmPQL(Bycatch~offset(Duration)+Net+Position, random=~1|Shot, family=Gamma(link=log))

A summary of the model output is:

Random effects:

	Formula: ~1 | Shot	
	(Intercept)	Residual
StdDev:	0.4479757	0.2342977

Fixed effects: Bycatch ~ offset(log(Duration)) + Net + Position

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.5726158	0.10344688	63	5.535360	0.0000
NetFishEX70	-0.5415937	0.05954144	63	-9.096081	0.0000
PositionPO	0.0238960	0.09018370	63	0.264971	0.7919
PositionSI	-0.0407817	0.08158009	63	-0.499898	0.6189
PositionSO	-0.1024297	0.08058160	63	-1.271131	0.2084

The fixed effects show the mean bycatch was significantly less in the FishEX70 BRD nets compared to the Square Mesh Panel BRD nets ($p<0.0001$). The transformed model coefficients indicate a reduction of approximately 41.82% in bycatch weights in the FishEX70 BRD nets (95% Confidence Interval: -34.62 to -48.23%) compared to the Square Mesh Panel BRD nets. The catch rates in the different main quad gear positions are compared against the Port Inside and no significant differences were detected.

3.2.2 Commercial prawn catch

We again initially tried to fit the model for the commercial prawn data using the glmer function (lme4 package) in R based on only the data where the gear performed correctly, however due to convergence problems we used the glmmPQL function (MASS package) in R.

The model for the commercial prawn data was fitted in R using the glmmPQL package in R and was of the form:

glmmPQL(Prawns~offset(Duration)+Net+Position, random=~1|Shot, family=Gamma(link=log))

A summary of the model output is:

Random effects:

Formula: ~1 | Shot

	(Intercept)	Residual			
StdDev:	0.5457728	0.2744936			

Fixed effects: Prawns ~ offset(log(Duration)) + Net + Position

	Value	Std.Error	DF	t-value	p-value
(Intercept)	-2.5954524	0.12375346	63	-20.972766	0.0000
NetFishEX70	0.0013169	0.06987834	63	0.018845	0.9850
PositionPO	0.0230932	0.10568415	63	0.218511	0.8277
PositionSI	-0.0706131	0.09567397	63	-0.738060	0.4632
PositionSO	0.0350117	0.09448309	63	0.370560	0.7122

There is no evidence of a significant difference between the mean commercial prawn catch rate for the FishEX70 BRD nets compared to the Square Mesh Panel BRD nets. The model indicates an increase in commercial prawn catch of 0.13% using the FishEX70 BRD nets (Confidence Interval: -12.68 to +14.83%). This 95% confidence interval is wide indicating that the loss could be as high as 12.6% or conversely, there could be a mean increase of up to 14.8%.

3.2.3 Sensitivity test

Removing the nets which were affected by gear failure reduced the dataset from 152 to 105 observations and made the data much less balanced (Table 8). All but one of the nets on the Port Outside, in the remaining dataset, were Square Mesh Panel BRDs.

Table 8. Number of times each net was used in each position in quad on the Newfish II after the data affected by gear failure was removed

Position	FishEX70	Square Mesh Panel
Starboard Outside	14	22
Starboard Inside	19	17
Port Inside	8	7
Port Outside	1	17

To test the sensitivity of the model to this lack of balance in the data, we removed all of the Port Outside records and refitted the bycatch model. The reduction in bycatch was estimated as 41.01%, a value very close to that estimated by the model fitted to the broader data (41.82%). Similarly, the estimate in mean prawn catch was a reduction of 0.6%, a value close to the broader model (increase of 0.13%). Given the similarity between the models, we have confidence that the model can handle the unbalanced data and see no reason to remove the Port Outside nets from the analysis.

3.3 Tom's Fisheye BRD (November trial)

The Eylandt Pearl completed sixteen nights of at-sea trawling. Each BRD was used 32 times in each net position on the vessel (Table 9Table 5). The trawl duration was mostly between three and four hours.

Table 9. Number of times each BRD was used in each position in the quad gear on the Eylandt Pearl

Position	Tom's Fisheye	Square Mesh Panel
Starboard Outside	32	32
Starboard Inside	32	32
Port Inside	32	32
Port Outside	32	32

There were large variations in both the total bycatch caught and the commercial prawns retained between each of the four quad gear nets for most shots (Appendix 1). The nets with the Square Mesh Panel BRD caught, on average, more bycatch but a very similar amount of commercial prawns when compared to the Tom's Fisheye BRD (Table 10).

Table 10. Comparison of the average bycatch caught and commercial prawns retained (kgs/hour) during the at-sea trial on the Eylandt Pearl.

	Tom's Fisheye	Square Mesh Panel
Bycatch Volume	57.46	103.35
Commercial Prawns	8.23	8.28

3.3.1 Bycatch

We initially tried to fit the model for the bycatch data using the glmer function (lme4 package) in R, however due to convergence problems we used the glmmPQL function (MASS package) in R:

The model for the bycatch data was fitted in R using the glmmPQL package in R and was of the form:

glmmPQL(Bycatch~offset(Duration) + Net + Position, random=~1|Shot, family=Gamma(link=log))

A summary of the model output is:

Random effects:

Formula: ~1 | Shot

	(Intercept)	Residual
StdDev:	0.7120319	0.1422119

Fixed effects: Bycatch ~ offset(log(Duration)) + Net + Position

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.3270023	0.09284700	182	3.521948	0.0005
NetTomFE	-0.5749697	0.01824617	182	-31.511805	0.0000

PositionPO	-0.0363627	0.02587585	182	-1.405275	0.1616
PositionSI	-0.0638446	0.02573378	182	-2.480964	0.0140
PositionSO	-0.0291946	0.02559679	182	-1.140557	0.2556

The results indicate that a large amount of the variability in the catches of bycatch is accounted for by the random effect i.e. the correlation between nets within a shot is very high. The fixed effects show a significantly lower mean bycatch rate in the Tom's Fisheye BRD nets compared to the Square Mesh Panel BRD nets (p<0.0001). Applying the exponential transformation to the model coefficients allows us to estimate the difference in bycatch for the two net types. The transformed model coefficients indicate a reduction of approximately 43.73% in bycatch weights in the Tom's Fisheye BRD nets (95% Confidence Interval: -41.68 to -45.70%) compared to the Square Mesh Panel BRD nets. The catch rates in the different main quad gear positions are compared against the Port Inside and some significant differences were detected. The highest catch rates of bycatch were in the Port Inside and least in the Starboard Inside.

3.3.2 Commercial prawn catch

The model for the commercial prawn data was fitted using the glmer function in R (lme4 package) and was of the form:

glmer(Prawns~offset(Duration) + Net + Position+ (1|Shot), family=Gamma(link=log))

A summary of the model output is:

Random effects:

	Formula: ~1 | Shot			
	(Intercept)	Residual		
StdDev:	0.3177	0.1661		
	Value	Std.Error	t-value	p-value
(Intercept)	-2.133e+00	1.010e-01	-21.134	<2e-16
NetTomFE	-9.161e-05	1.400e-02	-0.007	0.995
PositionPO	-1.100e-02	1.987e-02	-0.554	0.580
PositionSI	8.838e-03	1.973e-02	0.448	0.654
PositionSO	8.789e-03	1.959e-02	0.449	0.654

Again, a lot of the variability in commercial prawn catches is described by shot to shot variability. There is no evidence of a significant difference in commercial prawn catch between the different net positions. There is also no evidence of a significant difference between the mean catch rate of commercial prawns caught in the Tom's Fisheye BRD nets compared to the Square Mesh Panel BRD nets. The model indicates a reduction in commercial prawn catch of 0.01% using the Tom's Fisheye BRD nets (95% Confidence Interval: -2.72 to +2.77%). This 95% confidence interval was quite evenly spread around 0 so the difference in prawn catch between the two net types is likely to be minimal.

4 Conclusion and recommendations

There is sufficient data to clearly show that there is significantly less bycatch caught in the nets with all of the trialled BRDs; the FishEX 70 and Tom's Fisheye BRDs installed compared to the nets with the standard Square Mesh Panel BRD installed. In terms of bycatch reduction, the FishEX70 BRD and Tom's Fisheye BRD (November) were noticeably better than the Tom's Fisheye BRD trialled in June, achieving a mean reduction in bycatch of 41% and 44% compared to the 23% of the Tom's Fisheye BRD in June.

There was no significant difference in mean commercial prawn catches between the nets fitted with either of the two trialled BRDs compared to nets with the standard Square Mesh Panel BRD. The confidence intervals around the estimates are very wide so it was not possible to state that there was no difference with any statistical confidence.

To improve the estimates of the difference between prawn catches more trials would need to be conducted. Undertaking shots of more comparable duration during the May-June 2018 trial would have ensured a more balanced sample and help in improving the estimates by reducing some of the variability in the data.

Finally, given the gear failure resulting in the loss of all data on the Port Side of one vessel part-way through the trial, we would recommend in the future always ensuring there is one test BRD net and one control BRD net on each side of the vessel. This is more of a 'risk-management' strategy to maximise balance in the dataset in the event of malfunction.

5 Appendix 1

Table 11 Data collected on board the Ocean Producer trialling the Tom's Fisheye (TomFE) BRD in June 2018 against the standard Square Mesh Panel (SMP) BRD

						Starboard Outside			Starboard Inside			Port Inside			Port Outside		
Shot	Date	Shot Start Time	Shot Finish Time	Start Latitude	Start Longitude	BRD	Bycatch (kg)	Prawn Catch (kg)	BRD	Bycatch (kg)	Prawn Catch (kg)	BRD	Bycatch (kg)	Prawn Catch (kg)	BRD	Bycatch (kg)	Prawn Catch (kg)
1	25-May	23:25	01:50	16 26 18	138 20 30	SMP	264.02	2.98	SMP	293.64	3.36	TomFE	214.41	2.59	TomFE	213.97	3.03
2	26-May	02:25	05:00	16 22 87	138 11 26	SMP	439.43	2.57	SMP	439.34	2.66	TomFE	329.11	2.89	TomFE	339.37	2.63
3	26-May	22:30	00:20	15 42 51	137 09 46	SMP	199	3	SMP	208.43	3.57	TomFE	168.24	3.76	TomFE	162.95	4.05
4	27-May	18:00	20:00	15 38 03	137 08 89	SMP	114.95	2.05	SMP	134.26	2.74	TomFE	99.78	2.22	TomFE	94.77	2.23
5	27-May	20:20	22:44	15 40 83	137 09 42	SMP	97.17	4.83	SMP	102.19	4.81	TomFE	86.81	5.19	TomFE	82.28	4.72
6	27-May	23:05	02:05	15 41 18	137 09 24	SMP	144.66	7.34	SMP	159.09	7.91	TomFE	129.84	7.16	TomFE	130.2	6.8
7	28-May	18:15	20:25	15 26 69	136 53 35	SMP	126.88	10.12	SMP	141.66	10.34	TomFE	98.22	13.78	TomFE	127.93	14.07
8	28-May	21:00	22:45	15 26 42	136 51 72	SMP	103.37	23.63	SMP	104.9	27.1	TomFE	92.89	29.11	TomFE	92.9	24.1
9	28-May	23:10	01:45	15 26 65	136 52 63	SMP	81.25	25.75	SMP	101.75	25.25	TomFE	81.7	25.3	TomFE	111.6	25.4
10	30-May	18:30	20:50	12 08 96	136 43 13	SMP	197.98	9.02	TomFE	151.01	10.99	TomFE	151.6	10.4	SMP	166.33	10.67
11	30-May	21:15	00:15	12 08 78	136 44 23	SMP	290.71	19.29	TomFE	219.58	17.42	TomFE	195.12	16.88	SMP	262.62	19.38
12	31-May	00:50	04:00	12 08 90	136 44 44	SMP	203.64	13.36	TomFE	177.36	14.64	TomFE	172.59	14.41	SMP	229.3	12.7
13	31-May	04:25	06:00	12 08 89	136 44 01	SMP	90.09	6.91	TomFE	97.97	7.03	TomFE	102.5	6.5	SMP	100.61	8.39
14	31-May	18:00	21:40	12 09 16	136 42 64	SMP	249.29	17.71	TomFE	182.6	19.4	TomFE	199.25	17.75	SMP	259.62	17.38
15	31-May	22:05	01:40	12 08 64	136 44 79	SMP	230.04	16.96	TomFE	193.96	18.04	TomFE	192.53	24.47	SMP	250.19	21.81
16	1-Jun	04:10	06:00	12 08 87	136 42 37	SMP	249.94	17.06	TomFE	159.13	12.87	TomFE	185.58	21.42	SMP	245.7	16.3
17	1-Jun	18:20	21:55	11 30 04	136 21 63	SMP	302.87	29.13	TomFE	286.16	25.84	TomFE	259.32	27.68	SMP	344.82	27.18
18	2-Jun	02:10	05:20	11 38 93	135 51 27	SMP	486.58	0.42	TomFE	451.66	0.34	TomFE	341.09	0.91	SMP	521.85	0.15
19	2-Jun	19:45	23:35	11 50 41	134 48 54	TomFE	257	-	TomFE	292	-	SMP	462	-	SMP	452	-
20	3-Jun	18:10	21:00	11 47 92	134 42 91	TomFE	44.4	7.6	TomFE	98.29	18.71	SMP	143.54	23.46	SMP	142.42	24.58
21	3-Jun	21:30	01:00	11 47 30	134 42 65	TomFE	92.58	14.42	TomFE	59.98	12.02	SMP	173.38	23.62	SMP	162.05	24.95

22	4-Jun	01:15	04:30	11 46 72	134 42 29	TomFE	159.49	42.51	TomFE	134.49	42.51	SMP	148.28	73.72	SMP	133.28	73.72
23	4-Jun	17:30	21:10	11 45 65	134 40 91	TomFE	129.53	7.47	TomFE	144.74	7.26	SMP	184	8	SMP	180.37	6.63
24	4-Jun	21:30	00:50	11 47 30	134 43 31	TomFE	96.15	25.85	TomFE	99.05	27.95	SMP	123.85	18.15	SMP	150.55	21.45
25	5-Jun	01:15	04:50	11 47 47	134 43 48	TomFE	79.65	7.35	TomFE	145.29	16.71	SMP	163.44	18.56	SMP	160.06	16.94
26	6-Jun	04:10	06:30	11 01 93	132 21 02	TomFE	116.15	5.85	TomFE	127.08	4.92	SMP	166.92	5.08	SMP	161.47	5.53
27	6-Jun	19:45	22:55	10 59 84	132 19 74	TomFE	155.85	21.15	TomFE	144.39	22.61	SMP	181.1	25.9	SMP	200.02	21.98
28	6-Jun	23:15	02:30	10 58 33	132 21 69	TomFE	92.81	14.19	TomFE	121.62	10.38	SMP	138.48	8.52	SMP	133.65	8.35
29	7-Jun	02:50	07:00	10 59 86	132 19 38	TomFE	155.11	6.89	TomFE	166.6	5.4	SMP	205.34	6.66	SMP	192.03	4.97

Table 12 Data collected on Newfish II whilst trialling the FishEX70 BRD (FX70) in June 2018 against the standard Square Mesh Panel (SMP) BRD. The cells highlighted in yellow indicated that the net was TED'd and those in red indicate records where the net was not fishing correctly.

						Starboard Outside			Starboard Inside			Port Inside			Port Outside		
Shot	Date	Shot Start Time	Shot Finish Time	Start Latitude	Start Longitude	BRD	Bycatch (kg)	Prawn Catch (kg)	BRD	Bycatch (kg)	Prawn Catch (kg)	BRD	Bycatch (kg)	Prawn Catch (kg)	BRD	Bycatch (kg)	Prawn Catch (kg)
1	26-May	19:45	23:25	16 57 04	140 24 81	FX70	50	0.95	FX70	211	1.84	SMP	185	6.65	SMP	290	7.34
2	26-May	23:45	03:40	16 52 23	140 26 45	FX70	224	16.04	FX70	218	6.62	SMP	585	20.22	SMP	635	4.94
3	27-May	04:10	07:20	16 53 72	140 28 67	FX70	106	13.74	FX70	187	2.7	SMP	151	9.4	SMP	239	11.4
4	27-May	20:15	23:30	16 42 88	139 53 92	FX70	260	20	FX70	558	22.1	SMP	868	21.79	SMP	909	18.6
5	28-May	00:05	04:35	16 45 72	139 57 31	FX70	174	10.83	FX70	125	16.25	SMP	494	6.53	SMP	394	6.11
6	28-May	18:55	22:55	15 56 95	139 47 05	FX70	230	9.5	FX70	33	5.34	SMP	64	0.5	SMP	441	8.6
7	28-May	23:35	03:40	15 59 58	139 39 13	FX70	243	6.51	FX70	205	5.1	SMP	305	4.71	SMP	452	7.9
8	29-May	03:55	07:45	16 03 26	139 27 30	FX70	83	3.99	FX70	121	3.81	SMP	160	4.86	SMP	165	5.29
9	29-May	18:15	21:50	16 20 92	138 59 67	SMP	501	18.69	FX70	299	25.65	FX70	337	13.3	SMP	487	18.29
10	29-May	22:05	02:20	16 20 99	138 59 51	SMP	370	35.2	FX70	230	35.27	FX70	321	28.66	SMP	486	33.67
11	30-May	03:55	07:35	16 21 79	138 52 81	SMP	399	16.03	FX70	289	18.14	FX70	254	16.02	SMP	457	17.87
12	30-May	18:30	22:40	16 19 86	139 00 71	SMP	353	16.89	FX70	182	12.54	FX70	290	9.55	SMP	74	1.26
13	30-May	22:50	02:50	16 19 54	138 54 48	SMP	669	35.08	FX70	323	27.08	FX70	161	8.94	SMP	601	48.54
14	31-May	03:15	07:45	16 20 12	138 49 62	SMP	483	17.07	FX70	277	23.23	FX70	269	20.77	SMP	446	23.5
15	31-May	18:35	20:20	16 23 99	138 57 34	SMP	135	10.11	FX70	125	9.54	FX70	98	12	SMP	147	10.74
16	31-May	20:35	23:05	16 23 69	138 50 64	SMP	282	17.49	FX70	198	16.71	FX70	196	14.03	SMP	322	17.76
17	31-May	23:15	03:25	16 21 94	138 51 07	SMP	364	27.94	FX70	296	28.75	FX70	77	4.22	SMP	423	27.31
18	1-Jun	03:50	06:50	16 19 81	138 50 94	SMP	782	17.67	FX70	366	13.59	FX70	197	2.55	SMP	569	15.83
19	1-Jun	18:30	19:50	16 19 78	138 45 16	SMP	597	2.8	SMP	445	5.09	FX70	261	8.84	FX70	244	5.67
20	1-Jun	20:10	21:45	16 21 10	138 49 42	SMP	391	8.91	SMP	370	9.79	FX70	98	3.32	FX70	115	4.93
21	1-Jun	22:45	00:45	16 20 66	138 47 65	SMP	377	18.27	SMP	493	21.74	FX70	201	8.56	FX70	166	19.01
22	2-Jun	01:10	05:35	16 21 16	138 49 35	SMP	764	36	SMP	788	31.58	FX70	181	7.01	FX70	147	7.76
23	2-Jun	18:40	22:00	16 15 50	138 59 99	SMP	389	11.14	SMP	411	9.24	FX70	217	3.39	FX70	113	2.09
24	2-Jun	22:20	00:10	16 15 42	138 59 61	SMP	133	7	SMP	109	3.99	FX70	94	5.61	FX70	93	2.41
25	3-Jun	01:05	04:00	16 19 46	138 51 96	SMP	282	18.02	SMP	260	20.1	FX70	153	17.36	FX70	68	6.85
26	3-Jun	19:05	22:15	16 20 57	138 53 18	SMP	213	32.1	SMP	222	33.42	FX70	138	31.63	FX70	122	23.08

27	3-Jun	22:30	02:10	16 19 78	138 52 26	SMP	193	26.86	SMP	205	25.11	FX70	90	19.67	FX70	74	10.54
28	4-Jun	02:30	07:25	16 19 76	138 53 27	SMP	306	19.02	SMP	446	19.25	FX70	165	10.42	FX70	135	4.91
29	4-Jun	22:20	01:50	16 24 72	138 46 21	FX70	178	16.46	SMP	305	24.48	SMP	300	19.9	FX70	192	17.71
30	5-Jun	02:05	05:30	16 25 64	138 58 00	FX70	132	9.62	SMP	289	6.42	SMP	161	18.68	FX70	438	2.06
31	5-Jun	05:50	08:10	16 24 21	138 45 97	FX70	145	4.5	SMP	466	4.4	SMP	59	0.65	FX70	377	3.3
32	5-Jun	18:35	21:30	16 18 53	138 57 13	FX70	114	26.03	SMP	209	20.71	SMP	155	24.64	FX70	131	13.53
33	5-Jun	21:30	00:55	16 22 44	138 48 21	FX70	147	22.62	SMP	234	20.88	SMP	247	22.79	FX70	94	5.7
34	6-Jun	01:05	04:15	16 21 36	138 57 39	FX70	114	15.95	SMP	125	14.51	SMP	158	21.46	FX70	76	8.81
35	6-Jun	04:30	06:30	16 23 64	138 46 27	FX70	77	8.01	SMP	183	7.47	SMP	141	3.9	FX70	95	5.07
36	6-Jun	18:50	22:05	16 48 49	140 16 64	FX70	156	18.92	SMP	176	14.37	SMP	162	22.51	FX70	136	9.34
37	6-Jun	22:45	01:45	16 57 27	140 19 94	SMP	197	28.11	FX70	85	5.2	SMP	152	17.63	FX70	87	3.06
38	7-Jun	02:00	05:05	16 47 64	140 18 91	SMP	178	12.4	FX70	152	18.28	SMP	127	13.05	FX70	155	14.68

Table 13 Data collected on Eylandt Pearl whilst trialling the Tom's Fisheye BRD (TomFE) in November 2018 against the standard Square Mesh Panel (SMP) BRD. The cells highlighted in yellow indicated that the net was TED'd and those in red indicate shots where prawn weights from each bag were unable to be separated and therefore the total prawn weight divided equally between the four codends.

						Starboard Outside			Starboard Inside			Port Inside			Port Outside		
Shot	Date	Shot Start Time	Shot Finish Time	Start Latitude	Start Longitude	BRD	Bycatch (kg)	Prawn Catch (kg)	BRD	Bycatch (kg)	Prawn Catch (kg)	BRD	Bycatch (kg)	Prawn Catch (kg)	BRD	Bycatch (kg)	Prawn Catch (kg)
1	27-Oct	18:30	22:00	13 16 72	136 49 64	SMP	254.51	3.44	TomFE	159.52	4.48	SMP	306.56	5.49	TomFE	147.5	3.5
2	27-Oct	22:15	02:00	13 21 57	136 47 21	SMP	282.27	9.91	TomFE	148.02	9.98	SMP	294.09	9.73	TomFE	150.51	9.49
3	28-Oct	02:15	06:00	13 18 50	136 45 82	SMP	169.77	14.57	TomFE	112.61	13.39	SMP	173.43	15.23	TomFE	109.7	18.3
4	29-Oct	18:15	20:30	12 41 00	141 21 86	SMP	396.59	23.41	TomFE	163.69	21.31	SMP	415.86	29.14	TomFE	279.52	20.48
5	29-Oct	20:45	23:45	12 41 09	141 20 20	SMP	156.39	39.61	TomFE	102.68	40.32	SMP	233.39	42.61	TomFE	89.47	35.53
6	30-Oct	00:05	03:15	12 43 82	141 28 25	SMP	356.21	42.79	TomFE	191.64	38.36	SMP	404.42	54.58	TomFE	233.72	43.88
7	30-Oct	03:30	06:45	12 46 40	141 30 14	SMP	950.93	34.07	TomFE	462.14	37.86	SMP	1223.7	46.3	TomFE	598.06	39.94
8	30-Oct	18:15	20:00	12 48 30	141 30 27	SMP	346.91	28.09	TomFE	217.55	27.45	SMP	322.71	27.29	TomFE	86.77	23.23
9	30-Oct	20:15	23:15	12 45 99	141 30 01	SMP	80.49	45.51	TomFE	46.47	49.53	SMP	86.19	44.81	TomFE	49.14	46.86
10	30-Oct	23:30	02:45	12 45 76	141 29 96	SMP	136.27	57.75	TomFE	78.1	62.9	SMP	173.74	51.26	TomFE	87.97	50.03
11	31-Oct	03:00	06:00	12 49 14	141 30 35	SMP	179.59	42.41	TomFE	115.54	50.46	SMP	196.46	37.54	TomFE	124.18	42.82
12	31-Oct	06:15	08:00	12 46 47	141 30 05	SMP	848.75	11.25	TomFE	290.75	11.25	SMP	627.75	11.25	TomFE	286.75	11.25
13	31-Oct	18:00	20:00	12 49 41	141 30 15	SMP	299.19	11.81	TomFE	204.64	14.36	SMP	291.93	14.07	TomFE	163.6	12.4
14	31-Oct	20:15	23:15	12 48 60	141 30 09	SMP	119.44	42.56	TomFE	91.99	42.01	SMP	160.32	44.68	TomFE	63.46	42.54
15	31-Oct	23:30	02:45	12 47 56	141 30 01	SMP	94.66	54.34	TomFE	57.69	57.69	SMP	160.29	54.71	TomFE	48.83	48.83
16	1-Nov	03:00	06:00	12 49 02	141 30 10	SMP	205.51	33.49	TomFE	144.95	36.05	SMP	267.95	41.05	TomFE	143.81	36.19
17	1-Nov	18:00	20:00	12 47 16	141 30 09	TomFE	167.6	16.4	SMP	357.6	17.4	TomFE	221.6	13.4	SMP	417.6	12.4
18	1-Nov	20:15	23:15	12 46 18	141 30 01	TomFE	50.49	45.51	SMP	85.23	43.77	TomFE	53.5	42.5	SMP	71.48	44.52
19	1-Nov	23:30	02:45	12 49 03	141 30 02	TomFE	48.91	46.09	SMP	85.43	32.57	TomFE	34.71	25.29	SMP	93.23	34.77
20	2-Nov	03:00	06:00	12 48 64	141 30 19	TomFE	74.82	35.18	SMP	117.94	34.06	TomFE	77.86	33.14	SMP	130.68	35.32
21	2-Nov	18:00	20:00	12 44 45	141 30 16	TomFE	143.12	9.88	SMP	277.29	11.71	TomFE	196.35	8.65	SMP	274.31	7.69
22	2-Nov	20:15	23:30	12 41 39	141 30 15	TomFE	86.02	23.98	SMP	115.7	20.3	TomFE	76.56	20.44	SMP	146.7	26.3
23	2-Nov	23:45	03:15	12 43 40	141 30 13	TomFE	58.85	27.15	SMP	99.08	24.92	TomFE	66.32	24.68	SMP	93.47	26.53
24	3-Nov	03:30	07:00	12 42 66	141 30 13	TomFE	227.62	25.38	SMP	346.64	25.38	TomFE	234.62	25.38	SMP	313.62	25.38
25	3-Nov	19:15	22:00	12 48 19	141 23 14	TomFE	227.08	21.92	SMP	307.32	20.68	TomFE	190.94	21.06	SMP	318.35	22.65
26	3-Nov	22:15	01:15	12 45 44	141 24 38	TomFE	235.5	39.5	SMP	355.5	39.5	TomFE	182.5	39.5	SMP	382.5	39.5

27	4-Nov	01:30	04:30	12 47 40	141 23 47	TomFE	92.09	32.91	SMP	178.44	31.56	TomFE	112.59	31.41	SMP	198.29	25.71
28	4-Nov	04:45	07:15	12 44 87	141 24 62	TomFE	238.92	6.08	SMP	363.92	6.08	TomFE	183.92	6.08	SMP	371.92	6.08
29	4-Nov	18:00	20:30	12 47 07	141 24 24	TomFE	225.13	9.87	SMP	296.23	12.77	TomFE	157.33	8.67	SMP	343.84	8.16
30	4-Nov	20:45	00:05	12 46 01	141 24 55	TomFE	103.42	27.58	SMP	193.05	29.95	TomFE	110.18	25.82	SMP	186.4	23.6
31	5-Nov	00:15	03:45	12 46 76	141 24 32	TomFE	170.43	17.57	SMP	299.2	14.8	TomFE	161.18	19.82	SMP	259.07	19.93
32	5-Nov	04:00	06:45	12 53 57	141 25 30	TomFE	196.21	13.79	SMP	465.06	13.94	TomFE	207.92	13.08	SMP	409.82	12.8
33	5-Nov	18:00	20:20	13 00 13	141 18 68	SMP	543.13	15.87	TomFE	307.13	15.87	SMP	719.13	15.87	TomFE	315.13	15.87
34	5-Nov	20:45	23:45	12 58 68	141 19 48	SMP	369.25	30.75	TomFE	87.39	13.61	SMP	393.54	28.46	TomFE	213.92	28.08
35	6-Nov	00:05	03:15	12 56 08	141 20 89	SMP	453.81	20.19	TomFE	229.39	19.61	SMP	480.5	19.5	TomFE	250.11	19.89
36	6-Nov	03:30	06:15	12 59 31	141 19 20	SMP	550.38	19.62	TomFE	375.38	19.62	SMP	589.38	19.62	TomFE	384.38	19.62
37	6-Nov	18:30	21:00	12 54 54	141 23 68	SMP	269.96	10.04	TomFE	168.31	9.69	SMP	313.23	9.77	TomFE	171.48	10.52
38	6-Nov	21:15	00:30	12 49 70	141 19 85	SMP	199.2	20.8	TomFE	118.96	18.04	SMP	184.74	15.26	TomFE	73.45	16.55
39	7-Nov	00:45	04:15	12 51 28	141 19 85	SMP	197.57	22.43	TomFE	103.68	24.32	SMP	187.94	19.06	TomFE	112.79	25.21
40	7-Nov	04:30	07:15	12 50 27	141 19 85	SMP	445.93	10.07	TomFE	250.31	9.69	SMP	387.93	10.07	TomFE	235.82	11.18
41	7-Nov	18:00	20:45	12 45 88	141 20 80	SMP	340.55	12.45	TomFE	166.21	15.79	SMP	328.81	10.19	TomFE	177.16	13.84
42	7-Nov	21:00	00:15	12 45 88	141 20 80	SMP	173.14	26.86	TomFE	78.99	25.01	SMP	122.72	22.28	TomFE	79.89	29.11
43	8-Nov	00:30	04:15	12 44 04	141 21 07	SMP	122.66	21.34	TomFE	57.18	18.82	SMP	142.33	20.67	TomFE	57.6	18.4
44	8-Nov	04:30	07:15	12 47 07	141 20 30	SMP	285.32	7.68	TomFE	159.47	9.53	SMP	462.86	12.14	TomFE	310.54	11.46
45	8-Nov	18:00	20:45	12 44 55	141 21 10	SMP	223.47	12.53	TomFE	156.42	12.58	SMP	217.76	16.24	TomFE	367.97	12.03
46	8-Nov	21:00	00:30	12 45 57	141 21 10	SMP	129.79	32.21	TomFE	66.02	29.98	SMP	115.09	32.91	TomFE	67.6	29.4
47	9-Nov	00:45	04:15	12 44 57	141 21 21	SMP	121.18	18.82	TomFE	63.53	18.47	SMP	118.94	19.06	TomFE	73.33	19.67
48	9-Nov	04:30	07:30	12 45 70	141 21 09	SMP	292.99	8.01	TomFE	150.57	8.43	SMP	268.08	7.92	TomFE	170.1	7.9
49	9-Nov	18:00	20:45	12 40 36	141 22 62	TomFE	161.13	12.87	SMP	226.41	13.59	TomFE	87.83	14.17	SMP	257.85	11.15
50	9-Nov	21:00	00:30	12 42 77	141 21 89	TomFE	101.62	14.38	SMP	182.63	12.37	TomFE	102.81	16.19	SMP	201.03	15.97
51	10-Nov	00:45	04:15	12 41 82	141 22 75	TomFE	198.8	13.2	SMP	296.84	13.16	TomFE	208.11	11.89	SMP	162.61	3.39
52	10-Nov	04:30	06:00	12 40 61	141 24 76	TomFE	261.25	18.75	SMP	481.25	18.75	TomFE	260.25	18.75	SMP	551.25	18.75
53	10-Nov	06:15	07:55	12 40 01	141 26 72	TomFE	194	9	SMP	212	9	TomFE	167	9	SMP	196	9
54	10-Nov	18:00	20:00	12 40 21	141 26 62	TomFE	208.34	16.66	SMP	315.85	17.15	TomFE	225.72	16.28	SMP	334.26	15.74
55	10-Nov	20:15	23:45	12 41 13	141 26 70	TomFE	61.78	50.22	SMP	117.08	48.92	TomFE	62.93	49.07	SMP	113.69	53.31
56	11-Nov	00:30	03:45	12 41 08	141 26 70	TomFE	41.12	36.88	SMP	66.97	35.03	TomFE	48.05	32.95	SMP	70.21	34.79
57	11-Nov	04:00	07:00	12 40 73	141 26 71	TomFE	158.95	27.05	SMP	204.24	23.76	TomFE	106.46	23.54	SMP	183.25	23.75
58	11-Nov	18:00	20:15	12 39 09	141 26 20	TomFE	92.14	22.86	SMP	207.42	23.58	TomFE	131.09	22.91	SMP	210.31	21.69
59	11-Nov	20:30	00:15	12 39 66	141 26 89	TomFE	40.58	45.29	SMP	62.87	48.13	TomFE	39.71	40.42	SMP	85.44	41.56

60	12-Nov	00:30	04:30	12 40 30	141 26 88	TomFE	32.95	33.05	SMP	58.57	29.43	TomFE	38.14	30.86	SMP	69.43	32.57
61	12-Nov	04:45	07:50	12 39 14	141 20 89	TomFE	123.35	20.65	SMP	133.03	14.97	TomFE	89.91	16.09	SMP	190.45	20.55
62	12-Nov	18:00	20:30	12 38 48	141 26 97	TomFE	77.39	12.61	SMP	198.61	13.39	TomFE	87.29	14.71	SMP	196.38	14.62
63	12-Nov	20:45	23:30	12 38 96	141 26 96	TomFE	267.07	14.93	SMP	465.07	14.93	TomFE	233.07	14.93	SMP	435.07	14.93
64	12-Nov	23:45	02:45	12 41 56	141 30 13	TomFE	144.31	19.69	SMP	224.48	19.52	TomFE	150.09	20.91	SMP	226.1	20.9

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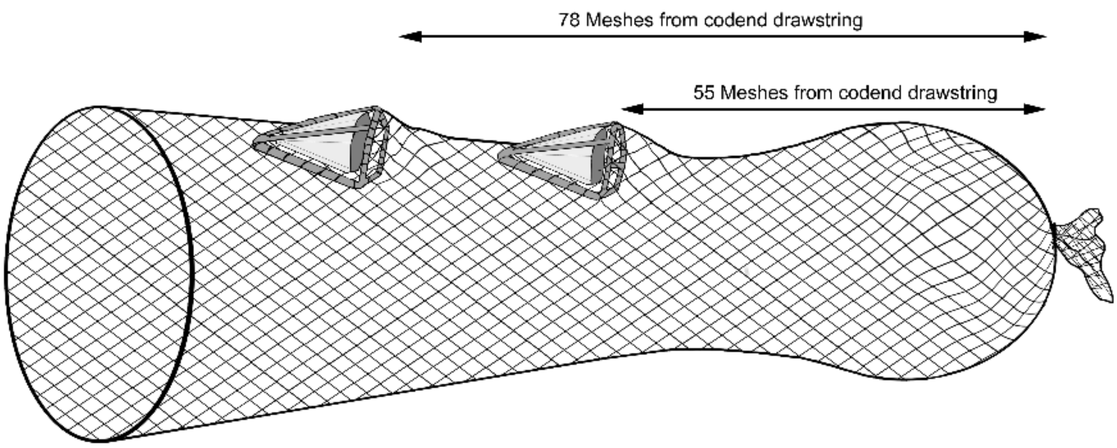
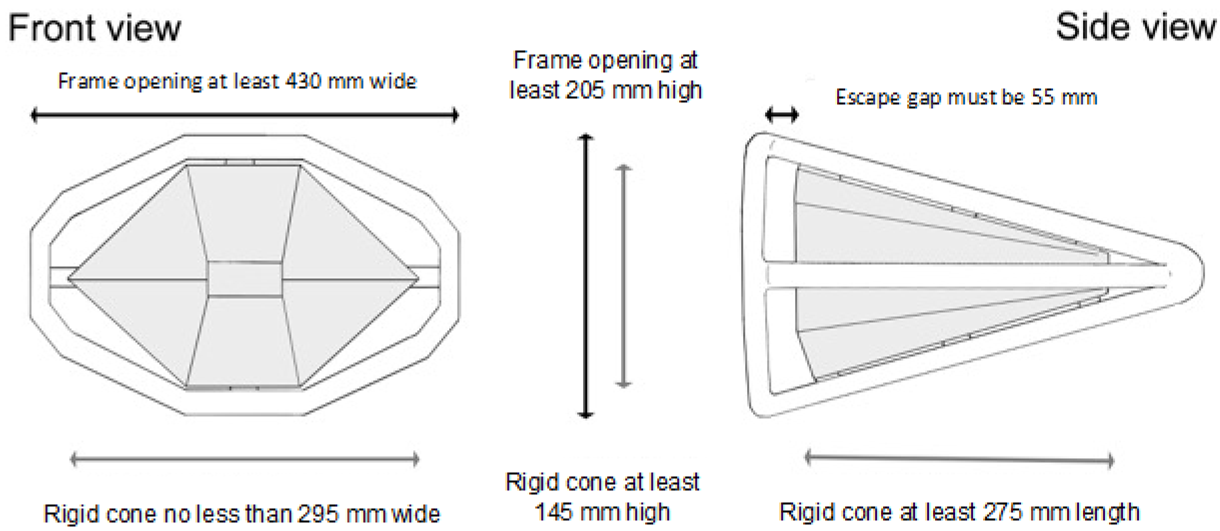
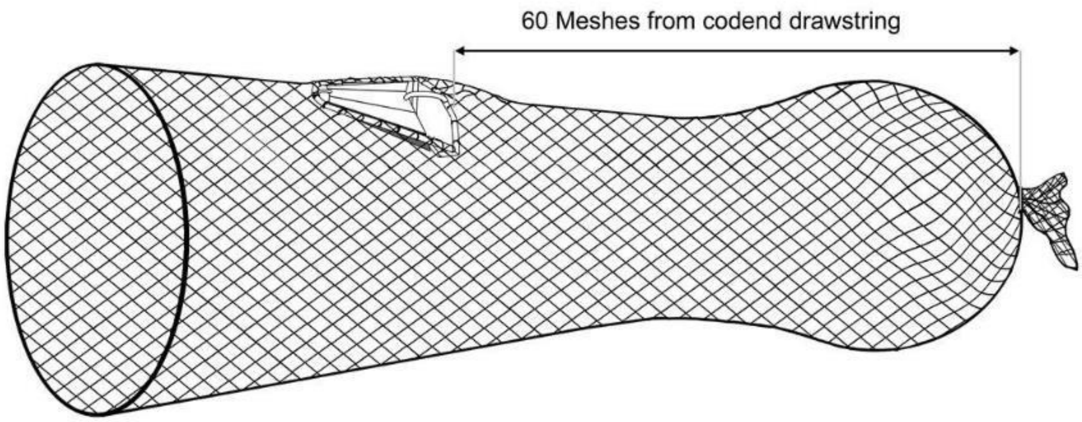
Appendix 4: BRD Schematics

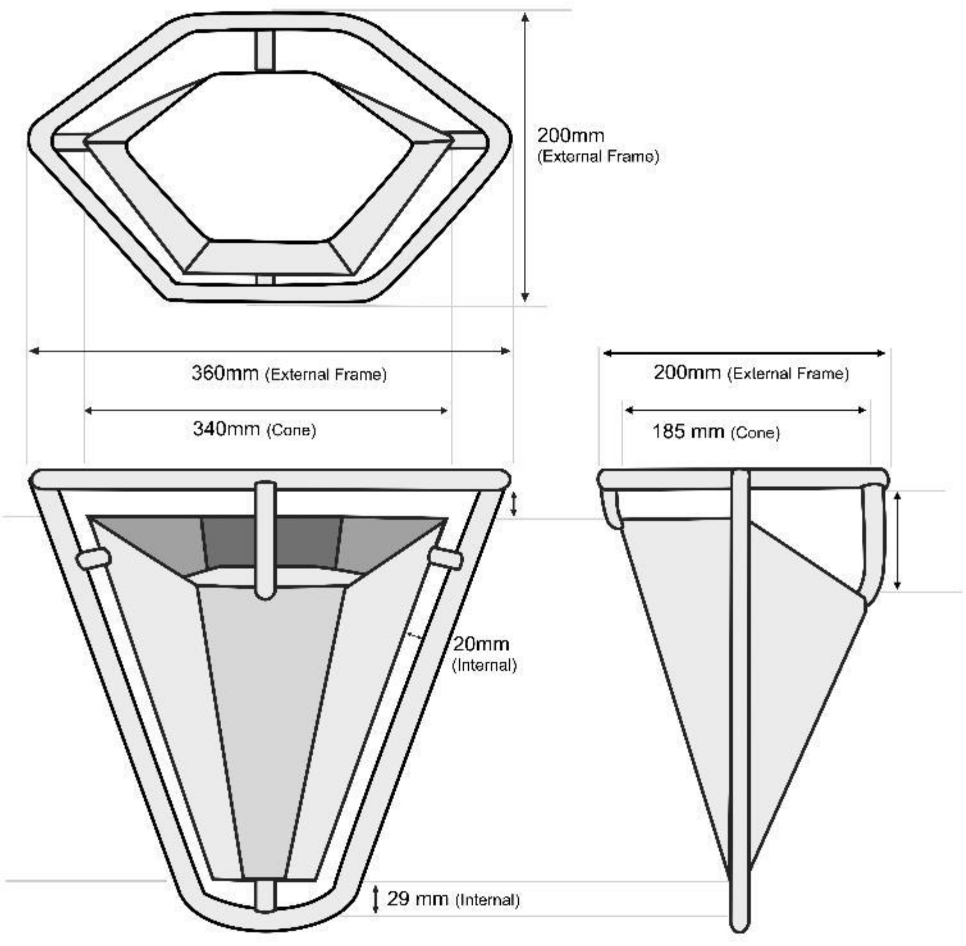
Kon's Covered Fisheyes BRD





Tom’s Fisheye BRD





FishEX 70 BRD