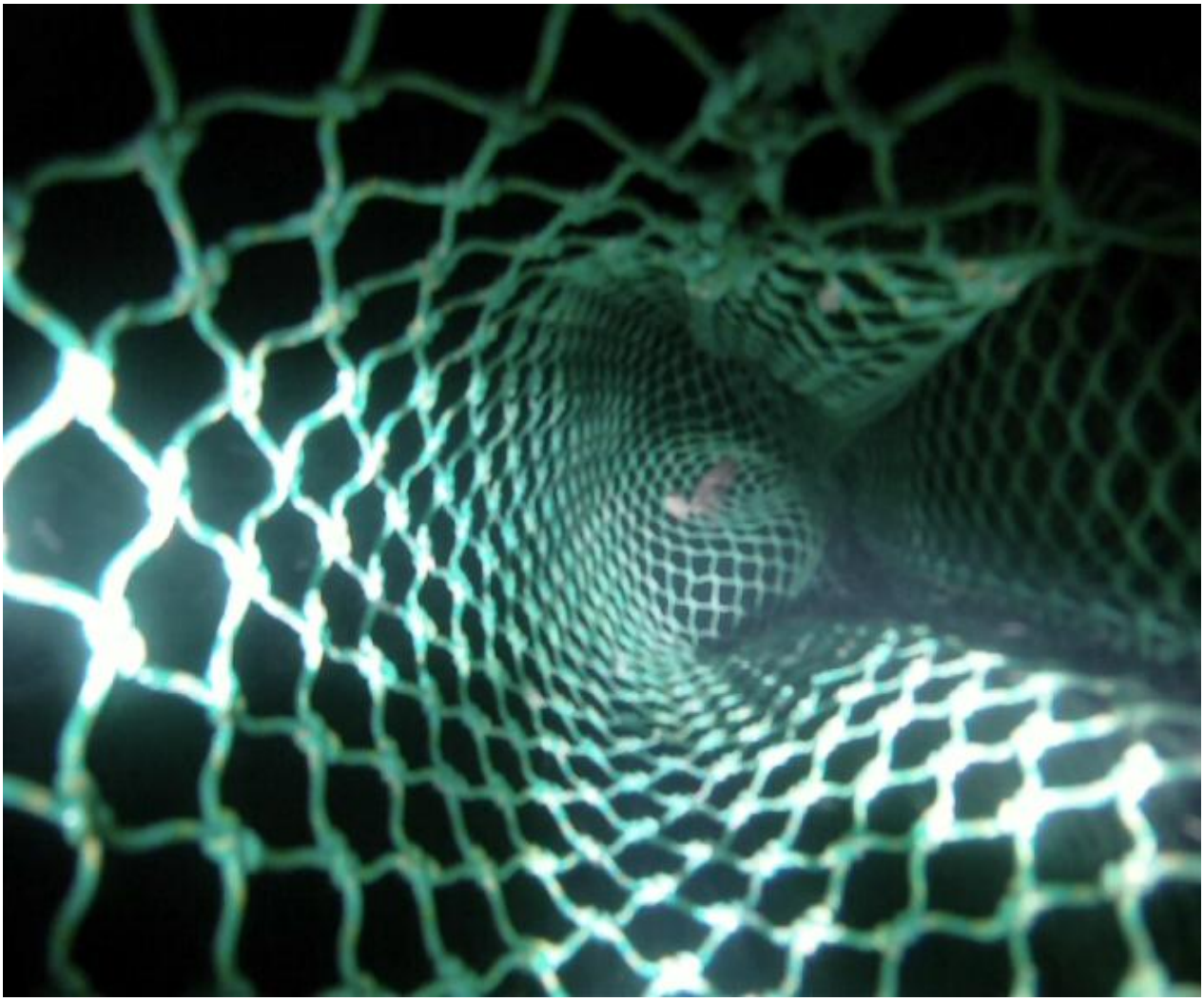

A collaborative approach to novel by-catch research for rapid development, extension and adoption into a commercial trawl fishery

Cameron Dixon, · Jim Raptis, · Daniel Gorman, · Shane Roberts, Graham Hooper, · Nathan Bicknell, · Shirley Sorokin, · Renee Newman, · Craig Noell · Thorsteinn Benediktsson · Jason Saint · Wallace Hill

Project No. 2009/069

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1. NON TECHNICAL SUMMARY

2009/069 A collaborative approach to novel by-catch research for rapid development, extension and adoption into a commercial trawl fishery

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OBJECTIVES:

Objectives 1 to 3 below were identified in the original project proposal. Objectives 4 and 5 were added to reflect additional outcomes:

1. To provide a platform for the development and extension of research products that minimise by-catch and improve the selectivity of demersal trawl gear in a temperate prawn trawl fishery.

2. To facilitate the quantitative assessment of measures of catch rate and catch selectivity (prawn size and species-specific by-catch composition) of T90 mesh cod-ends when compared to conventional diamond mesh designs.

3. To capture under-water video footage of operational trawl nets (conventional and modified) to inform and optimise current and future gear development (including, by-catch reduction devices) through observations of fishing performance and catch behaviour.

4. To facilitate the quantitative assessment of by-catch reduction devices used in conjunction with T90 mesh cod-ends.

5. To identify approaches for extension and pathways for adoption of novel by-catch technology for rapid implementation into a commercial fishery.

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED TO DATE

The primary outcome of this project was the voluntary adoption of by-catch reduction technology in the Gulf St Vincent (GSV) Prawn Fishery, commencing March 2012. This was achieved through a collaborative research approach among key stakeholders that enabled rapid development and extension of a novel trawl gear combination.

The main outcome for the fishery was a substantial reduction in total by-catch for the fleet, particularly for catches of mega-fauna (i.e. porifera (sponge), sharks and rays (elasmobranchs) and teleosts (fish)). The improved selectivity of the gear also facilitated a reduction in the capture of smaller, lower valued prawns. As a consequence of reduced by-catch levels, fishers were able to increase tow duration during commercial fishing in 2012. This should enable increases in efficiency and total fuel consumption for a given trawl effort.

These outcomes can be extended to other Australian fisheries through description of (a) the collaborative approach to research and adoption and/or (b) the novel use of T90 mesh plus grids developed for this prawn fishery.

In marine ecosystems, the removal of target and non-target species by commercial fishing is probably the most important of human impacts (Dayton et al. 1995). Sustainable management of fisheries resources should include a balance between exploitation and the minimisation of adverse effects on other components of the ecosystem (Thrush et al. 1998). The incidental capture of non-target species (collectively termed ‘by-catch’) is a contentious issue affecting the management of prawn trawl fisheries within Australia and globally (Alverson et al. 1994). Because of such concerns, pressure is increasing to improve gear selectivity (minimise by-catch) to meet environmental and commercial objectives (Broadhurst 2000; Hall et al. 2000). Much of the anticipated improvements to gear design are expected to come about through targeted research that facilitates the development, extension and adoption of novel by-catch reduction technologies and management systems.

This report describes the outcomes of a research project that has led to the adoption of novel by-catch reduction technology in a South Australian demersal prawn trawl fishery (Objective 1). The project was developed using the theories of practice change (Coutts 1997), which are based on the development of links between research, development, extension and adoption. The principal objective of the research and development stage (i.e.,

Objective 2 was to test the selectivity of T90 cod-ends as an alternative to conventional diamond-mesh net designs. This study represents the first scientific trials of T90 cod-ends within an Australian prawn trawl fishery. Empirical data obtained during fishery-independent trials and commercial operations demonstrate conclusively that the use of T90 cod-ends reduces catches of non-target species including small fish/crabs and sponge when compared to diamond mesh cod-ends. Importantly, the use of T90 cod-ends did not result in a significant reduction in the catch rates of the target species, western king prawns (*Penaeus (Melicertus) latisulcatus*). Furthermore, there was evidence that T90 mesh facilitates the escapement of small prawns.

In addition to the original objectives, research and development trials were done to examine the benefits of a by-catch reduction device (BRD) to conventional trawl gear fitted with the optimised T90 cod-end. Trials demonstrated that the use of a modified Nordmore grid (50 mm separation), placed anterior to the cod-end and angled up to direct mega-fauna out of a flap in the top of the net, can further reduce by-catch and improve net selectivity with no significant reduction in commercial catch rates. The 'top-shooter' design substantially reduced the capture of sponge, elasmobranchs, and fish. This reduction in overall by-catch is not only likely to improve fishing efficiency and reduce catch-handling time, but will improve the ability of the T90 to exclude juvenile prawns, small fish and crustaceans from the catch. This simultaneously achieves good environmental outcomes, improves catch quality (fewer damaged prawns), improves trawling efficiency due to longer trawl shot duration and increased fuel efficiency (total fuel consumption per hour of trawling), and; reduce handling times for prawn sorting and reduced risk of injury, particularly from stingrays.

We extended the results of research and development trials of 'T90' cod-ends to a variety of stakeholders of the Gulf St Vincent Prawn Trawl Fishery. Extension tools included the capture of under-water video footage of the T90 and diamond nets under trawling conditions. Updates and preliminary results were provided on a regular basis throughout the project. A workshop was held at the completion of the project where the final results were presented to fishers and a T90 net with grid was shown to aid understanding of its operation. A vital component of the acceptance of information by fishers was the involvement of the industry sector during the research and development phase.

In summary, transition to demersal trawl gear that incorporates T90 cod-ends and rigid-grid BRDs is likely to bring major benefits to the environment (i.e., reducing by-catch) and industry (i.e., optimising prawn catches and reducing costs). Critical to the success of the project and ultimately the rapid adoption of this technology, was the bottom-up research

approach where collaborative relationships between researchers, managers, key industry members and SeaNet enabled a rapid but scientifically defendable evolution of novel trawl gear in a commercial fishery environment. Research outcomes demonstrate the successful application of by-catch mitigation strategies within the Gulf St Vincent Prawn Fishery as required under the Commonwealth *Environmental Protection and Biodiversity Conservation Act (1999)*, and as recommended by the Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC).

KEYWORDS: T90, BRD, by-catch, sustainability, size selectivity.

2. ACKNOWLEDGEMENTS

The project was jointly funded by the Fisheries Research and Development Corporation (FRDC) and the Adelaide and Mount Lofty Ranges Natural Resource Management Board. Significant financial and in-kind support was provided from A. Raptis and Sons and Langhorst Euronet as well as in-kind support from SeaNet and PIRSA Fisheries and Aquaculture. Also thanks to commercial fisher Trevor Simms, skipper of the Fishing Vessel Angela Kaye, and to Skye Barrett and Alex Dobrovolskis of SARDI Aquatic Sciences for laboratory and data entry support. Dr Stephen Mayfield and Dr Jason Tanner of SARDI Aquatic Sciences provided valuable reviews of an early draft.

3. BACKGROUND

There are three demersal prawn trawl fisheries in South Australia that target the western king prawn, *Penaeus (Melicertus) latisulcatus* (i.e., Gulf St Vincent, Spencer Gulf and West Coast). Each fishery has adopted technology to reduce the impacts of trawling on the bycatch species. For example, of the 52 prawn trawling vessels operating across the three fisheries, all use crab bags to reduce the mortality of mega-fauna and 49 use hopper systems to rapidly return the remaining by-catch to the water (Dixon et al. 2010).

The largest of these fisheries, the Spencer Gulf Prawn Fishery, has invested considerably in by-catch research through initiatives such as the on-going assessment of by-catch distribution and abundance (Carrick 1997; Dixon et al. 2005) and Fisheries Research and Development Corporation (FRDC) funded projects investigating the fate and consumption of by-catch discards (Svane et al. 2007; Svane et al. 2008). Currently, Primary Industries and Regions South Australia (PIRSA) Fisheries and Aquaculture in conjunction with the Spencer Gulf Prawn Fishery is conducting a by-catch risk assessment using the methodology of Hobday et al. (2011) to identify individual species at greatest risk from prawn trawling, with an objective of developing mitigation strategies for species deemed at high risk. The risk assessment is underpinned by a gulf-wide by-catch survey conducted in February 2007 (Currie et al. 2009).

During the late 1990s, stakeholders of the Gulf St Vincent (GSV) Prawn Fishery made substantial investment in the development of trawl nets, particularly square mesh cod-ends (Broadhurst et al. 1999; Broadhurst et al. 2004). While results demonstrated a reduction in the abundance of small prawns caught with no significant impact on total catch, adoption of square mesh into the fishery was inconsistent and by 2004 most fishers had reverted to diamond mesh nets. At this time, total catches had declined to 172 t, down from 400 t in 1999/2000 (Dixon et al. 2012), prompting industry agreement to undertake a program of stock recovery. The implementation of fishery-independent surveys and a formal harvest strategy saw relative biomass and catch increase until 2008/09, when 288 t was harvested. However, both catch and relative biomass declined thereafter, with 189 t harvested in 2010/11 (Dixon et al. 2012). Since 2004, there has been a considerable shift in size structure of the population; primarily an increase in the abundance of smaller prawns. As a result, it has become increasingly difficult in recent years to find areas to fish at an appropriate mean target size. This increase in abundance of smaller prawns has meant that there were fewer places to fish where large prawns could be targeted, which has lead industry to reconsider approaches to improve size selectivity of their trawl gear.

Conventional South Australian prawn trawl nets comprise soft diamond meshes that run parallel with the linear length of the gear. During trawls, tension builds from weight in the cod-end resulting in distortion of the diamond meshes that causes them to collapse and reduce the escapement of juvenile prawns and other species (e.g., small fish). 'T90' mesh is a variation on the configuration of a traditional diamond net, where the mesh is turned 90 degrees allowing the mesh to remain fully open when trawled through the water. The orientation of the diamond meshes maintains the shape of the net under heavy loads conserving the exclusion potential for non-target catch (Knuckey et al. 2008). The mesh type is also thought to improve towing efficiency because of enhanced flow dynamics and reduced drag (Bicknell 2011). Whilst T90 mesh has been trialled and used in many demersal finfish fisheries, to our knowledge it has not been trialled in commercial prawn trawling.

The project was initiated by Mr Jim Raptis of A. Raptis and Sons, Pty Ltd who had commenced trialling T90 extensions early in 2010 using their vessel "Anna Pearl", skippered by Jason Saint. Prior to the commencement of the project, Jim Raptis established a relationship with Thorsteinn Benediktsson of Lankhorst Euronete Australia to jointly overcome the obstacles encountered early in the development phase. The objectives of this project were to trial T90 nets in conjunction with various available by-catch reduction devices to simultaneously achieve the goals of improving catch selectivity and reducing impacts on by-catch species. Additional objectives included the development of a research, extension and adoption platform that other fisheries could use for the rapid development and adoption of novel trawl gear designs.

4. NEED

Across Australia there is an increasing need to improve the extension and adoption of technology and policies that maximise the economic, social and environmental benefits of fisheries research. One of the key priorities of the Fisheries Research and Development Corporation is to fund the commercialisation of research through support, extension and adoption of best-practice fishing operations within Australia's fishing industry (Jennings et al. 2011). Identifying potential improvements to gear technologies and management systems that may help to achieve industry-defined priorities is an elementary step in extension and adoption practices (Coutts 1997; SELN 2006).

Future improvements to the economic and ecological sustainability of trawl fisheries can come about through the development, testing and adoption of gear designed specifically to improve target species selectivity (Campbell & Cornwell 2008). The need for the current project arose from the desire of key stakeholders to use this testing and development framework to reduce the by-catch of juvenile prawns and other non-target marine species within the GSV Prawn Fishery. The goal of the project was to improve the biological, economic and environmental sustainability of the fishery as a whole, while at the same time alleviate external perceptions about its consequences for other fisheries and bycatch species (e.g., crabs and fish). The need for the project also arises from the commitment by fisheries management and industry to continue a program of assessment, refining and ultimate adoption of by-catch mitigation strategies in South Australia under the requirements of the Environment Protection and Biodiversity Conservation Act (1999).

Extension and adoption of BRDs such as large-mesh panels, cones, hoops and grids have been successful in many tropical and subtropical trawl fisheries where the incidental capture of turtles and dolphins was a significant management problem (e.g., Queensland and New South Wales; Broadhurst 2000) but transferring these technologies to southern fisheries has been problematic (Bicknell 2011). Nevertheless, the success of BRDs in other fisheries suggests they could provide benefits for South Australia's prawn fisheries, and thus there was a need to test various existing BRDs with the T90 mesh.

The adoption of new gear technologies is often hindered by poor extension of results to the end users. To ensure improved extension, key industry members were important participants in the research and development phase. Furthermore, we utilised cheap and readily available under-water video systems to provide near real time footage of the various trawl gears, offering an opportunity for adjustments of gear at sea during trials, and improving the communication of results to the end users during workshops.

5. ORIGINAL OBJECTIVES

1. To provide a platform to test and develop enhanced gear modifications that minimise by-catch in temperate prawn trawl fisheries.

2. To evaluate catch selectivity (prawn size and species-specific by-catch composition) of conventional diamond vs. novel trawl mesh (T90) of two configurations.

3. To capture under-water video footage of operational demersal trawl nets (conventional and modified) in a temperate prawn fishery to inform and optimise current and future net modifications / by-catch reduction device (BRD) trials (gear and catch behaviour).

6. METHODS

6.1 The Research, Development, Extension and Adoption framework

The framework employed for this project utilises the link between research, development, extension and adoption that has been used successfully within other commercial fishing operations in Australia (Jennings et al. 2011). The collaborative approach between stakeholders demonstrates an 'innovation process' that could allow development, testing and adoption of new gear designs within other Australian trawl fisheries.

6.1.1 Research and Development

A research and development team was established that included: SARDI scientists for project leadership, data collection and reporting; SEANET officer Nathan Bicknell who has substantial experience in trawl fisheries, particularly regarding BRDs; key industry stakeholders, particularly Mr Jim Raptis and his vessel and crew from the Anna Pearl; net-makers Thorsteinn Benediktsson and Wally Hill of Lankhorst Euronete Australia and; PIRSA Policy Manager, Dr Craig Noell. In the planning stage, alternative gear designs were researched and a number of potential gear types determined to fulfil the objective of reducing the capture of by-catch species and small prawns. The cumulative knowledge and experience of all stakeholders was critical in this process. Once alternative gear types were determined, net-makers Thorsteinn Benediktsson and Wally Hill of Lankhorst Euronete Australia developed the T90 nets.

Trials began as part of routine fishery-independent surveys (FIS) that were conducted for stock assessment purposes (Gorman et al. 2011; Dixon 2012). However, it was immediately apparent that incorporating gear trials into an already demanding survey process did not allow for adequate data collection. Thus, PIRSA issued ministerial exemptions to allow gear trials to be undertaken for the specific purpose of this project. All prawns harvested during the trials were sold to recoup costs of the vessel and crew.

Gear development took a total of 14 nights at sea over a period from December 2009 to May 2011. The development phase was a balance of ensuring scientific rigour while allowing for rapid evolution of gear types. For T90 cod-end trials, comparisons were made by simultaneously towing one T90 cod-end and one diamond cod-end side by side in a double-rig. For BRD trials, comparisons were made by simultaneously towing one T90 cod-end with grid and one T90 cod-end without a grid. Where possible, data were gathered for each net and each trawl shot on prawn size, total catch and by-catch weight or volume.

Gear development was augmented by the collection of under-water video data that were examined immediately after a trawl shot. The combination of under-water video, data from each net and the cumulative experience of the project team enabled rapid evolution of the gear designs. The near real-time analysis of underwater video footage and the continual gear modifications at sea by net-maker Wally Hill was pivotal in this process.

6.1.2 Extension and Adoption

Voluntary adoption of a new gear type dramatically reduces the time and costs associated with legislation and compliance (Jennings et al. 2011). The extension process is critical to likelihood of adoption. In this project, we used a number of extension tools that ultimately assisted in the voluntary uptake of T90 cod-ends with a grid.

- From the outset we created a project team that included all stakeholders.
- Video technology was utilised to understand the behaviour of different gear types and to provide the broader industry with a visual understanding of the results.
- Nathan Bicknell of SeaNet posted the videos on the internet (YouTube).
- Regular updates of the results were provided to managers and the broader industry.
- A workshop was conducted to present the final results to fishers, including showing the final cod-end with grid so that industry members could see the gear first hand.

6.2 Development and evaluation of by-catch reduction systems

6.2.1 Testing T90 cod-end configurations

Trials of T90 mesh trawl gear were done on the commercial trawler Anna Pearl between 2009 and 2011 in Gulf St Vincent (Figure 1). Pilot gear trials (December 2009; March, May and June 2010) were run to compare six T90 cod-end configurations (mesh sizes, 52-58 mm) with traditional diamond cod-ends (mesh size, 52 mm). All comparisons were made between one T90 net design and one conventional diamond mesh design towed in a double-gear configuration. A variety of net configurations (Appendix 3; Table 3) were trialled until the fishers and net-makers were satisfied that the T90 design was operating well. Subsequent trials of an “optimal” T90 cod-end (configuration F design) were conducted during refinement phases (June and November 2010). Each test comprised of 6-10 shots of approximately 30 minute duration.

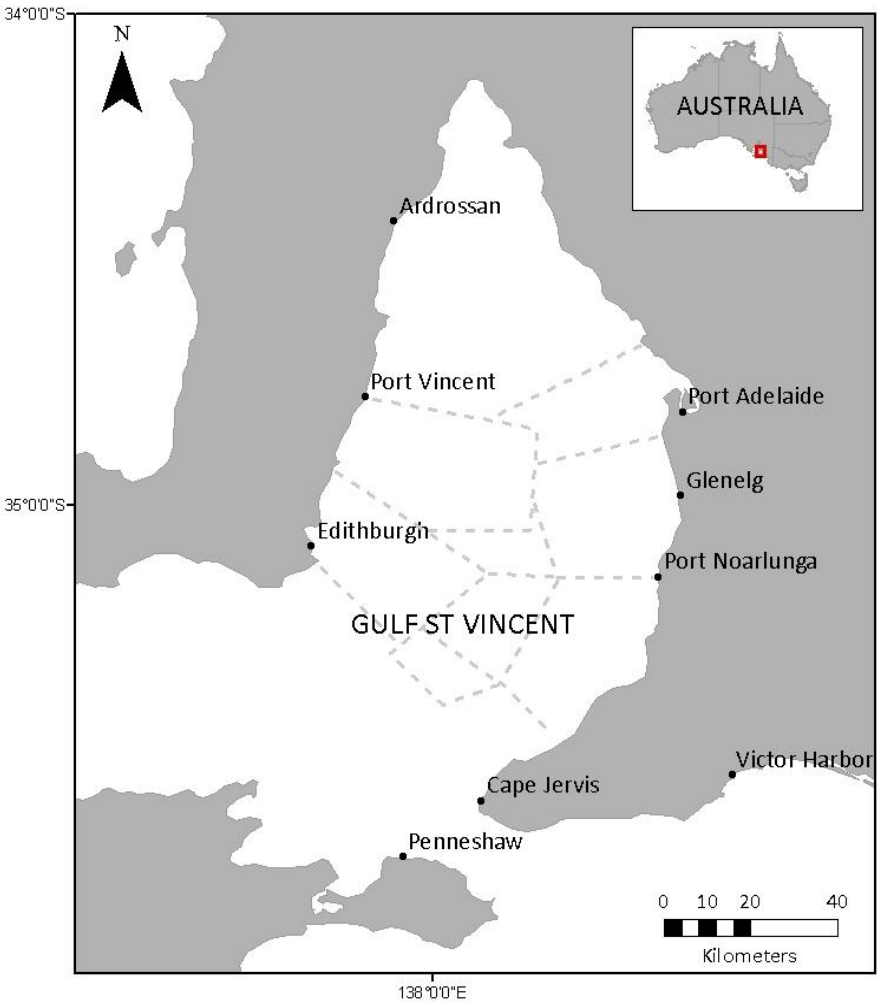

Figure 1. Map of survey location for T90 net trials within the Gulf St Vincent, South Australia.

Operational footage of gear configurations was collected using an under-water video array (hired from Moreton Bay Seafood Industry Association Inc.). HERO(R) HD digital video cameras (GoPro, Woodman Labs, Inc, California, USA) were housed in protective shrouds that were fastened inside the cod-ends (facing backwards) of the various trawl net designs (Figure 2). The arrays were equipped with lights to improve visual output. The use of cameras allowed the video to be displayed in near real-time immediately after each trawl shot. These videos were pivotal in the success of the project as they enabled rapid development of the gear by experienced net-makers Wally Hill and Thorsteinn Benediktsson.

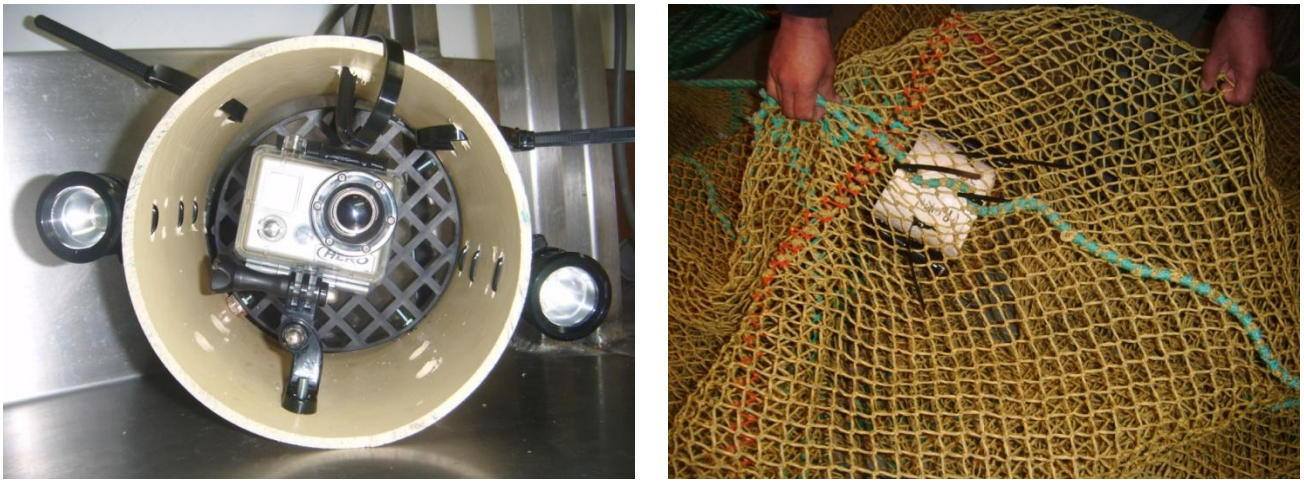

Figure 2. Hero® HD digital video camera and mount (including lights) (Left) and attached to the inside of the cod-end (Right).

Throughout trials data were recorded in the field by scientists (South Australian Research and Development Institute), SEANET and industry representatives. Data collected included; total prawn catch, three different measures of prawn size (bucket counts, prawn grades and length frequency) and crude by-catch categories (i.e., fish/crabs, sponge, elasmobranchs). On some occasions, by-catch were recorded as volumes (bins) and to simplify analyses we have assumed that one bin of fish/crabs = 25 kg and one bin of sponge = 30 kg. All large sharks and rays were counted.

6.2.2 Testing T90 cod-ends with by-catch reduction devices

The initial success of the T90 cod-end trials prompted additional work on BRD systems. These trials involved comparisons of the optimised T90 cod-end (configuration F), with T90 cod-end gear that incorporated various BRDs including hoops and grids (see Appendix 3 for details). Pilot trials were run to compare seven BRD configurations to quantitatively assess their efficiency and by-catch selectivity.

6.3 Adoption of T90 cod-ends with grids: survey and commercial fishing

Data from surveys were compared for March 2012 (T90 cod-ends with grid) with March 2005-2011 (diamond cod-ends) to examine selectivity. Commercial fishing logbooks were also compared for March 2012 (T90 cod-ends with grid) and March 2011 (diamond cod-ends) to compare selectivity (prawn grade composition) and trawl duration (hours trawling).

6.3.1 Mean weight of prawns during surveys

The mean weight of prawns was determined from data collected during March surveys from 2005 to 2012 from 50 locations in northern Gulf St Vincent. From 2005 to 2011 diamond nets were used and in 2012 T90 cod-ends with grid were used. The mean weight of prawns was calculated as the total mean of all 'bucket count' samples (the number of prawns per 7 kg) collected at each site.

6.3.2 Prawn grades (size composition)

Prawn grade data were available for >80% of the total catch each year, and thus were considered to be representative of the size structure of the commercial catch. Grade data were summarised into five categories as described in Table 1.

Table 1. Categories assigned to reported prawn grades from commercial logbook data.

Prawn grade (size description)	Categories in logbook
U10 (very large)	U10, L, U6, U8, XL
10/15 (large)	10/15, 9/12, U12, 13/15, LM, 10/20 (50%), 12/18 (50%)
16/20 (medium)	16/20, M, 10/20 (50%), 12/18 (50%)
21+ (small)	20+, 19/25, 21/25, 21/30, 26+, 30+, 31/40, S, SM
SB (Soft & Broken)	S/B, B&D, MIX, REJ, SMS, blank, ERR

6.3.3 Trawl duration

The mean duration of trawl shots for diamond mesh cod-ends and T90 with grid was determined by calculating the average duration of trawl shots conducted by the fleet during March in 2011 and 2012, respectively. Trawl shots of 30 minutes or less in duration were excluded from analyses as these reflected searching not commercial fishing.

6.4 Data analysis

Comparisons of catch rate, weights, trawl effort and prawn grades among treatments were done using Analysis of Variance (ANOVA). Data were transformed where necessary to meet the assumptions of normality and homogeneity of variance. Size frequency distributions were compared using Kolmogorov–Smirnov tests.

7. RESULTS

7.1 The Research, Development, Extension and Adoption framework

Following the research, development, extension and adoption framework, we gathered an expert team including scientists (South Australian Research and Development Institute - Aquatic Sciences), fishers from the GSV Prawn Fishery, a SeaNet officer experienced in by-catch reduction technology (OceanWatch), commercial net makers (Lankhorst Euronete Australia, QLD), and Fisheries Policy and Compliance Officers from PIRSA. This team enabled the:

(1) identification of appropriate alternative net designs and BRD systems (research), (2) optimisation and quantitative assessment of a T90 cod-end with grid (development), (3) transfer of knowledge of the system and its benefits to industry (extension), and (4) development of a legislative pathway for adoption.

7.2 Development and evaluation of by-catch reduction systems

7.2.1 Testing T90 cod-end configurations

While there were significant differences in catch rates among survey nights (ANOVA; $F_{4, 154}$ = 14.13; $P < 0.001$) which reflected the timing of surveys, all T90 configurations that were tested were effective at catching prawns, with no significant difference in mean catch rates (by weight) between diamond-mesh and T90 cod-ends (Figure 3; ANOVA: $F_{1, 154} = 0.133$; $P = 0.716$). The most effective (optimal) design was achieved by using a full T90 cod-end (configuration F) which resulted in a notable difference in prawn size between nets and an apparent decrease in drag when both were towed together (twin trawl rig). This was apparent from both the vessel's list towards the diamond cod-end net and video footage showing greater water flow through the T90 cod-end, which was more open than that of the standard cod-end (Figure 4).

Further testing of configuration F on two occasions (June and November) yielded no significant differences in catch rate between traditional diamond and T_{90} mesh net designs (Figure 5; ANOVA: $F_{1, 32} = 0.104$; $P = 0.749$).

Length-frequency distributions differed between net designs, with T90 nets typically retaining larger prawns during June (Kolmogrov-Smirnov, $K_{d\ 497, 495} = 0.090$, $P < 0.05$) but not during November (Figure 6; $K_{d\ 988, 1002} = 0.015$, $P > 0.05$).

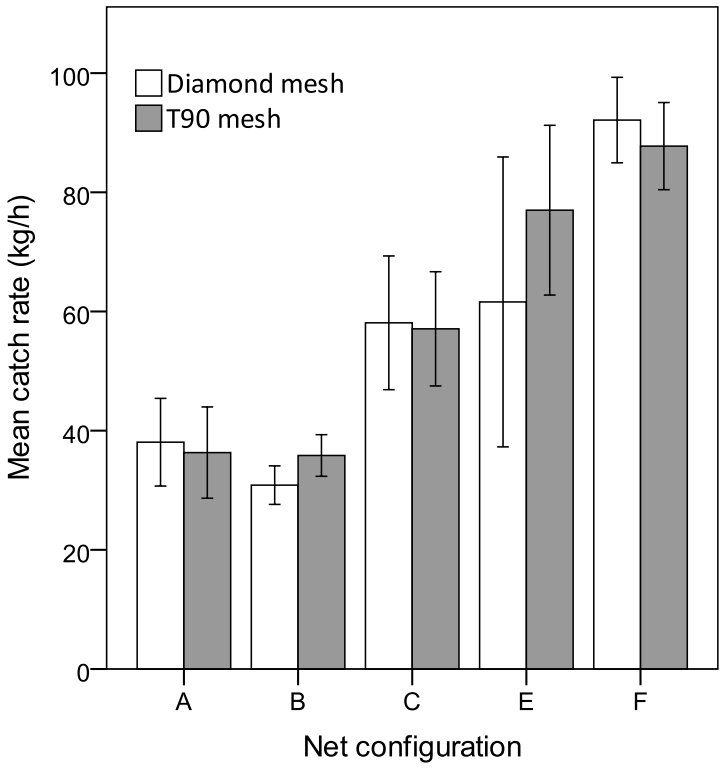

Figure 3. Mean (SE) catch rates for *P. latisulcatus* using different cod-end configurations (A-C, E-F) for standard diamond and T90 cod-ends. For differences in net design see Appendix 3. Configuration D has been omitted because of insufficient data to compare net types.

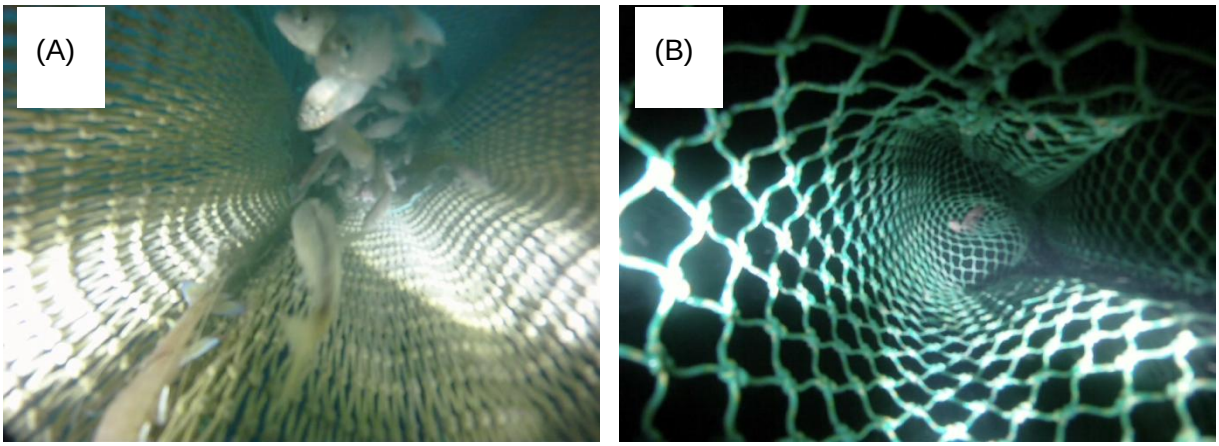

Figure 4. Still frames captured from under-water video footage of (left) standard diamond trawl net used in the GSV prawn fishery (52 mm mesh) and (right) T90 cod-end, configuration F(58 mm mesh).

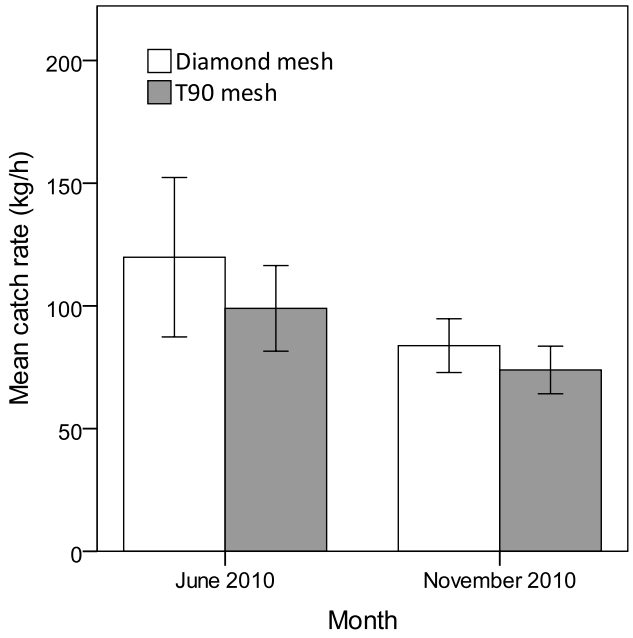

Figure 5. Mean (SE) catch rates for *P. latisulcatus* using trawl gear comprising diamond and T90 (configuration F) cod-ends trialled during two survey periods.

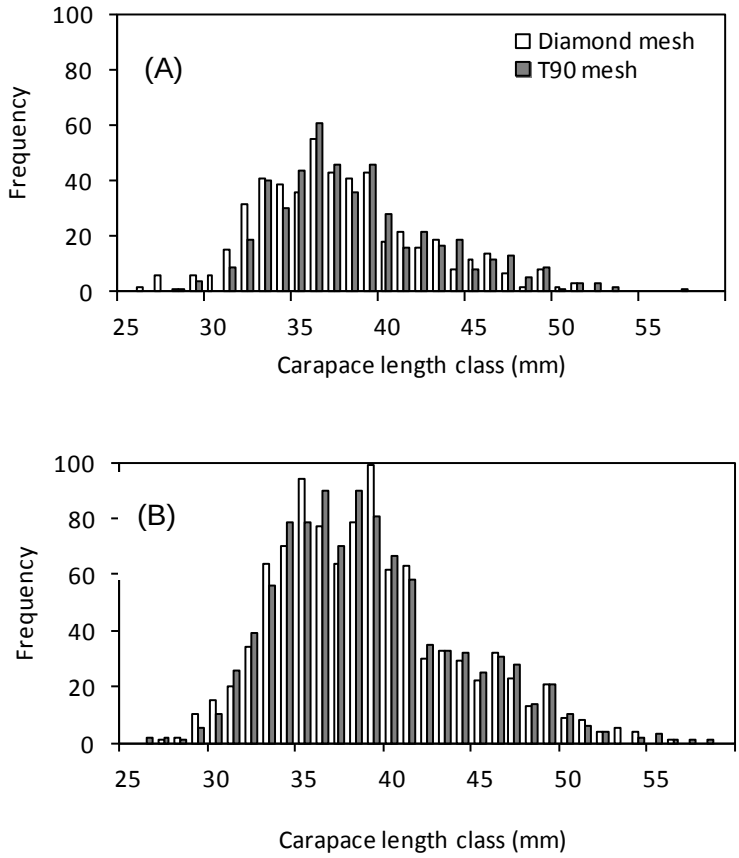

Figure 6. Length-frequency distributions for *P. latisulcatus* caught using conventional diamond and T90 mesh cod-ends during (A) June and (B) November 2010.

There was clear seasonal variation in prawn grades (Figure 7), with catches in June having good representation of all size classes, whereas those in November were dominated by smaller size grades (i.e. 16-20s & 21-30s) with very few larger individuals (i.e. U8s). The survey catch results for June identified a significant interaction between net type (diamond vs. T90) and prawn grade (Figure 7a; ANOVA: $F_{4, 60} = 3.85$; $P = 0.008$; SNK-tests; U8s, U10s, 10-15s & 21-30s: T_{90} = diamond; 16-20s: T_{90} > diamond). Despite the absence of statistical differences for 21-30s among net types, the visual trend of lower catches for T90 and the significantly lower catch of 16-20s suggest an issue of insufficient statistical power that may be reconciled with further testing and greater replication. The survey catch rate for November highlights a significant effect of prawn grade only (ANOVA: $F_{4, 100} = 32.52$; $P < 0.001$); despite apparently lower catches of 21-30s when using aT_{90} mesh net (Figure 7b).

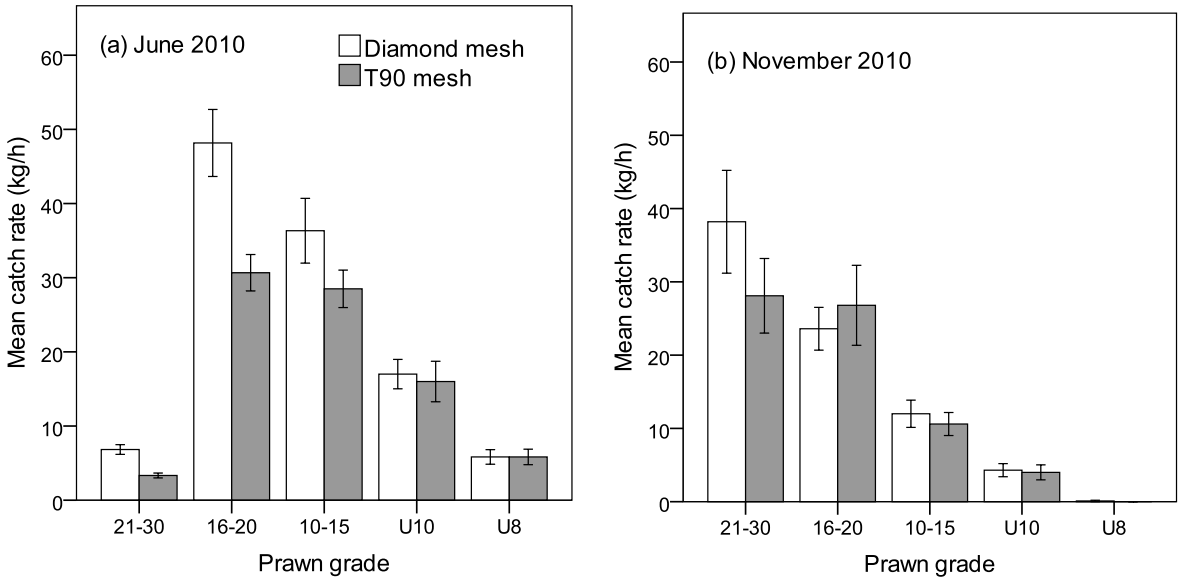

Figure 7. Mean (SE) catch of prawns by commercial size-grade captured during fishery independent trials of diamond and T90 mesh cod-ends conducted during (a) June and (b) November 2010.

Comparison of by-catch between T90 and diamond cod-ends

By-catch differed among broad taxonomic groups and with cod-end type (diamond vs. T90; Figure 8), with the estimated weights of both sponge and fish/crabs caught in T90 lower than that caught in diamond cod-ends for June and November (ANOVA: $F_{1, 28} = 3.92$; $P = 0.059$ and $F_{1, 28} = 9.92$; $P = 0.008$).

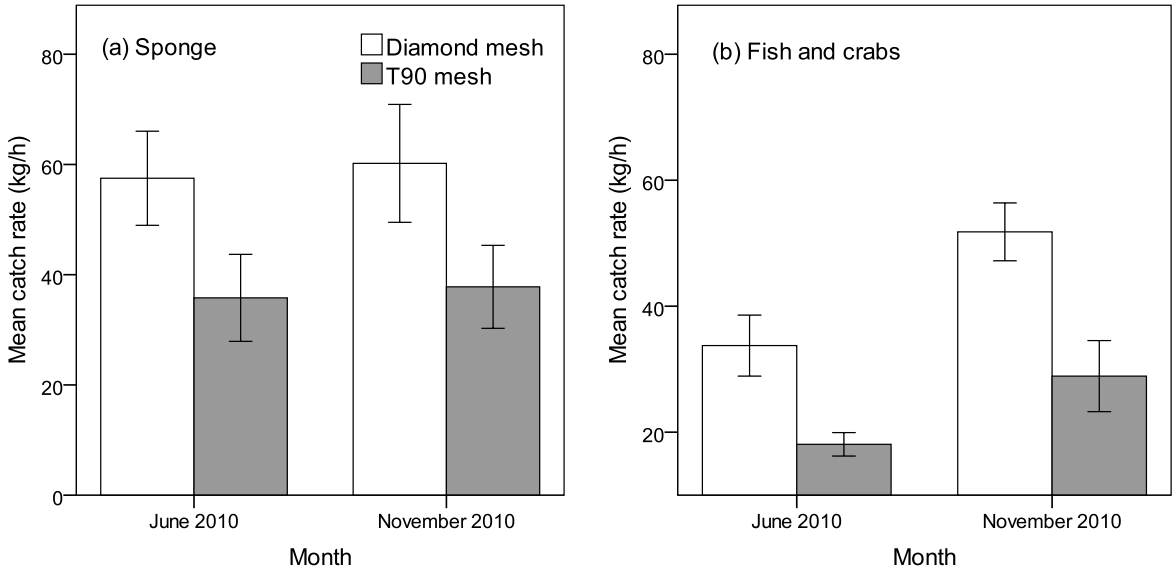

Figure 8. Mean (SE) catch of; (a) 'sponge' and (b) 'fish/crabs' caught during June and November 2010, using conventional diamond and T90 mesh cod-ends.

Counts of elasmobranchs were not significantly different among net types (diamond vs. T90 cod-end) or months (Figure 9).

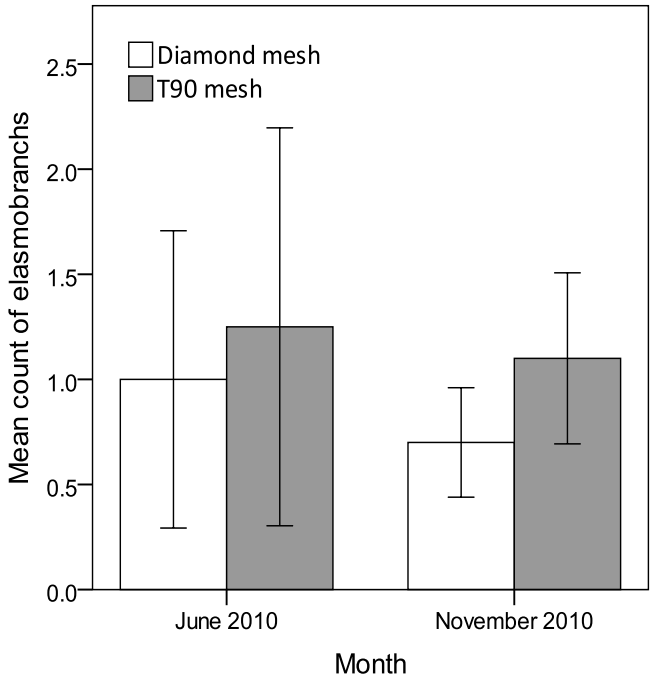

Figure 9. Mean (SE) counts of elasmobranchs caught using conventional diamond and T90 cod-ends trialled during June and November 2010.

7.2.2 T90 cod-ends with by-catch reduction devices

A number of BRDs were tested (for details see, Appendix 4) with some successful at removing by-catch and maintaining prawn catches (configurations 2, 3, 4 & 7), whilst others were not (configuration 1). For the successful trials, the mean catch rate of prawns did not differ significantly between T90 cod-end only and T90 with BRD (Figure 10; ANOVA: $F_{1, 60} = 1.78$; $P = 0.188$).

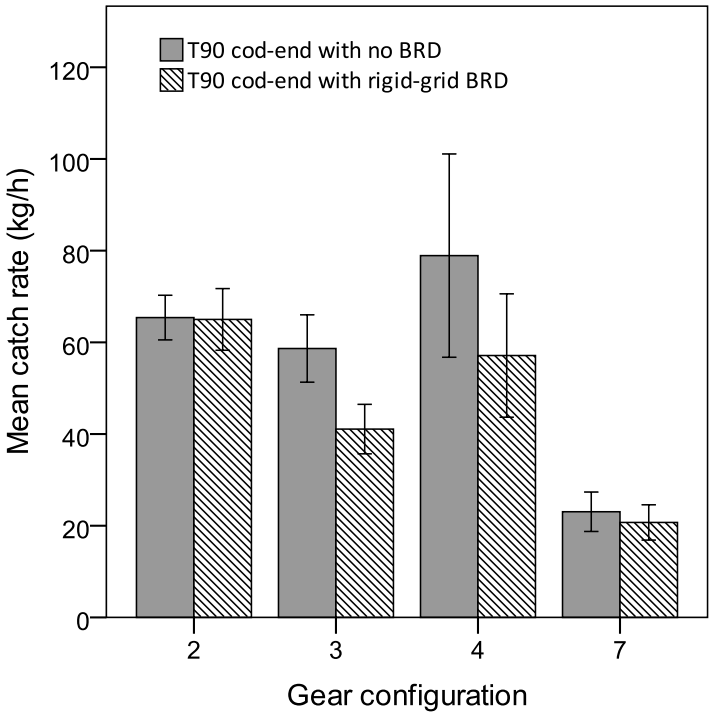

Figure 10. Mean (SE) catch rate of prawns using trawl gear comprising of T90 cod-ends only compared to T90 cod-ends with the addition of various BRD's (configurations 2, 3, 4 & 7).

There was no significant difference in mean catch rate between the optimal T90 cod-end and the optimal T90 cod-end with anterior rigid-grid (Figure 11).

By-catch varied among taxonomic grouping and gear design (Figure 12). Estimated catch weights of sponge and elasmobranchs (sharks and rays) were significantly reduced with the addition of an anterior rigid-grid (ANOVA: $F_{1, 8} = 8.49$; $P = 0.027$ and $F_{1, 8} = 8.23$; $P = 0.028$, respectively). Whilst displaying a similar general trend, estimated weights of fish/crabs did not differ between net designs (ANOVA: $F_{1, 8} = 2.95$; $P = 0.137$) probably because of the low number of replicate trials.

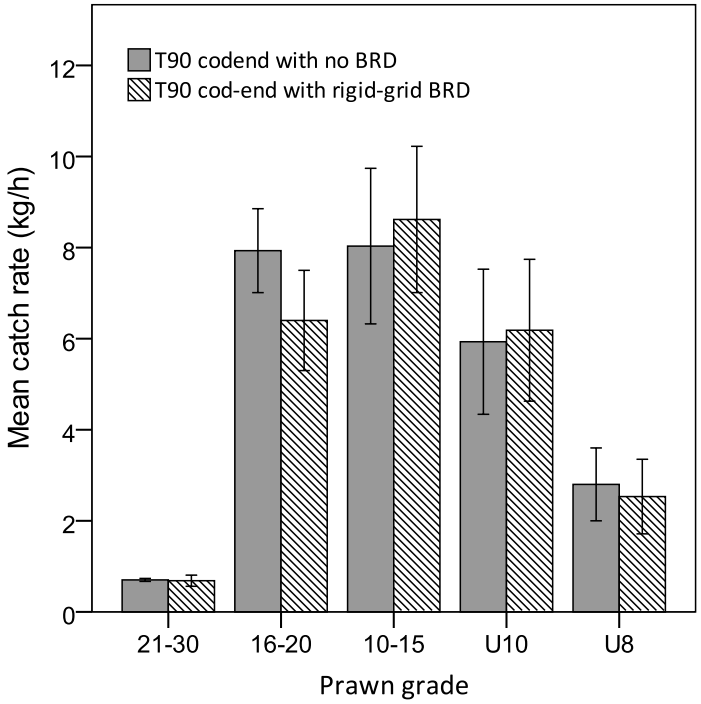

Figure 11. Mean (SE) catch rate by prawn grade using trawl gear comprising of a T90 mesh cod-end only and one that included a rigid-grid BRD anterior to the T90 cod-end (configuration 7).

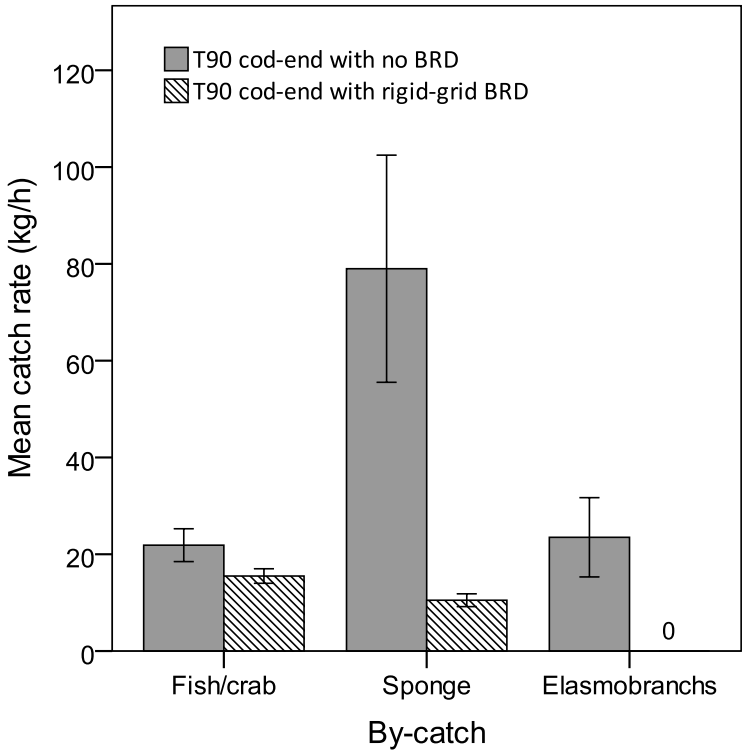

Figure 12. Comparison of the estimated weight of 'fish/crabs', 'sponge' and elasmobranchs caught using trawl gear comprising of a T90 mesh cod-end only and one that included a rigid-grid BRD anterior to the T90 cod-end (configuration 7).

7.3 The use of under-water video for gear development and extension

Near real-time video analyses facilitated rapid net refinement by enabling the net-makers, skipper and crew to immediately identify and rectify gear issues. Video footage provided clear evidence that skates, rays and other elasmobranchs were excluded by the grid (Figure 13). While sponges were typically excluded (Figure 12), there were some instances of sponge partially blocking the grid during trawling. Observations such as these led to the testing of alternative approaches, such as varying the angle of the grid, to attempt to resolve these issues.

Video footage was also a useful extension tool. In particular, comparison of T90 and diamond mesh cod-ends provided evidence of the differences in flow between the two gear types, the exclusion of by-catch species in T90 cod-ends, and the capture of prawns in both net types. Video footage from these trials can be found at:
http://www.youtube.com/watch?v=mH3iVeioEnQ

7.4 Adoption of T90 cod-ends with grids: survey and commercial fishing

7.4.1 Mean weight of prawns during surveys

The mean weight of prawns surveyed in northern Gulf St Vincent during March declined substantially from 2005 to 2011 when only diamond mesh cod-ends were used. There was a substantial increase in the mean size of prawns in March 2012 when T90 cod-ends were used (Figure 14). The magnitude of the increase in mean prawn size between 2011 and 2012 likely reflects increases in selectivity of T90 cod-ends rather than a change in the mean size of the population, because later surveys using diamond nets (April and May 2012) indicated that levels of recruitment to the fishery were similar between 2011 and 2012 (SARDI unpublished data).

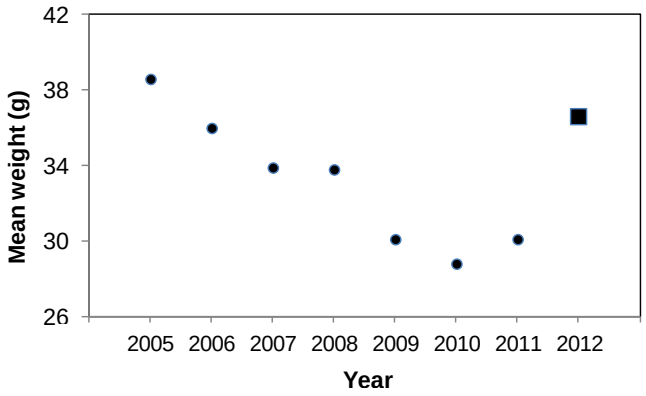

Figure 14. Mean weight of prawns surveyed in northern Gulf St Vincent in March using diamond cod-ends from 2005-2011 (circles) and using T90 cod-ends in 2012 (square).

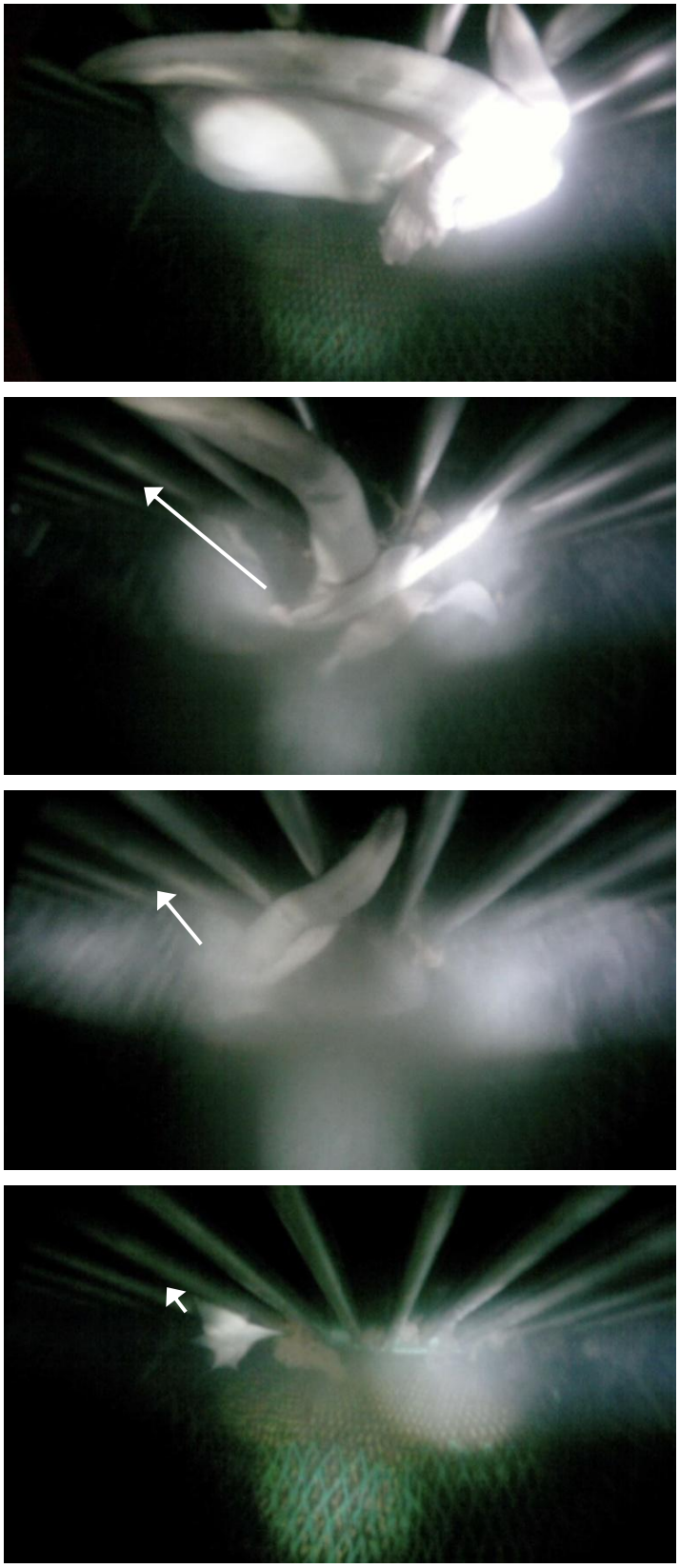

Figure 13. Serial still frames (top left to bottom right) from under-water video footage of a Melbourne skate (*Dipturus whitleyi*) being excluded from the trawl net by the grid (in the direction of the arrow).

7.4.2 Prawn grades (size composition)

The size composition of prawns harvested in March 2012 using T90 with grids comprised more large prawns than for the corresponding fishing period in March 2011 when diamond cod-ends were used (Figure 15). In particular, there were substantial increases in the proportion of U10 and larger prawns and reductions in the relative capture of 16-20s and 20+ prawn grades. The proportion of soft and broken prawns was also lower in 2012.

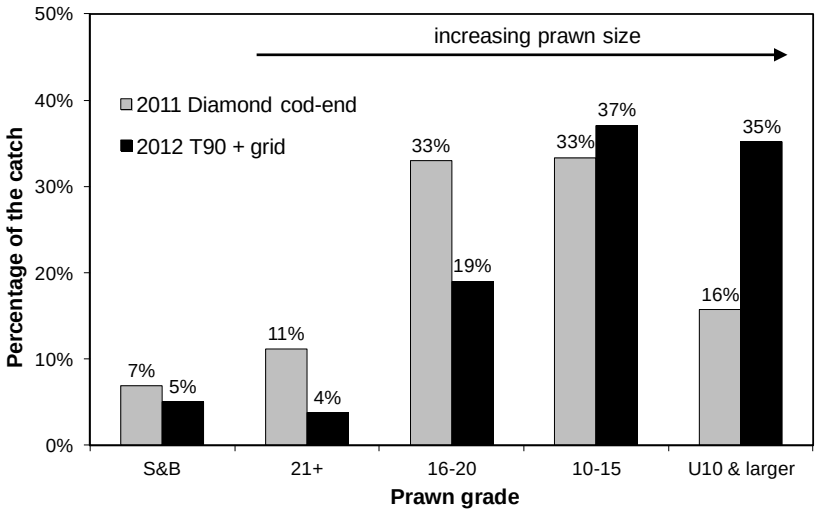

Figure 15. Percentage of the catch in various prawn grades during commercial fishing in March using diamond cod-ends in 2011 and T90 cod-ends with grid in 2012. S&B is Soft and Broken.

7.4.3 Trawl duration

The mean duration of trawl shots was significantly longer (ANOVA: $F_{1,\ 841} = 28.154$; $P < 0.001$) for trawls conducted in March 2012 using T90 cod-ends with a grid than for corresponding trawl durations using diamond cod-ends in March 2011 (Figure 16).

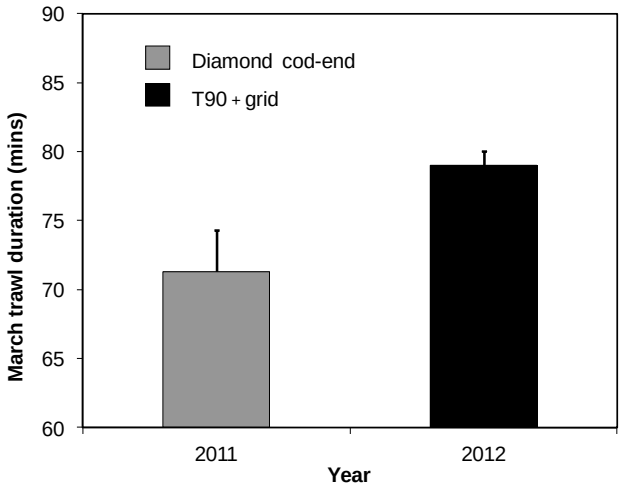

Figure 16. Mean (SE) trawl shot duration per night during commercial fishing in March using diamond cod-ends in 2011 and T90 cod-ends with grid in 2012.

8. DISCUSSION

8.1 The Research, Development, Extension and Adoption framework

This project provides an example of participative, cost-effective research and development that resulted in rapid adoption of significant by-catch reduction technology for a demersal prawn trawl fishery. There were several elements of the project that were critical to its success.

(i) The establishment of an experienced and inclusive research and development team.

While SARDI scientists provided project leadership, supervision of the survey design and data collection process, and the responsibility for reporting, the “innovation” leader was Jim Raptis of A. Raptis and Sons, whose collaboration with Lankhorst Euronete Australia and SEANET underpinned the project concept. The combined experience of these team members enabled rapid evolution of the T90 cod-end and BRD designs. Importantly, this also engendered significant ownership of the process within the broader industry, a factor that proved pivotal in the extension phase. PIRSA had an important role in the research phase, providing policy advice and ensuring that appropriate exemptions were in place for T90 and BRD trials.

(ii) A focus on rapid evolution of technology.

This research was conducted in a manner unlike most other by-catch projects, with a clear focus on rapid development of technology and only a cursory focus on critical assessment. From the outset, it was determined that the role of science in this project was to enable rapid gear development by fishers and net-makers in a manner that was both measurable and robust. For the initial T90 cod-end development phase, only critical measures of prawn catch rate and mean prawn size (bucket counts) were collected. Once the optimal T90 design was achieved, more detailed data were gathered including by-catch composition and prawn length-frequency data. A similar process was followed for the testing of BRDs. In both instances, once the optimal configuration had been determined, both fishers and net-makers had confidence in the results after only a few shots. These results were achieved at a fraction of the cost of many previous by-catch research programs.

However there are limitations to this economically efficient approach. Of primary importance, once the optimal configuration had been determined, financial constraints meant that there were no resources remaining to thoroughly trial the gear. While the degree of improvement in by-catch exclusion was clear, insufficient temporal and spatial replication in testing the optimal configuration leads to some uncertainty, particularly regarding the impacts on

commercial prawn catch. Despite this uncertainty, the majority of industry was convinced by the technology such that they chose to implement the new gear rather than invest in further testing.

(iii) The use of under-water video technology.

Prior to the development of affordable under-water video, observations on trawl gear were generally done by direct diver observations (e.g., Freedman et al. 2009) which are inherently expensive and logistically difficult, or via controlled experiments done in flume tanks which have considerable issues associated with scaling-up to commercial scale designs (e.g., Fiorentini et al. 2004). In this project, we used affordable, high definition under-water video cameras (HERO$^{(R)}$: GoPro, Woodman Labs, Inc, California, USA) to obtain video footage that was often viewed immediately after hauling to improve the understanding of gear and animal behaviour. The video clearly demonstrated the limitations of diamond mesh cod-ends, with substantial restrictions in water flow through the net as the diamond meshes almost completely closed up. The majority of the catch appeared to swim easily within the cod-end while trawling, only being caught once the cod-end was hauled and thus limiting the opportunity for escapement. In stark contrast, the meshes of the T90 cod-end remained open, with a strong water flow apparent as fish and prawns were rapidly flushed to the back of the cod-end. This footage, seen very early on in the trial process, was important for all participants to understand how T90 worked, and provided great confidence in the potential outcomes. In this same manner, video footage was then used as a development tool for alternative T90 and BRD configurations, improving the understanding of what was observed in the cod-ends upon hauling.

(iv) Extension of results to fishers

Many well-researched by-catch reduction technologies have failed to be adopted by the fishing industry due to poor or ineffective communication of results to the end-user (Jennings et al. 2011). This reluctance may also result from mistrust in the results, perceived increases in cost, reduced performance and failure to maintain catches at the same levels as conventional trawls (Rulifson et al. 1992; Robinstroeger 1994). In this project, trust in the results was achieved because the project concept and development came from a key member of industry. Also, we kept the scientific objectives and performance measures simple and achievable, with the primary objective being to ensure that losses in catch rate and value for new net configurations were minimised. The inclusion of key industry members in research and development also resulted in discussion among fishers not directly involved in the project, including other prawn fishing industries within South Australia and other

states. As previously mentioned, the posting of under-water video on the internet was an important tool of extension to all stakeholders and the broader community. Finally, at the completion of the development phase a workshop was held for Gulf St Vincent prawn fishers to view the results of the project and critically, to examine firsthand the T90 net and grid.

(v) Adoption of T90 cod-ends with grids

Following the workshop, a large majority of Gulf St Vincent Prawn Fishery licence holders voluntarily agreed to adopt the optimal configuration of T90 cod-ends with grids. To ensure an equitable harvest strategy, PIRSA agreed to change the legislation regarding net configurations for all licence holders. With less than three months prior to the next fishing period, it was determined that the most practical legal instrument to use was a condition attached to the issuing of each Gulf St Vincent Prawn Fishery Licence (a licence condition; Appendix 4). The licence condition was developed with input from PIRSA Policy Managers, Compliance Officers and Legal Advisers. The use of a licence condition rather than a change in legislation provided two primary benefits. Firstly, the licence condition was quick to implement as it did not require approval by Cabinet (whereas regulations do). Secondly, a licence condition can be easily amended or revoked if the new gear configurations do not perform as expected. It is anticipated that implementation of the new gear by regulation will be sought once the licence condition has been established satisfactorily for a period of time.

8.2 Development and evaluation of by-catch reduction systems

8.2.1 T90 cod-ends

Initial testing procedures for six alternative T90 cod-end configurations began in December 2009. In each trial, there was no significant difference in the total catch of prawns in the T90 cod-end compared to the diamond cod-end when towed side by side. The optimal T90 cod-end configuration was determined in June 2010 after seven trial nights.

The optimal configuration was tested for six shots on one night in June 2010 and again for ten shots in November 2010. While the total catch was slightly lower in the T90 cod-end during June, the differences between T90 and diamond cod-ends on a shot by shot basis were not statistically significant. Prawn-grade data suggested that the majority of prawns escaping capture were small (21-30s and 16-20s prawn grades). While a reduction in the capture of 21-30s was apparent in November 2010, overall the repeat trials were not as selective as those in June. Similar trends were observed between treatments and seasons for the other two prawn size measures: bucket counts and length frequency.

Comparisons of by-catch weight between T90 and diamond cod-ends provided similar trends between seasons, with significantly lower catches of fish/crabs and sponge in T90 nets during June and November 2010. However, there was no significant difference in the capture of elasmobranchs. The weight of by-catch was significantly greater in November than June, and the consensus opinion of the research and development team was that the reduced selectivity in November 2010 was likely to have resulted from the greater levels of by-catch that month. There were insufficient data to examine the relationship between by-catch weight and selectivity.

8.2.2 T90 cod-ends with by-catch reduction devices

The adoption of BRDs into trawl operations is helping to minimise the catch of non-target species in many trawl fisheries around the globe (Garcia-Caudillo et al. 2000; Lucchetti & Sala 2010; Broadhurst et al. 2012). An Australian perspective has been the successful adoption of rigid-grid BRDs and turtle exclusion devices (TEDs) in the Northern Prawn Fishery (see, Salini et al. 2000). BRDs have also been shown to reduce the amount of debris entering trawl nets (Lucchetti & Sala 2010) which is likely to improve the selectivity of the T90 cod-end and improve not only the condition of commercial catch (Salini et al. 2000), but reduce handling time and improve fuel efficiency.

Several different BRD configurations were tested with the optimal T90 cod-end. The most successful BRD (best selectivity with minimal prawn loss; Figure 10 Configuration 7) was a modification of the Nordmore grid (Brothers 1992). The grid was placed anterior to the cod-end and was angled upward such that by-catch was released out of a hole in the top side of the net that was covered by a flap of net. The T90 cod-end and grid combination was compared against the optimal T90 cod-end and showed no significant difference in the total catch of prawns or size composition. However there were significant and substantial reductions in the capture of elasmobranchs (zero with grid) and sponges (~85% reduction). While the remaining by-catch of predominantly small fish and crabs did not differ significantly between gear types, the total weight was about 25% lower with the grid.

8.3 Commercial fishing

8.3.1 Commercial trials

A commercial fishing trial of T90 cod-ends (without grids) was conducted in March 2011 to compare the performance of these nets under commercial fishing conditions however the results of the trials were not presented in this report. The vessel previously involved in the research trials used the T90 cod-ends for the full night, towing side by side and for the same shot durations as another commercial fishing vessel using standard diamond cod-ends.

While initial examination of the size structure of the catch displayed substantial differences in selectivity, post-hoc examination of the size structure of the catch for the remainder of the March fishing period (when both vessels used diamond nets) also showed similar differences in size structure, suggesting that the differences in the T90 trial at least partly reflected differences between vessels. Thus, the analysis was confounded by vessel and gear configuration. A more appropriate approach for testing the T90 gear would have been for each vessel to use diamond and T90 on alternative nights to remove vessel effects. This demonstrates the importance of a well replicated statistical design that minimises all potential sources of variance, which is often a challenge when working within commercial fishing constraints.

8.3.2 Adoption of T90 with grids: surveys and commercial fishing.

Data from surveys conducted in March from 2005 to 2011 using diamond mesh cod-ends showed a general decrease in mean prawn size in the population of prawns in GSV. Surveys conducted in March 2012 using T90 cod-ends with grid showed a substantial increase in mean size. While this comparison is confounded by differences in the size structure of the population between years, given the magnitude of the difference in prawn size between 2011 and 2012 compared to other inter-annual differences, it is reasonable to assume that the difference primarily reflects gear selectivity.

Following this logic, the substantial differences in the size structure of the commercial catch using T90 cod-ends with grid in March 2012 compared to diamond cod-ends in March 2011 are also likely to reflect differences in gear selectivity. Importantly, large prawns of size grade U10 and larger more than doubled in proportion, while the catch of 16-20s and 20+ prawns substantially decreased. Further, the proportion of soft and broken prawns was less with T90 and grids due to the reduced interaction between prawns and large by-catch species. The increase in proportion of large prawns and reduction in small and soft and broken prawns, results in a substantial increase in the relative value of prawns harvested.

Effort data from commercial fishing in March 2011 and 2012 were analysed to assess differences in mean trawl duration. Skippers using T90 cod-ends with grid significantly increased the mean duration of trawl shots. The increase of 10% in trawl duration may be an underestimate of the potential increase in trawl duration because fishers were only becoming accustomed to the new gear in March 2012 and there were many shorter searching shots in 2012 because the areas open to harvest were much larger than March 2011.

9. BENEFITS

This project has resulted in the voluntary adoption of by-catch reduction technology that provides immediate benefits for the Gulf St Vincent Prawn Fishery. The application of T90 cod-ends with grids also provides significant opportunities for other commercial trawl fisheries, nationally and internationally. Further, Australian fisheries research in general may benefit from the research and development framework presented.

The successful adoption of T90 cod-ends with grids into the Gulf St Vincent Prawn Fishery provides several immediate economic and social benefits to the industry, while delivering benefits to the environment for this fishery. A significant reduction in the total weight of by-catch captured was demonstrated, particularly for elasmobranchs and sponges, which reduces the impact of trawling on the environment and improves the public perception of the fishery. T90 cod-ends also enabled substantial escapement of small, lesser valued prawns which should provide long-term benefits for the sustainability and economic viability of the resource. Additionally, T90 cod-ends with grids improve the quality of the catch, enable efficient, longer duration trawls to be undertaken, reduce handling times and eliminate the risks associated with handling large elasmobranchs (e.g., stingrays). Although not an objective of this report, the potential for reduced drag associated with T90 codends and grids is also likely to improve fuel efficiency (Moderhak 2000).

Extension of these outcomes has already resulted in significant interest in this gear type by other commercial trawl fisheries in Australia, for species that include prawns, scallops and finfish. A well planned project to extend the knowledge gained from this research could potentially result in efficient and widespread adoption of this technology throughout Australia. Adoption may be voluntary or mandatory (e.g. by regulation), depending on the needs of the fishery or jurisdiction.

Fisheries research in Australia can benefit from the demonstration of a collaborative approach that resulted in cost-effective research and development in a scientifically robust manner that, coupled with an appropriate extension plan, provided sufficient confidence in the results that industry pursued rapid adoption into the commercial fishery. This outcome was aided by the use of inexpensive under-water video cameras that enabled rapid gear development by examining footage immediately after trawling to improve our understanding of the behaviour of various gear configurations and animal interactions. Further, the footage was pivotal in the extension of results to key stakeholders and to the broader fishing and general community.

The benefits from this project far exceeded the original objectives which were limited to the examination of various T90 cod-ends (did not include BRDs) and the development of a framework to allow fishers to collaboratively develop gear in an efficient and robust manner.

10. FURTHER DEVELOPMENT

The process undertaken for this research was dissimilar to most research and development approaches for by-catch mitigation technology. This program focused on rapid development by maintaining broad and achievable scientific objectives. Whilst the research was conducted over three years, the optimisation of i) T90 cod-ends and ii) T90 cod-ends with grids each took seven nights to achieve. At the end of each process, the research team built sufficient confidence in the optimum gear configurations that few shots were required for scientific assessment. As such, there is an immediate need for rigorous evaluation of the differences between T90 cod-ends with grid and traditional diamond nets for stock assessment of the Gulf St Vincent Prawn Fishery.

Concomitant to the completion of this report, robust scientific comparisons of T90 cod-ends with grid versus traditional diamond cod-ends were undertaken during routine Gulf St Vincent fishery-independent surveys in April and May 2012. As for the trials in this report, the two gear configurations were towed together, side by side. More than one hundred 30-minute survey shots were conducted on each occasion. Surveys concentrated on obtaining accurate measures of catch rate and prawn size from each net, with an assessment of by-catch from each net collected during May only. Preliminary analyses indicate that T90 significantly reduced by-catch weights throughout Gulf St Vincent. However, the differences in the catch rate of prawns between net types appeared to be variable among vessels, which was a similar result to comparisons of square mesh cod-ends used in the commercial eastern king prawn (*Melicertus plebejus*) fishery in New South Wales (Macbeth *et al. 2012*). While it is currently unclear why there appeared to be vessel effects, it is possible that towing T90 cod-ends alongside diamond nets does not provide an accurate comparison due to the additional drag associated with diamond nets. From these experiences, and the commercial trials conducted on T90 cod-ends in March 2011, it is proposed that future comparisons of gear type will be conducted by two vessels towing side by side at the same speed and trawl duration, each towing either twin T90 cod-ends with grid or twin diamond cod-ends, then repeating the process on a second night with the alternative gear type. A well replicated experiment in this manner could achieve all objectives of accurately assessing differences in prawn catch, selectivity, by-catch reduction, fuel efficiency and handling time.

A key uncertainty in the potential benefits of T90 cod-ends with grids for the Gulf St Vincent Prawn Fishery is the unknown survival rates of small prawns that interact with the gear but avoid capture (Wooden et al. 2008). Previous studies for square mesh cod-ends indicate that survival rates are high and while it is reasonable to assume that similar survival estimates would be obtained for T90 cod-ends, validation of these results would provide

greater confidence for industry and managers. Alternatively, smaller T90 mesh sizes could be considered that would reduce the losses in catch of 16-20 and 20+ prawn grades.

The Spencer Gulf Prawn Fishery began trials of T90 cod-ends with grids in June 2012. Initial objectives were to target the effective removal of blue crabs, which can be captured at high catch rates on occasions. Also, smaller mesh sizes will be trialled in the future as the fishery generally targets a smaller size range than Gulf St Vincent, with the 16-20 grades comprising a large proportion of the catch.

Understanding gear performance (i.e., drag resistance and hence towing efficiency) of T90 nets could be substantially augmented by flume tank experiments. These are likely to lend weight to the anecdotal benefits to industry such as improved fuel efficiency. Whilst there are inherent issues with using scale models (Fiorentini et al. 2004), there are specific advantages related to the qualitative observation of design features of the trawl net itself. Although such tests cannot provide an overall view of the trawl system and its working environment, models may provide valuable insight into the physical interaction of various component and performance factors to highlight areas worthy of close attention in full-scale trials.

Finally, the benefits of novel T90 cod-ends may provide significant opportunities for improvements in by-catch reduction and catching efficiency for other Australian trawl fisheries. Given the results of this research, a co-ordinated approach to the trialling of T90 cod-ends in other jurisdictions would be sensible, as many of the issues that T90 could address may be common across fisheries. A similar approach to this study should also be encouraged, with inclusive research and development teams and a focus on rapid development and optimisation.

11. PLANNED OUTCOMES

The original planned outcomes of this project were 1) to provide a baseline assessment of T90 cod-end mesh that may facilitate the future uptake of by-catch reduction devices in the GSV prawn fishery and 2) to develop a framework that enabled industry to trial and evaluate by-catch reduction technology. The final outcomes of the project exceeded the planned outcomes and include:

- Voluntary agreement to uptake T90 cod-ends with grids by the vast majority of Gulf St Vincent Prawn Fishery licence holders.
- Reductions in total by-catch for the Gulf St Vincent Prawn Trawl Fishery.
- Improvements in selectivity by the exclusion of a high proportion of small prawns from capture.
- The reductions in by-catch resulted in improved catch quality (less damaged prawns), longer duration trawl shots, reduced sorting and handling times, and improved safety by eliminating interactions with large stingrays.
- Demonstration of a process for cost-effective, participative research and development for by-catch mitigation strategies that can lead to improved extension and rapid adoption.

12. CONCLUSIONS

This project has resulted in the voluntary adoption of by-catch reduction technology for the Gulf St Vincent Prawn Fishery. The current focus on Ecosystem Based Fishery Management suggests that community scrutiny of by-catch for trawl fisheries is likely to continue to rise. With concurrent increases in economic pressure on fisheries and research agencies, this project can be used as a model for future by-catch mitigation programs to ensure inclusive, cost-effective research and development that maximises the likelihood of adoption.

The T90 cod-end with grid delivers substantial environmental benefits, as well as direct economic benefits for the Gulf St Vincent Prawn Fishery. To our knowledge, this is the first adoption of T90 mesh into a prawn/shrimp trawl fishery in Australia. Under-water video clearly demonstrated the increased flow associated with T90 mesh compared to traditional diamond mesh and this was pivotal in the effectiveness of the rigid grid BRD. The performance of the T90 and grid combination was above the expectations of all stakeholders, and the potential benefits for other prawn trawl fisheries may be substantial. Trials performed subsequent to this project have demonstrated that the T90 and grid can exclude large catches of small finfish. Flume tank experiments that examine the flow dynamics of the T90 and grid may aid understanding of why this gear is more effective in reducing by-catch than most current alternatives.

T90 cod-ends with grids were introduced into the Gulf St Vincent Prawn Fishery in March 2012. This has had a substantial and immediate impact for the fishery, particularly regarding the development of fishing strategies. In recent years, there has been a significant increase in the abundance of small prawns in Gulf St Vincent which has made it difficult to identify areas to fish at the appropriate target size (Dixon *et. al.* 2012). The introduction of the more selective T90 gear has meant that the area opened to fishing has increased substantially while still maintaining protection of small prawns. Preliminary examination of catch and effort data also suggests that the size composition of the catch has improved considerably and that trawl durations have increased. Further assessment of these data will shed light on the strength of these benefits for the fishery.

In summary, the results of this project substantially exceeded the planned benefits of the original proposal. This was largely due to the involvement, enthusiasm and project ownership by key industry members (A. Raptis and Sons PTY LTD) from the initial concept through to the adoption phase. This project is a clear example of collaborative, applied research that has provided significant community and stakeholder benefits in an

economically efficient manner. It is hoped that other Australian trawl fisheries can benefit from the technology and approach reported here.

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APPENDIX 1: INTELLECTUAL PROPERTY

The T90 trawl net configurations were developed by commercial net-makers (Thorsteinn Benediktsson of Lankhorst Euronete Australia and Wally Hill of Hills Nets). A commercial version of the Configuration F cod-end with top-shooter grid has been be produced and distributed to the GSV prawn trawl fleet. All gear designs trialled are provided in the appendices.

The research output from this project is for the public domain. The report and any resulting manuscripts are intended for wide dissemination and promotion. All data and statistics presented conform to confidentiality arrangements.

APPENDIX 2: STAFF

Table 2. List of all staff engaged on the project

Name	Organisation	Project Involvement
Dr Cameron Dixon	SARDI	Principle Investigator
Jim Raptis	A Raptis and Sons	Co-investigator
Dr Shane Roberts	SARDI	Co-investigator
Nathan Bicknell	SeaNet	Co-investigator
Thorsteinn Benediktsson	Lankhorst Euronete Australia	Co-investigator
Wally Hill	Hills Nets	Co-investigator
Jason Saint	A Raptis and Sons	Co-investigator
Alice Fistr	PIRSA	Co-investigator
Justin Phillips	Extension Officer	Co-investigator
Dr Daniel Gorman	SARDI	Analysis/reporting
Graham Hooper	SARDI	Field coordinator
Dr Craig Noell	PIRSA	Fishery Manager
Shirley Sorokin	SARDI	Laboratory processing
Renee Newman	SARDI	Data entry/Analysis
Skye Barrett	SARDI	Data entry/Analysis
Alex Dobrovolskis	SARDI	Laboratory processing

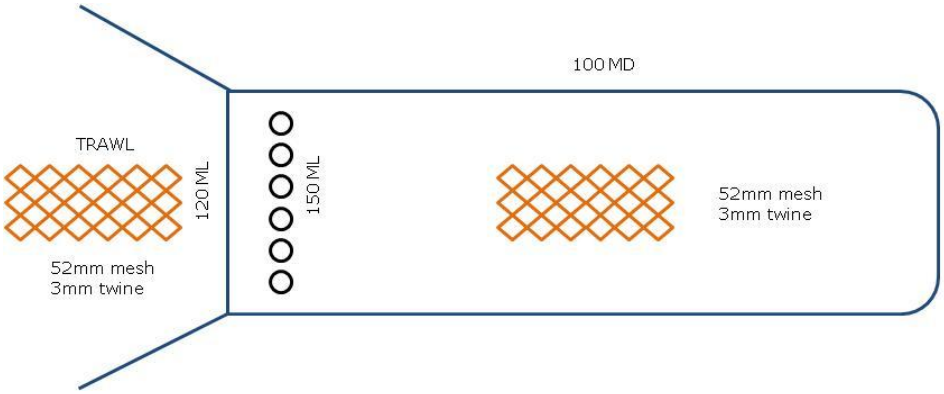
APPENDIX 3: SURVEY DETAILS AND GEAR CONFIGURATIONS

Cod-end configuration evolved throughout the development phase of the project during the fishery-independent trials. Configurations were optimised by integrating observations of gear performance, catch rates and near real-time video footage. In total, six configurations of T90 cod-ends were tested during the GSV prawn fishery 'net trial' project (December 2009 - June 2010). Further trials of the optimised (Configuration F) design were done in November 2010. Note the drawings provided in the following appendices are indicative of the configurations tested during the project. They do not necessarily reflect the final version of the net that was adopted for the Gulf St Vincent Prawn Trawl Fishery.

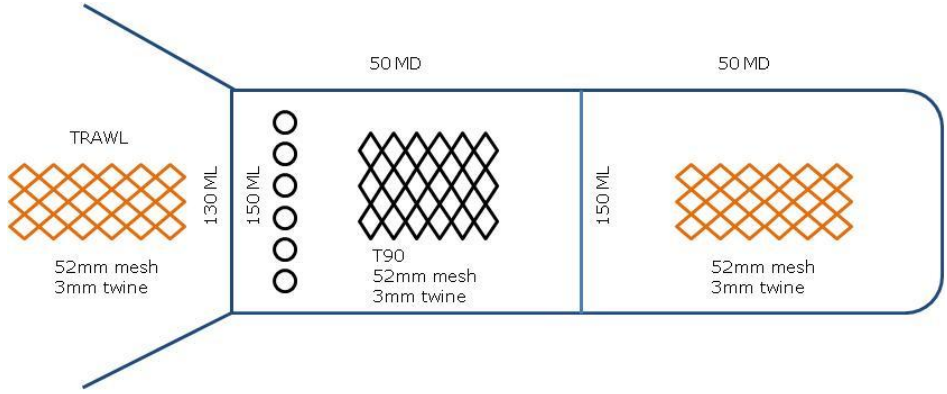
Table 3. Summary of Gulf St Vincent prawn fishery T90 net trials. Note: the standard industry cod end (also shown below in Fig. 17 for comparison) has a length of 100 meshes of 52mm diamond mesh, which is the largest mesh size used in the GSV fishery (minimum mesh size legislated at 45mm).

Dates	Vessel	Diamond-mesh cod-end tested against:
11/12/2009	Anna Pearl	T90 cod-end (configuration A)
12/12/2009	Anna Pearl	T90 cod-end (configuration B)
7/05/2010	Anna Pearl	T90 cod-end (configuration C)
11/06/2010	Anna Pearl	T90 cod-end (configuration E)
11/06/2010	Anna Pearl	T90 cod-end (configuration F)
11/11/2010	Anna Pearl	T90 cod-end (configuration F)

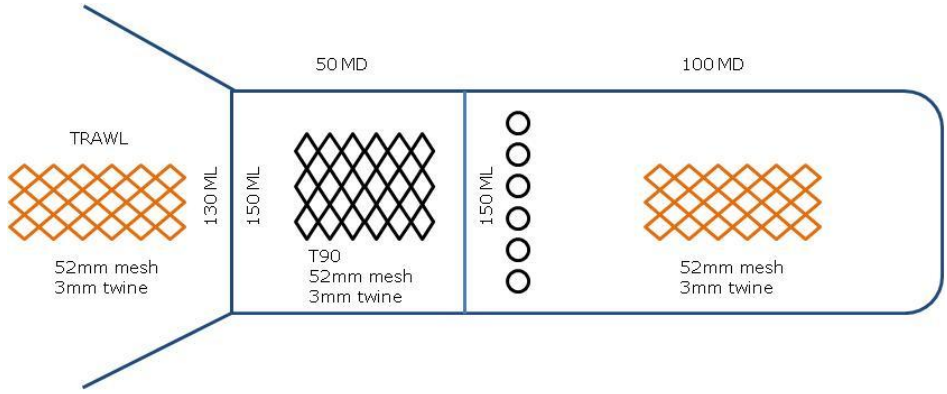
Standard diamond cod-end



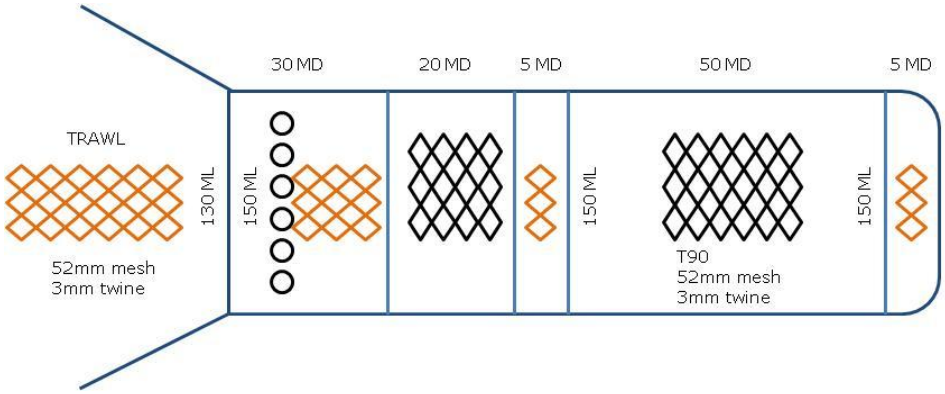
T90 cod-end configuration A



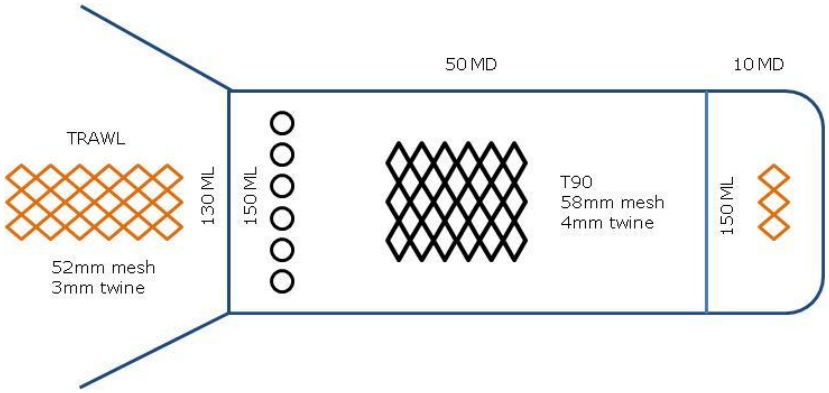
T90 cod-end configuration B



T90 cod-end configuration C



T90 cod-end configuration E



T90 cod-end configuration F

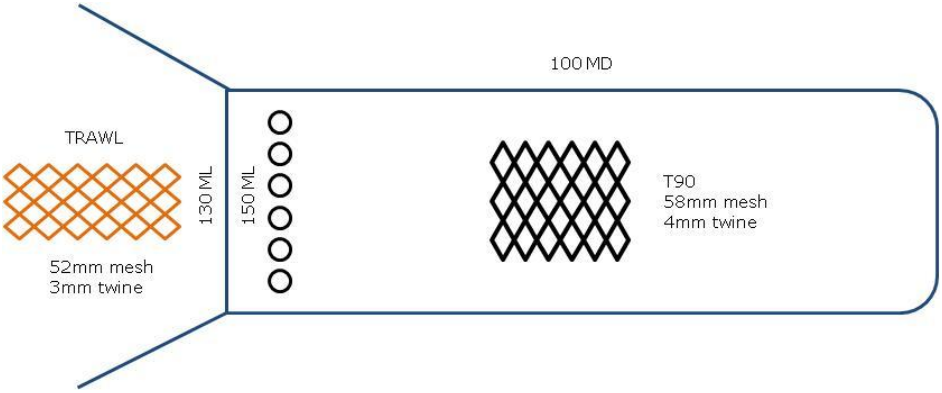
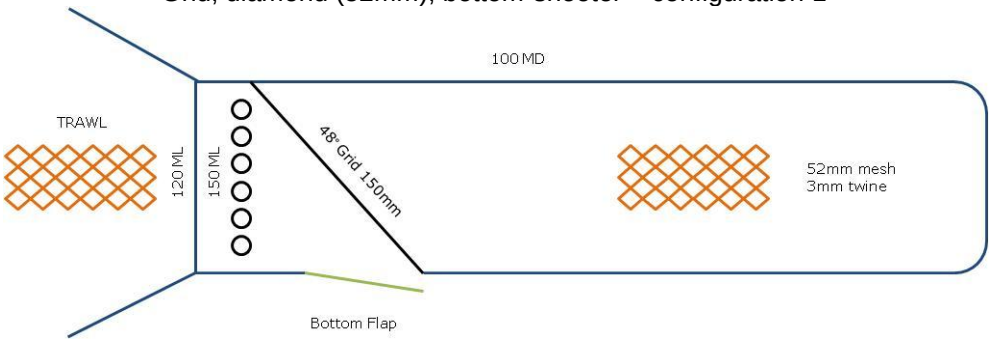


Figure 17. Net configurations tested during the course of the project; (a) Standard cod-end, (b) T90 Configuration A, (c) T90 Configuration B, (d) T90 Configuration C, (e) T90 Configuration E, (f), T90 Configuration F. Note drawings are indicative only and reflect configurations tested during this project, not the final design utilised for the GSV Prawn fishery.

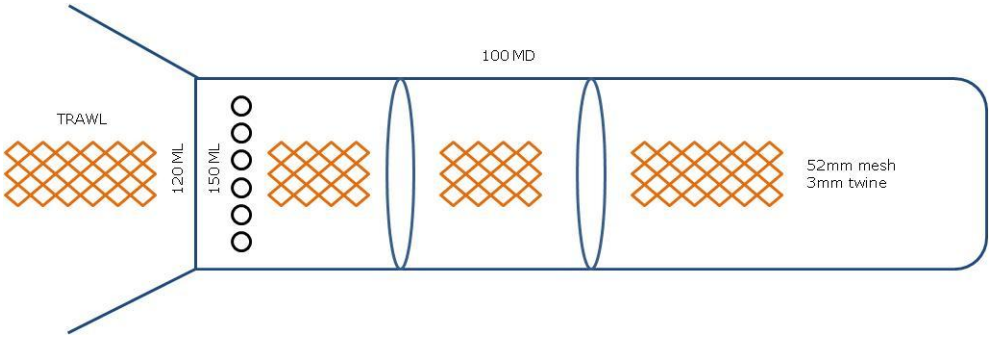
Table 4. Summary of Gulf St Vincent prawn fishery BRD (T90) net trials. Note: the standard industry cod end (indicated in the table as 'Diamond') has a length of 100 meshes of 52mm diamond mesh, which is the largest mesh size used in the GSV fishery (minimum mesh size legislated at 45mm).

Date	Vessel	Description
8/5/2010	Anna Pearl	Diamond vs. Diamond with grid (configuration 1)
10/6/2010	Anna Pearl	Diamond vs. Diamond with hoops (configuration 2)
10/6/2010	Anna Pearl	T90 (E) vs. T90 (E) with grid (configuration 3)
2/11/2010	Anna Pearl	T90 (F) vs. T90 (F) with grid, bottom-shooter (configuration 4)
3/11/2010	Anna Pearl	T90 (F) with grid, bottom-shooter, both sides (configuration 4)
25/3/2011	Anna Pearl	T90 (F) vs. T90 (F) with grid, top-shooter (configuration 6)
25/5/2011	Anna Pearl	T90 (F) vs. T90 (F) with grid, top-shooter (configuration 7)

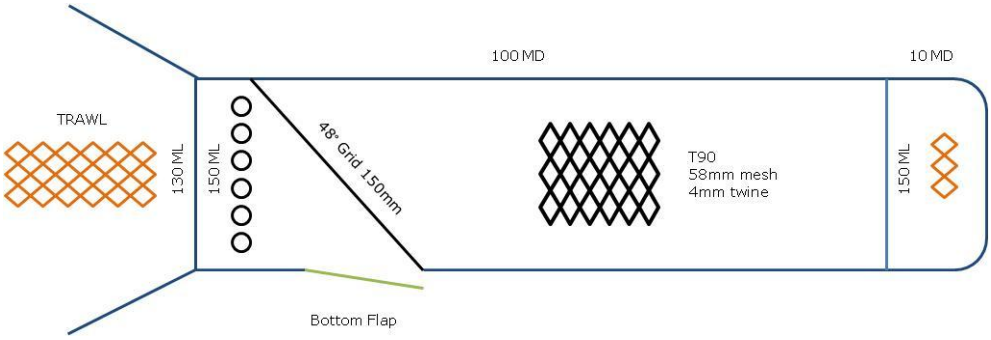
Grid, diamond (52mm), bottom-shooter – configuration 1



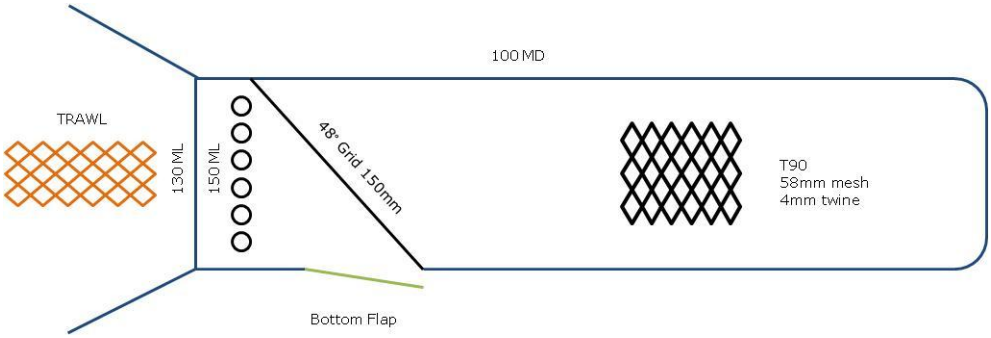
Hoops, diamond (52mm) – configuration 2



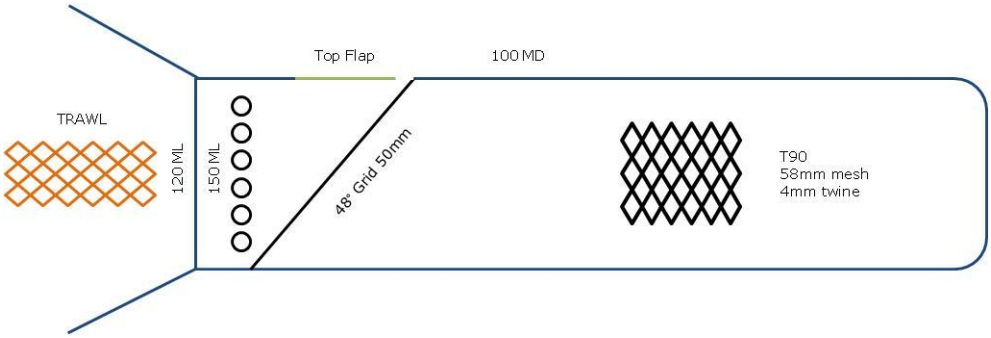
Grid, large mesh T90 (58mm), bottom-shooter – configuration 3



Grid, large mesh T90 (58mm), bottom-shooter – configuration 4



Grid, large mesh T90 (58mm), top-shooter – configuration 6



Grid, large mesh T90 (58mm), top-shooter – configuration 7

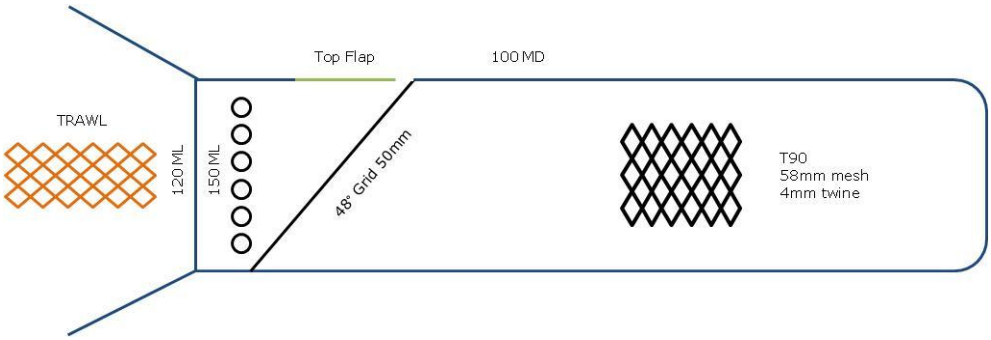


Figure 18. By-catch Reduction Device (BRD) configurations tested during the course of the project; (A) T90 Configuration F. Note drawings are indicative only and reflect configurations tested during this project, not the final design utilised for the GSV Prawn fishery.