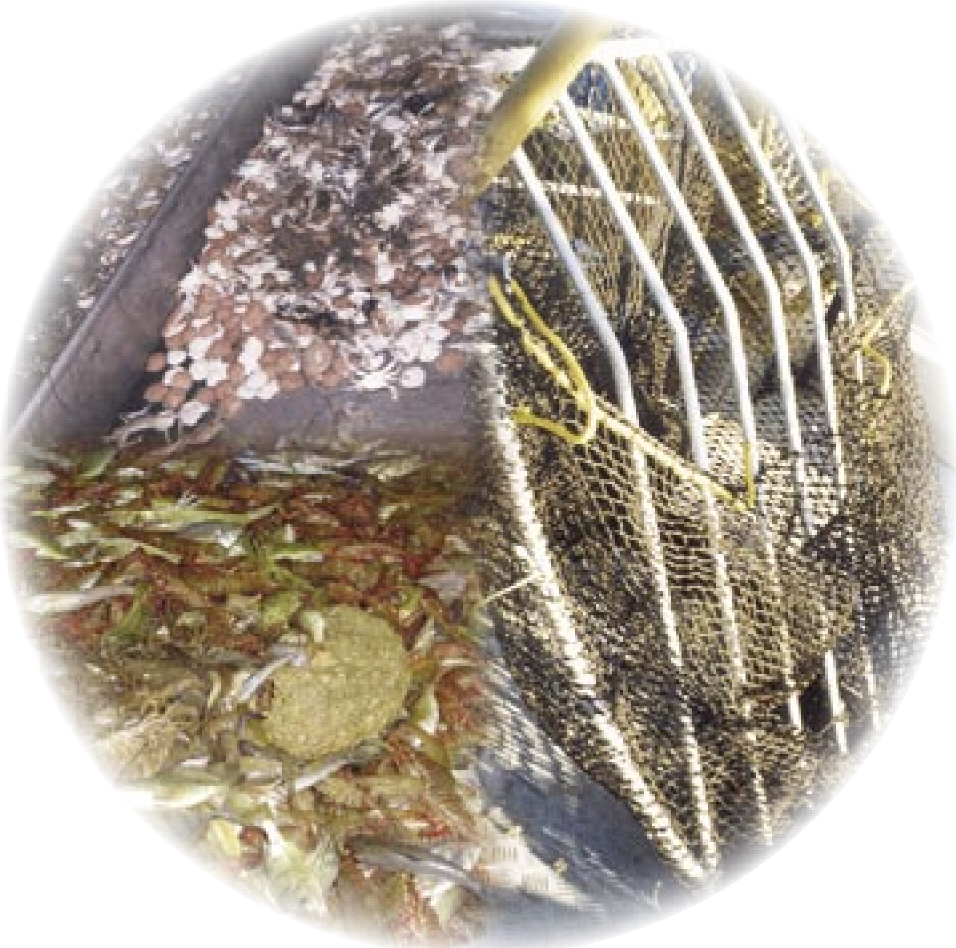
Implementation and Assessment of Bycatch Reduction Devices in the Shark Bay and Exmouth Gulf Trawl Fisheries

Mervi Kangas and Adrian Thomson



Project 2000/189

Government of Western Australia
Department of Fisheries

Australian Government
Fisheries Research and Development Corporation

Fish for the future

Implementation and Assessment of Bycatch Reduction Devices in the Shark Bay and Exmouth Gulf Trawl Fisheries

FRDC Project No. 2000/189

Mervi Kangas and Adrian Thomson

Published by: Research Division, Department of Fisheries, Government of Western Australia.
PO Box 20, North Beach WA 6920, Australia

September 2004

ISBN: 1 877098 47 7

The Fisheries Research and Development Corporation plans, invests in and manages fisheries research and development throughout Australia. It is a federal statutory authority jointly funded by the Australian Government and the fishing industry.

TABLE OF CONTENTS

2000/189 Implementation and Assessment of Bycatch Reduction Devices in the Shark Bay and Exmouth Gulf Trawl Fisheries

PRINCIPAL INVESTIGATOR: Dr Mervi Kangas

ADDRESS: WA Marine Research Laboratories
PO Box 20
North Beach WA 6920
Telephone: 08 9246 8480
Fax: 08 9447 3062
Email: mkangas@fish.wa.gov.au

OBJECTIVES:

1. To improve the efficiencies of BRDs (particularly fish escape devices) being introduced into the Shark Bay and Exmouth Gulf Trawl fisheries and ensure full implementation of the most appropriate BRD by the whole fleet in each fishery.
2. To assess the effect of implementation of BRDs (grids and fish escape devices) on trawl bycatch and on the relative fishing power of the Shark Bay Prawn and Scallop fleet and the Exmouth Gulf Prawn fleet

NON-TECHNICAL SUMMARY:

Valuable fisheries for prawns and scallops worth $60 million operate within the waters of the Shark Bay World Heritage Property and Exmouth Gulf. These three fisheries also contain some of the most extensive data sets in Australia. There is a desire by both community and industry to ensure that the fishery and its impacts are ecologically sustainable. The trialing, implementation and validation of the efficiency of Bycatch Reduction Devices (BRDs) to limit the impact of the fishery on mobile marine fauna such as turtles, sea snakes, sharks and juvenile fishes is important. However it is also important to quantify the impact on stock assessment models of prawn and scallop stocks arising from adopting new and modified gear.

OUTCOMES ACHIEVED

1. Existing BRDs (grids) in use in other Australian trawl fisheries were modified in order to function appropriately in the Shark Bay and Exmouth Gulf trawl fisheries. The Shark Bay prawn and scallop fisheries are generally using two grids types that have evolved during the three years of development. The Exmouth Gulf fleet is using one (due to smaller nets of quad gear) standard grid type for all boats. Square mesh panels are the main type of secondary bycatch reduction device being trialled and used by fishers in the Shark Bay and Exmouth Gulf prawn fisheries. Due to the larger mesh size (100 mm) of nets on scallop boats, secondary bycatch reduction devices are not required.
2. An assessment of the impacts of grid implementation on prawn and scallop catches was made. Prawn catches are reduced by between 5 and 9% on average in Shark Bay when grids are used. However these prawns are still available for capture. No additional loss of prawns was observed with using square mesh panels. No significant differences were observed in scallop catches in nets with or without grids for the scallop fishery but a 9% reduction in scallop catch was observed in prawn nets towing grids, 95-100% of turtles, larger sharks and rays are excluded by grids. The high weed volume that is sometimes encountered in Shark Bay is an ongoing issue with the current grids functioning adequately in moderate weed levels but no satisfactory solution has been found for high weed volume areas. During peak catch periods, grid are therefore exempt for a short time. In the Exmouth Gulf prawn fishery, improvements in overall net performance (equal or higher catches of prawns) when grids are used have been observed.
3. In general, fishers have accepted that grids are beneficial under most circumstances. They recognize improved work conditions with less sorting time, reduced hazards in handling large animals and improved product quality.
4. Grids have been successfully implemented in the Shark Bay and Exmouth Gulf trawl fisheries. Full implementation of grids occurred in 2002. Each fishery is using grids most suitable for their fishing operations but all fit within generic grid specifications as part of a condition on their fishery licenses. Secondary BRDs have been voluntarily trialled since late 2000 and were compulsory in one side of trawl gear in Shark Bay and Exmouth Gulf during 2004. They will be mandatory in all gear in these two fisheries in 2005. In all other prawn and scallop fisheries in mid-west and northern WA grids were mandatory from 2003 and secondary BRDs will be phased in during 2005/06.
5. A communication strategy was developed in consultation with the trawl industry and the outcomes of the research and industry innovation has been disseminated to the broader fishing community and the public.

Objective 1 - ***To improve the efficiencies of BRDs (particularly fish escape devices) being introduced into the Shark Bay and Exmouth Gulf Trawl fisheries and ensure full implementation of the most appropriate BRD by the whole fleet in each fishery.***

Grid trials took place in all the three main fisheries between 2000 and 2002 with the process involving towing a grid on one side and one without for two fishing seasons. In the Shark Bay prawn fishery ten different grid designs were trialed over three years. In August 2002, use of grids in all nets became mandatory and the 27 boats in the fishery are using one of three grid designs. Difficulties were encountered using grids in some locations and under high weed conditions. This weed is dead seagrass

(*Amphibolis antarctica* and *Posidonia australis),* which breaks off the shallow water seagrass beds in summer and drifts onto the trawl grounds where it builds (or rolls) up blocking the grids. This can result in a total loss of catch and difficulties for crew to clear the nets of the blockage that affect the safety of the operation. In order to alleviate these problems several grid designs were trialed with some, but not total success. Management arrangements are in place to accommodate this weed problem with the provision of a short period of time of grid exemption in those areas that are prone to high weed volumes and where turtles are uncommon. The fourteen scallop boats in Shark Bay trialed three different grid types and these are still being used in the fishery with full implementation in 2003. For the Exmouth Gulf prawn fishery, implementation of grids was relatively straightforward with fishers embracing their use and full implementation occurred at the commencement of the 2003-fishing season (April).

Limited trials of secondary bycatch reduction devices occurred in both the Shark Bay and Exmouth Gulf prawn fisheries between 2001 and 2003. Square mesh panels and fish eyes were the main devices trialed. Secondary devices will be mandatory in one side of the gear in 2004 with full implementation in 2005. For the Shark Bay scallop fishery, the use of 100mm mesh in trawl nets precluded them from having to implement secondary bycatch reduction devices, as there is very little fish bycatch in scallop trawls.

Objective 2 - ***To assess the effect of implementation of BRDs (grids and fish escape devices) on trawl bycatch and on the relative fishing power of the Shark Bay Prawn and Scallop fleet and the Exmouth Gulf Prawn fleet***

Grids were shown to exclude nearly all (95-100%) large animals including sharks, rays and turtles. Sponges and rocks are also significantly reduced. Smaller individuals of shark and ray species are still retained as these pass through the bar spacings. Only a minor reduction (0-7%) of bycatch (smaller invertebrate and fish species) results with grid use alone. Incorporation of square mesh panels can result in a reduction of smaller fish species between 20-75% with some individual species being reduced by over 90%.

In Shark Bay, a 5-9% reduction in prawn catch was observed on average for the most commonly used grids. No additional loss of catch was observed when a square mesh panel was used in addition to the grid because square mesh panels placed in the appropriate position result in no loss of target species. Overall, it is considered that fleet efficiency will not be greatly affected by the small loss in prawns overall as those prawns escaping will remain on the trawl grounds and should be available for later capture. However, an exception is when high weed volumes block the grid and then up to 100% loss can occur. In addition, changes in fisher behaviour will need to be monitored over the next few years due to the inability of boats to go into high weed areas with grids. This may result in a more restricted area of trawling with higher intensity of trawling in those areas remaining available. As weed distribution and abundance varies annually, fleet dynamics will also vary. The proportion of soft and broken prawns was reduced by 5-15% in both Shark Bay and Exmouth Gulf fisheries resulting in higher quality retained product. Scallop catches were not affected by use of grids in experimental trials but observer data from commercial prawn boats showed a reduction of 9%.

In Exmouth a reduction in catch by 8% was observed in early trials of grids but fishers have been able to make nets with grids work more effectively with catches equal if not slightly (3%) improved when grids are used. Grid and secondary device combinations indicate similar results to grids alone but to date insufficient data has been collected for rigorous analysis.

KEYWORDS: Bycatch, trawl fisheries, Bycatch reduction devices, Shark Bay, Exmouth Gulf.

1.0 INTRODUCTION

1.1 BACKGROUND

The effects of trawling on non-target species (Saila 1983, Andrew and Pepperell 1992, Alverson et al. 1994, Kennelly 1995) and the benthic communities (Hutchings 1990, Jones 1992) have received attention internationally and within Australia for a number of years. These concerns include trawling impacts on benthic habitats, communities and fish assemblages, the mortality of endangered species such as turtles and catch of juvenile and/or adult fish and invertebrate species of commercial or recreational importance.

The concern over environmental and ecosystem impacts of trawling, particularly in the northern hemisphere (Gunter 1936, De Groot 1984, see review by Jones 1992) has provided the impetus for the implementation of bycatch reduction devices (BRDs) into trawl fisheries worldwide since the late 1980's and early 1990's (Isaksen et al. 1992, Thorsteinsson 1992, Diamond et al. 2000) even though earlier studies on reduction of unwanted catch were undertaken in the mid 1960's and 1970's (Boddeke, 1965, Bensançon 1973, High et al. 1969). The development and implementation of more selective gears and fishing practices are one of the suite of tools available to ameliorate environmental impacts of demersal trawling (Kennelly 1995). In the 1980's and early 1990's extensive trialing by researchers on various bycatch reduction devices were undertaken (review by Broadhurst 2000) with varying levels of uptake of the technology by fishers. In Australia, increasing concern over bycatch issues by conservation groups and government agencies led to BRD trials commencing around the mid 1990's (Mounsey et al. 1995, Robins-Troeger et al. 1995, McGilvray et al. 1998, Robins and McGilvray 1999), with some fisheries adopting selective gear during the late 1990's.

However, many implementation programs also involved the mandatory use of strictly specified gears (Alverson et al. 1994), which often preclude the involvement of industry in the development of more innovative and/or appropriate gears for specific fisheries. This 'top-down' approach, although effective when there is sufficient compliance monitoring and penalties, does not necessarily provide for the most effective gears to be used for real reduction in levels of bycatch. BRDs, particularly secondary devices, are incorporated into the trawl nets so that fishers comply with legislation without it being demonstrated they are effective. This approach was not adopted in WA in order to allow for innovation and selective gear development by industry.

In December 1998, the Australian Standing Committee on Fisheries & Agriculture finalised the National Policy on Fisheries Bycatch (SCFA 1998). The Policy was developed to provide a national framework for coordinating action to address bycatch issues. In June 1999, the WA government adopted this national policy. This required the development of bycatch action plans, which commenced in 2001, and these provided a framework for the implementation of bycatch reduction devices into prawn and scallop trawl fisheries (Bunting 2002).

Bycatch reduction devices fall into two categories. Primary bycatch reduction devices which are those that physically exclude large organisms allowing them to pass out of the net. These will be referred to as grids. Secondary bycatch reduction devices such as square mesh panels are more passive devices that take into account the behavioral differences between target and bycatch species in order to allow for bycatch species to escape (Broadhurst et al. 2002).

In 1998/99 experimental trials of grids were undertaken in Western Australia (WA) by researchers in the Department of Fisheries (DOF) using grid types used in other Australian trawl fisheries and the US (Watson and Taylor 1996, Robins and McGilvray 1995, Olsen 1999). In addition, a few fishers had trialed several grids independently, indicating a proactive approach by some operators to reduce bycatch in their catch before any government legislation was considered. However, subsequent adoption of some of the grid types trialed during the experimental phase by industry found that these grids were not effective in eliminating large animals and/or bycatch without substantial loss of target species under some conditions. Hence this FRDC project was initiated tailored to the specific requirements of each fishery, particularly the Shark Bay prawn fishery which encounters large quantities of drift wire weed in some areas/times of the fishery resulting in blockage of grids and substantial loss of prawns.

The commercial trawling industry has recognised the need to improve harvesting practices to increase product quality as well as reducing marine ecosystem impacts. Several collaborative research projects involving industry, technicians and researchers have been undertaken in Australia to develop and improve bycatch reduction devices (BRD's) and turtle exclusion devices (TED's), which have originated overseas or within Australia. This knowledge has been utilised in the development of the current project plan to implement BRD's in these three key Western Australian trawl fisheries.

The standardisation of fishing effort is necessary in the stock assessment of trawl fisheries (Brunenmeister 1984). The Shark Bay and Exmouth Gulf trawl fishers have been providing comprehensive voluntary daily log book information to DOF for over 30 years. These data sets which exist from the commencement of the fisheries are quite unique and very valuable. In addition to this information, vessel and gear characteristics have been well documented. This information had allowed for estimates of effective fishing effort for the fleet. The Shark Bay and Exmouth Gulf prawn fisheries have many years of standardised research surveys using industry vessels to provide indices of recruitment and spawning. The alteration of fishing gear by the introduction of bycatch reduction devices will alter the fishing effectiveness of the fleet and this needs to be quantified. The effectiveness and incorporation of BRD's have significant impacts on the long-term datasets available for the Exmouth Gulf and Shark Bay trawl fisheries. The value of long-term datasets is often highlighted and the ability to utilise historical and future fishery dependent information is important in stock assessments. In addition, development of standard methodology to determine fishery independent measures of spawning stock and recruitment indices will assist in long-term monitoring of stocks without bias and need for regular modification due to increases in fishing effort.

1.2 FISHERY DESCRIPTION

In Western Australia there are three major demersal trawl fisheries, Shark Bay prawn and scallop and Exmouth Gulf prawn fisheries (Figure 1.1). The Shark Bay region is a World Heritage Property and State Administered Marine Park. The Shark Bay Prawn Managed Fishery is a multi-species prawn fishery mainly targeting western king prawns *Penaeus latisulcatus* (70%), brown tiger prawn *Penaeus esculentus* (30%) and a variety of smaller prawns including endeavour prawns (*Metapenaeus* spp.) and coral prawns. The value of this fishery in 2002 was $42 million. The 27 vessels in this fishery also catch about 20-30% of the annual saucer scallop (*Amusium balloti*) catch in Shark Bay. The Shark Bay Scallop Managed Fishery has 14 dedicated scallop boats. The estimated value for the scallop fishery during 2002 was $3.5 million. The Exmouth Gulf Prawn Managed Fishery takes western king prawns, brown tiger prawns, endeavour prawns and banana prawns (*Penaeus merguiensis*) and has an annual value around $10 million.

1.3 NEED

Valuable fisheries for prawns and scallops worth $60 million operate within the waters of the Shark Bay World Heritage Property and Exmouth Gulf. These three fisheries also contain some of the most extensive data sets in Australia. There is a desire by both community and industry to ensure that the fishery and its impacts are ecologically sustainable. The trialing, implementation and validation of the efficiency of Bycatch Reduction Devices (BRDs) to limit the impact of the fishery on mobile marine fauna such as turtles, sea snakes, sharks and juvenile fishes is seen to be important. However it is also important to define the impact on the stock assessment arising from adopting new and modified gear and move toward fishery independent data for continued stock management. The development of key indicators will assist in determining the impacts that different levels of fishing may have on fish communities and will facilitate monitoring of fisheries that have been operating for over 30 years.

In Shark Bay, the project falls within the Shark Bay World Heritage Property. Part of the project is to identify those species that are important to the overall values of the World Heritage Property and develop gear that is successful at reducing the bycatch of those species in particular. As the fishery falls within a World Heritage Property, there is a greater responsibility for the fishery to be ecologically sustainable as well as sustaining the target fish stocks. It is seen as an environmental management priority for the two major fisheries operating in the World Heritage Property. For all of these fisheries, high nightly catch rates are a feature and typically vessels are sorting and processing on board, up to one tonne of product per night. Skippers and crew are simply unable to record detailed information from individual nets and hence the need for an observer program in conjunction with the implementation of BRDs.

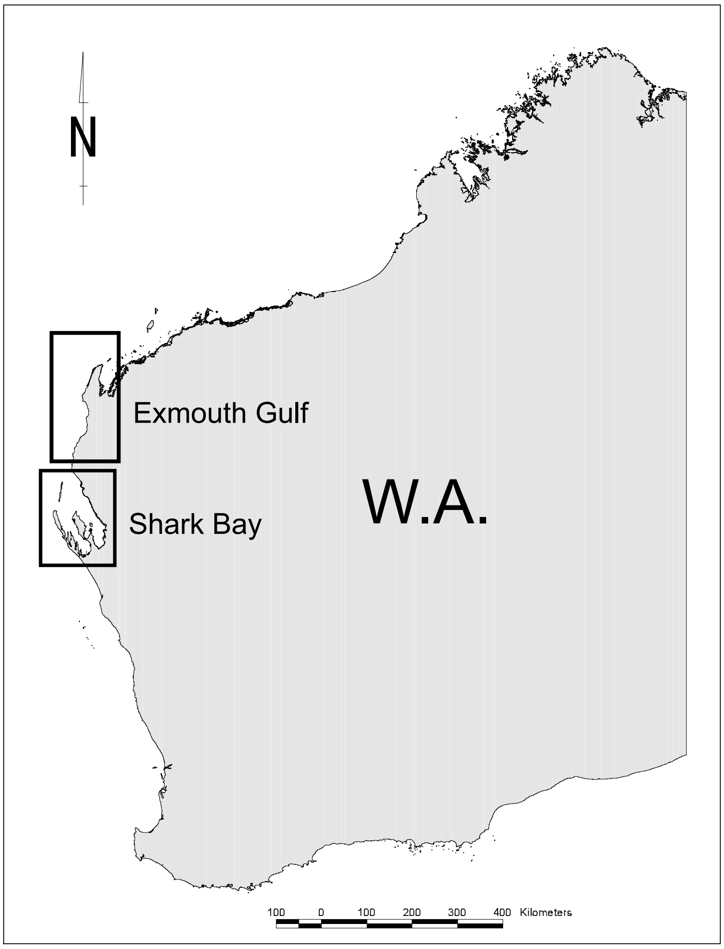


Figure 1.1 Location of Shark Bay prawn and scallop and Exmouth Gulf trawl fisheries in Western Australia.

1.4 OBJECTIVES

1. To improve the efficiencies of BRDs (particularly fish escape devices) being introduced into the Shark Bay and Exmouth Gulf Trawl fisheries and ensure full implementation of the most appropriate BRD by the whole fleet in each fishery.

2. To assess the effect of implementation of BRDs (grids and fish escape devices) on trawl bycatch and on the relative fishing power of the Shark Bay Prawn and Scallop fleet and the Exmouth Gulf Prawn fleet.

2.0 METHODS

2.1 SELECTION OF GRID AND SECONDARY DEVICES

Prior to the commencement of this project, after consultation with BRD researchers (Steve Kennelly, Mike Day, Steve Eayrs, Matt Broadhurst, Julie Robins), technician (Garry Day), BRD users (John Olsen, Herb Olsen, Bill Fitti) and BRD net makers (Popeye net makers), several grids were trialed in the Shark Bay Prawn Managed Fishery during the 1998 and 1999 seasons with funding from the Natural Heritage Trust (NHT).

Initially, meetings were held with industry representatives to discuss the implementation process and information was provided on types of grids and secondary devices. Members of industry had also visited fisheries where BRDs were being used and one company in Carnarvon employed a net maker with experience in grid manufacture.

The commercial fishing industry's participation and involvement in trialing and modification of gear has been, and is essential in the refinement and uptake of bycatch reducing technology. Licence holders purchased standard BRDs that have been used in Eastern Australia, namely the Olsen grid and NAFTED for these trials. During these initial industry trials (with observers on board some vessels) the volume of drift weed in the trawl grounds was much larger than normally experienced (partly due to a recent cyclone event in Shark Bay) and these grids did not perform satisfactorily and provided a safety hazard to crew members who need to manually extract the weed in front of the grid. Therefore further trials and modification of the BRDs' were required to overcome this problem, which is unique to Shark Bay. Several operators built their own grids with modified designs after consultation with DOF. Three grids were generally accepted as working models by 2003. Trials to improve the effectiveness of fish escape devices used in conjunction with grids were undertaken using square mesh panels, radial escape panels and fish eyes during 2002 and 2003.

In 2001, Exmouth Gulf vessels changed from twin (two 7.5 fathom nets) to quad trawl (four 4.5 fathom nets) gear and in conjunction with these gear changes vessels trialed by-catch reduction gear. Although there are some similarities in fish species between Shark Bay and Exmouth Gulf, there are differences in the bottom type and bycatch affecting the efficiencies of the BRDs and their impact on the fishery. Exmouth Gulf does not have the weed problem of Shark Bay and there are no scallop catches to retain. Key fleet personnel have traveled to Queensland and met with people experienced in the design, construction and use of BRDs including Julie Robins, Herb Olsen, Popeye Net makers, Net Perfection and Gulf Netmending. They also met a number of fishers who were using BRDs with 5-fathom quad trawl gear, similar to that used in Exmouth Gulf. Two BRDs from Popeye and Bill Fitti (Master Fisheries, net makers) were purchased for trialing in Exmouth Gulf conditions. The Popeye BRD has had good performance in Queensland whilst the Fitti may help in removing rocks from the cod-end, which is a common feature in this fishery. Bottom opening grids were trialed during 2001 but some prawn losses were experienced and boats moved to trialing top-opening grids in the 2002 season.

2.2 OBSERVER PROGRAM SAMPLING AND FISHER BYCATCH LOG SHEET RECORDS

On vessels with departmental observers, commercial catch and bycatch is recorded for most trawl shots conducted (Appendix 3). A shot is defined as a trawl of two nets (or four in Exmouth Gulf), one (or two) port side of the boat and the other starboard, for between 30 minutes and three hours. Each boat generally towed two types of nets: a control or standard net (one that fishers typically used prior to the trialing of grids) and one fitted with some type of bycatch reduction device (BRD).

The categories recorded for each side (port and starboard side (side with BRD noted)) were; total bycatch weight or volume (small or juvenile fish, crustaceans, echinoderms and molluscs), target species catch and component that is soft & broken (king, tiger, endeavour, coral prawns and scallops) and numbers of sharks, rays, sea snakes, sponges and turtles. However, for some trawl shots, not all of the categories listed above could be recorded so a variation in number of trawls per grid type can vary between categories in the results. In Shark Bay, the number of pink snapper *(Pagrus auratus)* and tailor (*Pomatotus saltator*) was also noted because of their commercial and recreational fishing importance, and their size composition recorded for some trawls. The 'other larger fin-fish' category included all large (>50cm) and easily counted finfish that were identified to species excluding snapper and tailor. The volume of weed on each side was also noted for Shark Bay prawn fishery.

2.3 STATISTICAL ANALYSIS FOR OBSERVER AND FISHER LOG BOOK INFORMATION

The effect of various grid types on the above catch categories was analysed for each of the three fisheries: Shark Bay Prawn, Shark Bay Scallop and Exmouth Gulf Prawn.

Firstly, analysis of variance (ANOVA) was used to test for a difference in performance between different grid types. Data used in these ANOVA's were restricted to trawl shots that had a control net on one side and a net fitted with a BRD on the other; and to those shots that recorded a total catch greater than zero for the catch category being considered.

ANOVA's show type 3 sum of squares (this is appropriate in an unbalanced design) and have been weighted by the duration of the shot used to obtain each observation.

For each catch category the proportion of total catch taken in each shot by the control net was modeled. For all catch categories, a BRD factor has been included in the analysis. When modelling prawn catch, species and its interaction with grid type have also been included. Once the full model has been applied, each non-significant factor has been removed until only significant factors remain. In this way the optimal reduced ANOVA model was defined.

Having determined the optimal fully reduced ANOVA model, linear regressions were performed comparing the grid (and grid and secondary device combination) catch to the control catch for each of the significant factor groupings. These regressions were also weighted by the duration of each shot and were fitted without an intercept. The ratio of BRD to control catch (BRD catch / control catch). A t-value, along with its significance, is also presented comparing this ratio to one.

For catch categories with limited data only, a summary of recorded catch is presented and in some cases, the results of a paired t-test comparing the control catch to the grid (or grid and secondary device combination) catch are presented.

Throughout, secondary devices have been combined with the grid type as a separate grid type category. In this way, the effect of grids and grids with secondary devices can be gauged. It is desirable however, to compare shots that have the same grid on both sides but also a secondary device on only one side, so as to specifically test the effect of the secondary device. When enough data existed for such an analysis, the ANOVA method was used for this comparison.

The infrequent capture of large animals (sharks, rays, turtles, seasnakes and sponges) precluded regression analysis. The total numbers of individuals caught for each type of BRD are compared for the control and BRD net(s).

In addition to the observer program, a number of skippers filled in voluntary bycatch log sheets in 2000 and these results are summarised but not analysed due to the variability in quality of the data. The log sheet program was terminated after three months due to difficulties in attaining consistent data from skippers.

2.4 EXPERIMENTAL TRIALS OF GRID AND SECONDARY DEVICES

2.4.1 Shark Bay and Exmouth Gulf prawn fisheries

Two experiments were completed by Matt Broadhurst (consultancy to project) on established prawn-trawl grounds in Shark Bay and Exmouth Gulf in August 2000 using two chartered commercial prawn trawlers.

The Shark Bay experiment was done using a twin-rig system (each with a headline length of 14.6 m), all trawls were made from polyethylene twine with a stretched mesh size of 52 mm in the body and 47 mm in the codend (unless stated otherwise, all stretched mesh sizes were measured as centre knot to centre knot and not inside mesh opening). All tows were done over a combination of sandy and light coral bottoms in depths ranging from 13.7 to 18.5 metres and at speeds (across the bottom) of between 3.5 and 4.6 knots (Broadhurst et al. 2002, Appendix 4).

The grid was an industry-designed aluminium grid with the upper third offset at 45^0 and bar spacings of 100 mm (Figure 2.1a). The grid was located at an angle of 45^0 in a 30-mesh extension piece, 120 meshes in circumference (47-mm, 60 ply, UV-stabilised, high-density polyethylene twine) with the anterior end attached to the trawl body. To maintain stability, two plastic floats (16 cm in diameter) were attached to either side of the upper edge of the grid (Figure 2.1a). A zipper (Burashi S-146R, pinlock side) was attached to the posterior end of this extension to facilitate changing codends. Unlike previous designs of grids (Isaksen et al., 1992; Broadhurst and Kennelly, 1996a; Broadhurst et al., 1996; 1997a; 1997b), this BRD had no funnel or guiding panel, but included two flexible panels of 47-mm diamond-shaped mesh (60 ply, UV-stabilised, high density polyethylene twine) hung loosely above and below the escape exit (Figure 2.1b). These panels were attached to the net only anteriorly and were free to lift through and above the escape exit, respectively (see also Broadhurst and Kennelly, 1996a). The theory behind these panels was that they would prevent prawns escaping but still allow organisms larger than the bar spacings to be released from the trawl.

Three codends were constructed and rigged with zippers so that they could be attached posterior to the extension containing the grid. The first codend was a conventional design and comprised 47-mm diamond-shaped mesh (60 ply, UV-stabilised, high-density polyethylene twine) throughout with a circumference of 120 meshes and a length of 70 meshes (Figures 2.2a and 2.3a). The second and third designs, termed the composite square-mesh panel aft (CSMPA – Figures 2.2b and 2.3b) and composite square-mesh panel forward (CSMPF – Figures 2.2c and 2.3c) codends had the same circumference and length as the codend described above, but included secondary BRDs. These BRDs comprised composite panels made of 47 mm, 94 mm and 155 mm mesh cut on the bar (Figure 2.2d – see also Broadhurst and Kennelly, 1996b) and inserted into the top sections of the codends at distances anterior to the draw strings of 24 and 43 meshes, respectively (Figure 2.2b and c). The location of the panel in the CSMPA codend was based on designs developed for use in New South Wales and South Australian prawn-trawl fisheries (e.g. Broadhurst and Kennelly 1996b; Broadhurst et al. 1997b; 1999a). Broadhurst et al., (1999b) showed that at this location there is substantial displacement of water anterior to catch in the codend, that can assist small fish to maintain position under the composite square-mesh panel, increasing their probability of randomly encountering the open meshes and escaping. In the CSMPF codend, the square-mesh panel was located further forward and away from the flow-related effects due to catch in the codend. Instead, a restricting cord (4 mm polypropylene rope, 1.3 m in circumference – Figures 2.2c and 2.3c) was located posterior to the square-mesh panel. This cord reduced the circumference of the codend by approx. 35% - calculated assuming a fractional mesh opening of 0.35 (Broadhurst et al., 1999a) x the stretched mesh length (between the knots) x the mesh circumference. It was thought that reducing codend circumference immediately behind the composite square-mesh panel would create a taper in the codend, possibly displacing some water forwards and thereby assisting fish to maintain position beneath the composite square-mesh panel. The control codend represented normal commercially used codends and was made entirely of 47-mm diamond shaped meshes (60 ply, UV-stabilised, high-density polyethylene twine), measuring 120 meshes in circumference and 100 meshes in length (i.e. the same length as each of the codends described above attached to the extension containing the grid).

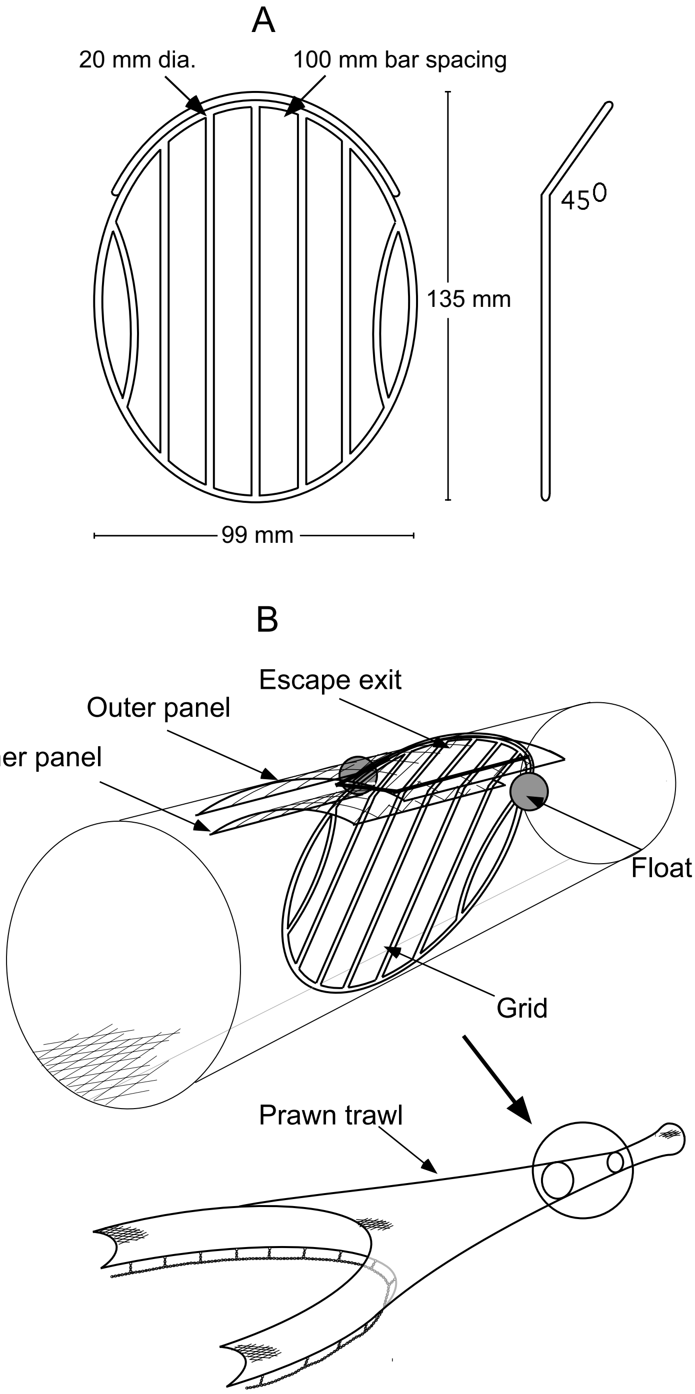


Figure 2.1 Diagrammatic representation of a) the grid used in the Shark Bay experiments (135mm high and 99mm wide, 100 mm bar spacing and 20mm bar diameter,) and b) its location in the prawn trawl.

Using zippers, the conventional (i.e. no BRD), CSMPA and CSMPF codends described above were alternatively attached posterior to the grid (Figure 2.3b and c) and the entire assembly tested against the control codend, on each side of the twin-rigged gear (i.e. three separate paired comparisons: grid only - i.e. no secondary BRD vs. control; grid and CSMPF codend vs. control; and grid and CSMPA codend vs. control). Two replicate 40-min tows of each paired comparison were made on each night, providing a total of 10 replicate comparisons of each configuration over five nights. The position and order of the three codends attached posterior to the grid were randomly assigned. However, because the grid could not be easily removed from the net (i.e. it was not possible to attach a zipper between the trawl body and this BRD), it was alternated between nets on different nights so that equal numbers of paired comparisons of each treatment against the control were made on port and starboard trawls. Trawls were tested prior to the trials to ensure no biases between sides of the vessel.

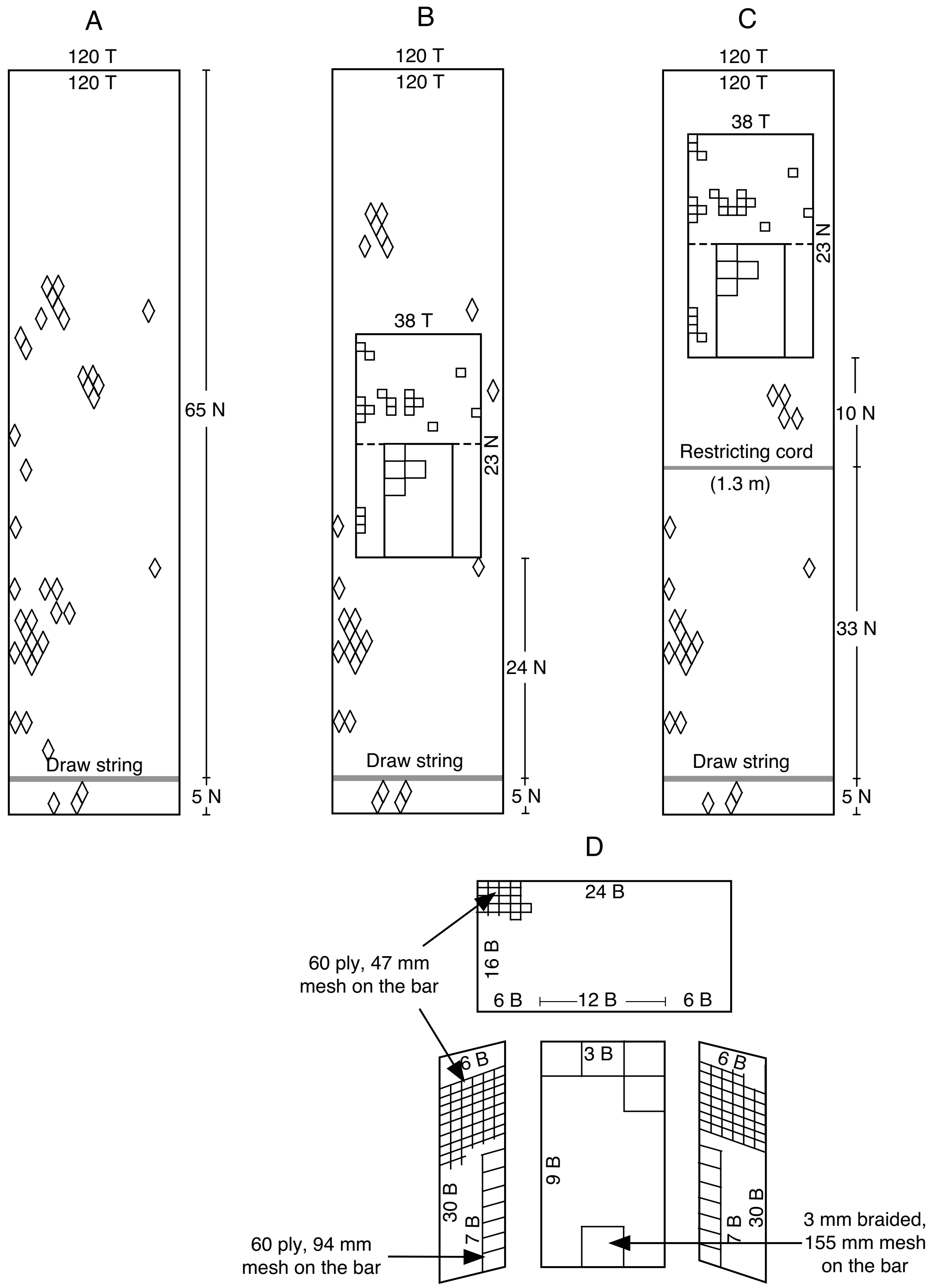


Figure 2.2 Diagrammatic representation of the (A) conventional codend, (B) composite square-mesh panel aft codend, (C) composite square-mesh panel forward codend and (D) composite square-mesh panel used in Shark Bay. T = transversals; N = normals; and B = bars.

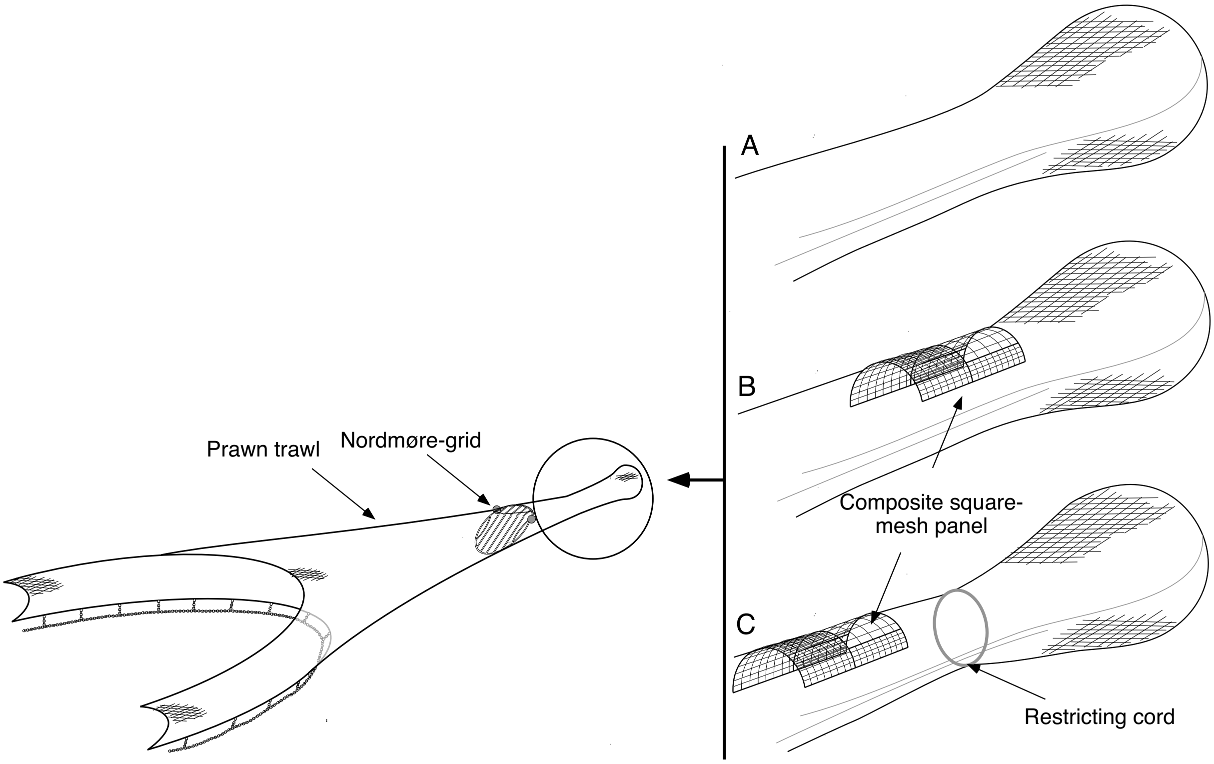


Figure 2.3 Diagrammatic representation of the prawn trawl with the Nordmøre-grid and location of the (A) conventional codend, (B) composite square-mesh panel aft codend and (C) composite square-mesh panel forward codend.

The Exmouth Gulf experiment was done using the two port nets in a quad-rig system (each with a headline length of 8.2 m). All trawls were made from polyethylene twine with a stretched mesh size of 52 mm in the body and 47 mm in the codend. All tows were done over a combination of sandy and light coral bottoms in depths ranging from 13.7 to 18.5 metres and at speeds (across the bottom) of between 3.5 and 4.6 knots.

In this experiment, a grid was tested on its own and in combination with a modified Composite Square Mesh Panel Aft (CSMPA) codend against a control. The grid comprised an aluminium grid (Figure 2.4a) sewn at an angle of 45° into an extension piece made from 47 mm diamond-shaped mesh (60 ply, UV-stabilised, high-density polyethylene twine) measuring 100 meshes in circumference and 30 meshes in length. To assist in stability, two plastic floats (16 cm in diameter) were attached to the upper edge of the grid (Figure 2.4b). A zipper (Burashi S-146R, pinlock side) was attached to the posterior end of the extension to facilitate changing codends. Two rectangular panels of flexible mesh were sewn anterior to the grid and bottom opening escape exit, respectively. The first panel extended to the grid, while the second extended past the base of the grid. Small floats were sewn to the posterior edge of the latter panel to help maintain closure over the escape exit.

Two codends were constructed and rigged with zippers so that they could be attached posterior to the extension containing the super shooter grid. The first codend was a conventional design and comprised 47 mm diamond-shaped mesh (60 ply, UV-stabilised high-density polyethylene twine) with a circumference of 80 meshes and a length of 70 meshes (Figure 2.5a). The second codend was identical in materials, circumference and length, but included a composite square-mesh panel (scaled to fit into the smaller codend circumference Figure 2.5b) located in two positions in the net. The control codend represented normal commercial codends and was made entirely from 47 mm diamond-shaped meshes (60 ply, UV-stabilised high-density polyethylene twine) measuring 80 meshes in circumference and 100 meshes in length (i.e. the same length as the codends described above each attached to the extension containing the grid).

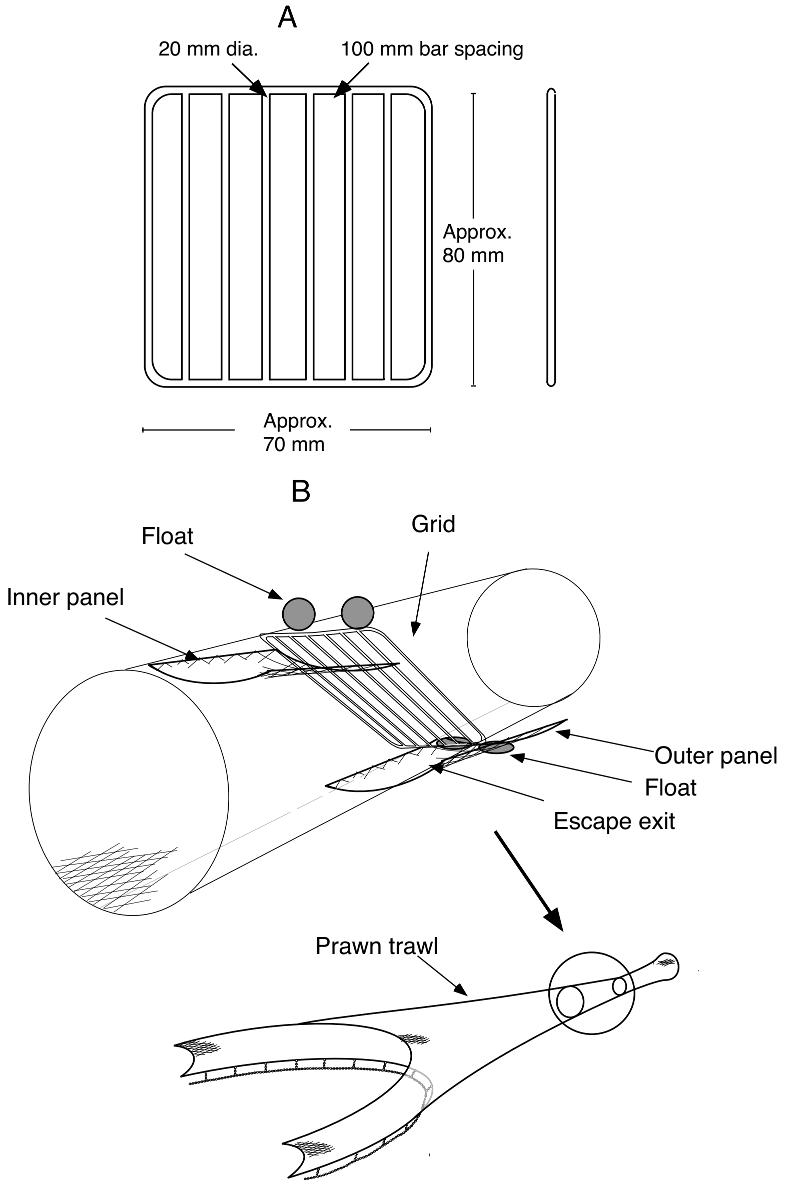


Figure 2.4 Diagrammatic representation of (A) the super shooter grid used in Exmouth Gulf and (B) its location in the prawn trawl.

The zippers were used to alternately attach the conventional and CSMPA codends posterior to the extension containing the grid. These configurations were compared against the control codend, using only the two port-side nets of the quad-rigged gear (i.e. two separate paired comparisons: grid only – with no secondary BRD vs. the control; and the grid with the CSMPA codend vs. the control). Three replicate 90-min tows of each paired comparison were made on each night, providing a total of 6 replicate comparisons over two nights. The position and order of the codends attached posterior to the grid was determined randomly, however, because it was not possible to change the grid after each tow, it was alternated on the different nights.

For both experiments, after each tow, the two codends were emptied onto a partitioned tray (Figure 2.6). Prawns, all individuals comprising commercially and/or recreationally important species and individuals of the most abundant non-commercial species were separated. The following categories of data were selected for each tow: the total weight of prawns, the weights of individual species of prawns, the numbers of king and tiger prawns and a sub-sample (3 kg from each codend) of their lengths (to the nearest 1 mm carapace length); the weight of bycatch; the weights and numbers of commercially and/or recreationally important species and the most abundant noncommercial species; and their sizes (to the nearest 0.5 cm). Ponyfish (*Leiognathus leuciscus*), stout whiting (*Sillago robusta*), trumpeter whiting (*Sillago burrus*), leatherjackets (Monacanthidae), goatfish (*Upeneus asymmetricus*), trumpeter (*Pelates quadrilineatus*), bar-tailed flathead (*Platycephalus endrachtensis*), small-toothed flounder (*Pseudorhombus jenynsii*), blue swimmer crab (*Portunus pelagicus*) and 3-spot crab *(Portunus sanguinolentus)*.

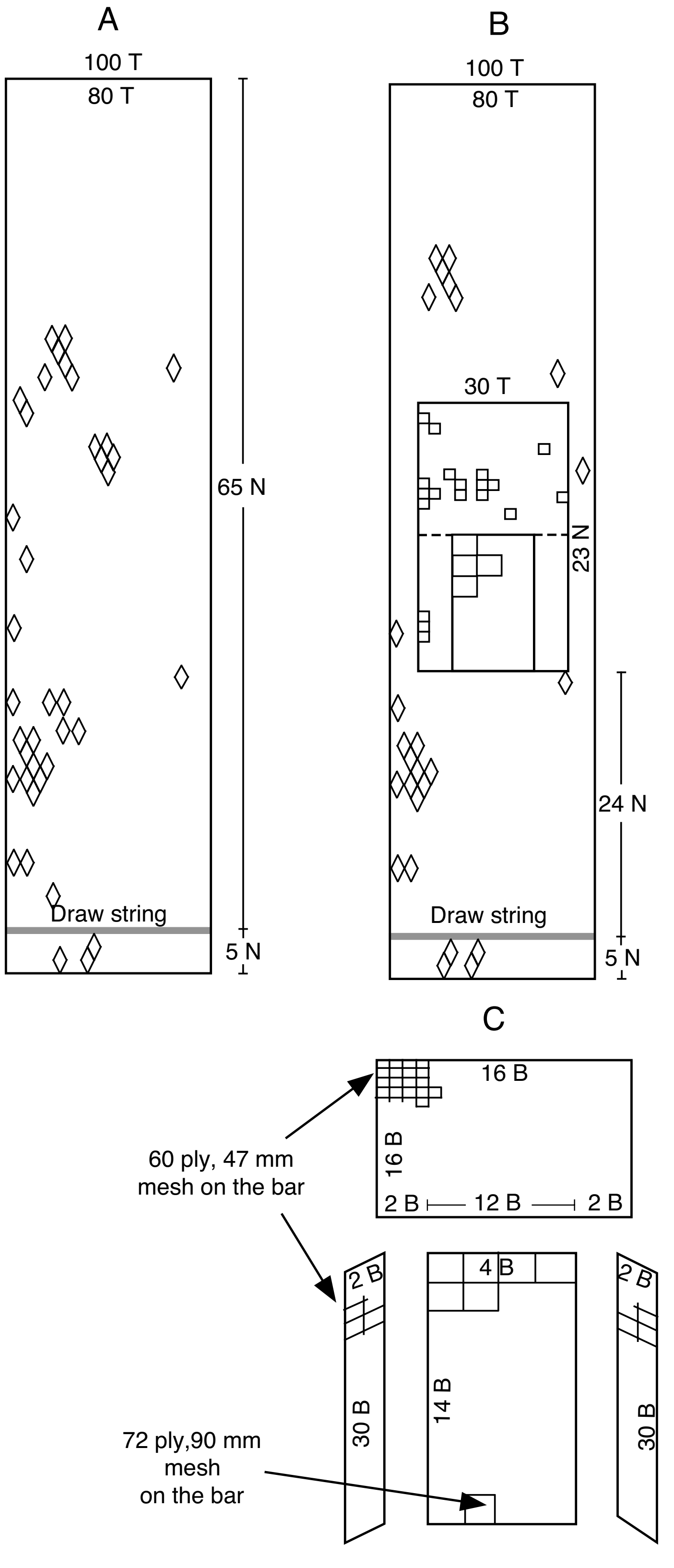


Figure 2.5 Diagrammatic representation of the (A) conventional codend, (B) composite square-mesh panel aft codend and (C) composite square-mesh panel used in Exmouth Gulf. T = transversals; N = normals; and B = bars.

Figure 2.6 Sorting table with split of catch components per side in the Shark Bay prawn fishery (M. Broadhurst).

Catch data for all replicates that had sufficient numbers of each variable (i.e. 1 individual in at least 7 replicates in experiment 1 and all 6 replicates in experiment 2) were analysed with one-tailed paired *t*-tests ($P \leq 0.05$) testing the hypothesis that the BRDs retained fewer individuals than the control. To examine the relative effectiveness of the grids and combinations of secondary BRDs in each experiment, the differences in catches (between each treatment and their respective controls) for those variables with numbers present in all tows were analysed using Cochran's test for homogeneity of variances and two-factor orthogonal analyses of variance. In these analyses, BRDs and nights were considered fixed and random factors, respectively. Means were separated following significant F-tests using the Student-Newman-Keuls (SNK) test. With the exception of data for catches of prawns, where analyses provided similar results for weights and numbers of variables, only data concerning numbers were included.

Size-frequencies of prawns and commercially important fish were plotted and compared with two-sample Kolmogorov-Smirnov tests ($p = 0.05$), where there were sufficient numbers measured for comparison.

2.4.2 Shark Bay scallop fishery

Two types of grids (Figure 3.11) were trialed over three days on a commercial scallop vessel during April 2001. No secondary devices were incorporated due to the large mesh (100mm) used by the scallop fleet. Standard scallop trawl gear was used (twin seven fathom nets with 100mm mesh). Each grid was trialled against the control scallop trawl net for one night and then the two grids were compared side by side.

Each trawl was 30-33 minutes (trawl period begins when the trawl gear started to fish until the commencement of retrieving the trawl gear) for comparison of grid type against a control net whereas five of the total of 12 trawl shots comparing the two grids side by side were conducted for 60-69 minutes.

For each trawl, the port and starboard sides were kept separate, scallops and the rest of bycatch was sorted separately into baskets and recorded. For selected trawl sites, scallops were measured for size composition. Large animals such as sharks, rays and turtles were recorded for presence or absence for every trawl and the number of sponges and sea snakes, were also noted. If any pink snapper or prawns were caught they were measured and recorded.

3.0 RESULTS

3.1 Objective 1 – Improved efficiencies of BRDs and full implementation into the Shark Bay and Exmouth Gulf trawl fisheries

3.1.1 Shark Bay prawn fishery

The proposed implementation process in the Shark Bay prawn fishery was for all 27 boats to tow a BRD (a grid) in one net and one without for the 2000 season and would progress to towing grids both nets in the 2001 or 2002 seasons.

In Shark Bay, eight main styles of grids have been trialled (examples in Figures 3.1-3.7). The grid types were categorized into:

- Shape -circular (C) or rectangular (R);
- Straight vertical bars (S) or with horizontal 'flounder' gap at the bottom (F);
- Narrow (N) or wide (W) bar spacings;
- If top section of grid has bars that are bent as an accelerator (A) or not (N).

Additional secondary BRD devices (radial escape section and square mesh panels) have been installed in some grids in Shark Bay (Figures 3.8 and 3.9). Specific and detailed composite square mesh trials were conducted in Shark Bay in August 2000 using a chartered trawler (Broadhurst *et al*. 2002).

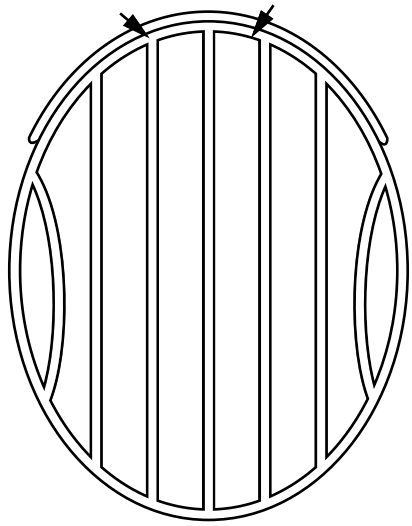


Figure 3.1 CSNN – circular, straight vertical bars, narrow bar spacing and no accelerator (incline). Top or bottom (Exmouth Gulf only) opening.

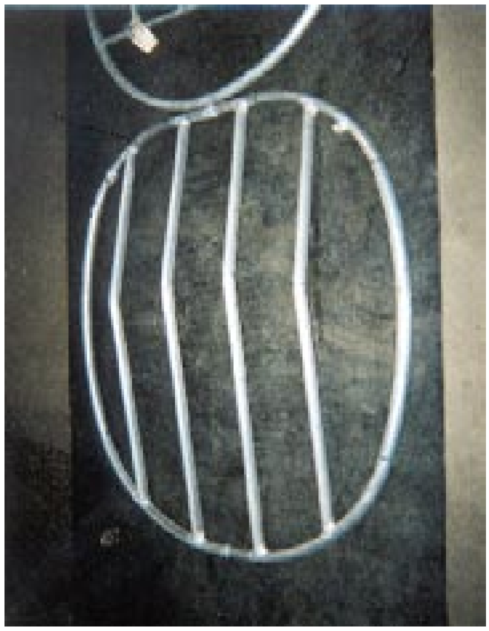


Figure 3.2 CSWA – circular, straight vertical bars, wide bar spacing and accelerator.

Figure 3.3 RSNN – rectangular grid with straight vertical bars with narrow spacing and no accelerator.

Figure 3.4 RSNN2 – Rectangular double grid, and Rectangular double grid and square mesh panel.

Figure 3.5 RSNA – Rectangular grid with straight vertical bars and accelerator.

Figure 3.6 RFNN – Rectangular grid with narrow bar spacing and gap at the bottom.

Figure 3.7 RFWN – Rectangular grid with wide bar spacing and horizontal gap with no accelerator.

Figure 3.8 Square mesh panel and hoop set-up trialed in Shark Bay prawn fishery.

Figure 3.9 Composite square mesh panel trialed in Shark Bay prawn fishery.

3.1.2 Shark Bay scallop fishery

Two styles of grids have been trialed by the Shark Bay scallop boats, with or without the flounder gap (Figures 3.10 and 3.11). As the scallop vessels tow nets with 100 mm mesh (compared to 50 mm mesh of prawn trawlers) no secondary bycatch reduction devices are required as there is very little bycatch caught by scallop trawling.

Figure 3.10 RSWN – Rectangular grid with straight vertical bars, wide bar spacing and no accelerator.

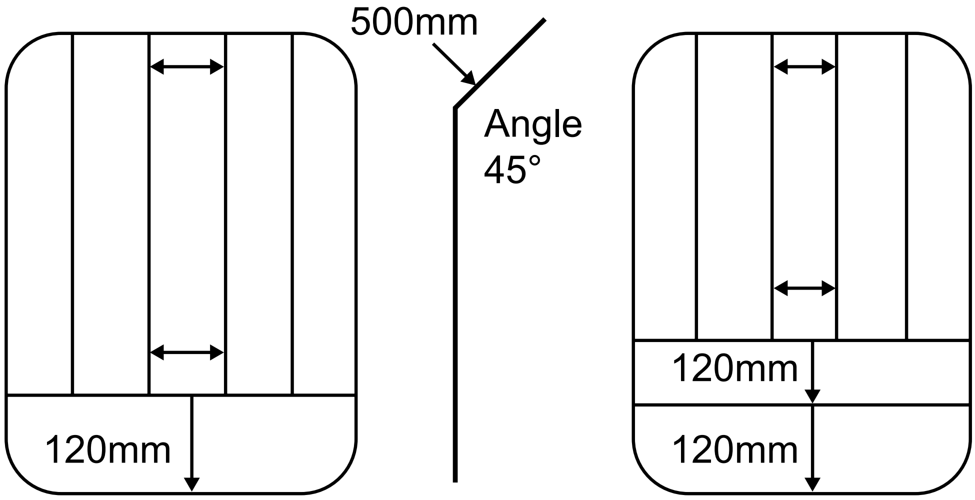


Figure 3.11 RFNA – Shark Bay scallop grid trial grids with a single and double flounder.

3.1.3 Exmouth Gulf prawn fishery

The first type of BRD trialed was a grid and radial escape section combination (Figure 3.12) but its use was discontinued due to difficulties in maintaining its shape and configuration. One type of grid was trialed in Exmouth Gulf that could be used as either top or bottom opening (Figure 3.13). After the two-night experiment testing composite square mesh panels in August 2000 for ease of operation and insertion, square mesh panels in a metal frame (25 cm x 35 cm, 5mm stainless steel frame with mesh size of 8cm or 10 cm on the square) were trialed by the vessels in combination with grids.

Figure 3.12 First grid type trialed in Exmouth Gulf with a radial escape section.

Figure 3.13 RSNN – Grid type trialed in the Exmouth Gulf prawn fishery (quad gear). Horizontal gap not effective as towed in the top-opening position.

3.1.4 Minor Western Australian trawl fisheries

Grids became compulsory in all nets for the Broome, Onslow, Nickol Bay and Kimberley prawn fisheries and the Abrolhos Islands and Mid-West trawl scallop fishery in 2003. Secondary bycatch reduction devices will be trialed in 2004, becoming compulsory in half of the nets in 2005 with full implementation in 2006.

3.1.5 Grid specifications as condition of license in all trawl fisheries in Western Australia

To improve and simplify the mechanism of BRD implementation, all grid specifications throughout the state are the same. The descriptions are maximum dimensions for grid bar widths so that the weed issue of Shark Bay is also encompassed in the same condition of license. The other fisheries use grids well within the maximum limits.

Currently the specifications are a part of the Managed Fishery Licence conditions. The definition of bycatch reduction devices are: A device fitted within a net, and any modifications made to a net, which allows bycatch, or part thereof, to escape after being taken in the net, and consists of a grid and a fish exclusion device either in combination or as separate devices.

'Grid' means a device fitted with a net and any modifications made to a net, which allows large animals (including turtles) and or objects to escape immediately after being taken in the net and which has:

a) a rigid inclined barrier (installed at an angle no greater than 60^{o}), comprising bars that are attached to the circumference of the net which guides animals and/or objects towards an escape opening forward of the grid;
b) an escape opening with the following minimum measurements when measured with the net taut:
    i. 75 centimetres across the widest part of the nets; and
    ii. a perpendicular measure of 50 centimetres from the midpoint of the width measure in i) above; and
c) a maximum vertical bar clearance spacing of 20 centimetres (measurement to be taken from inside bar to inside bar) (Figure 3.14);

and; 'Fish exclusion device' means a device fitted within a net, and any modification made to a net which allows fish to escape after being taken in the net.

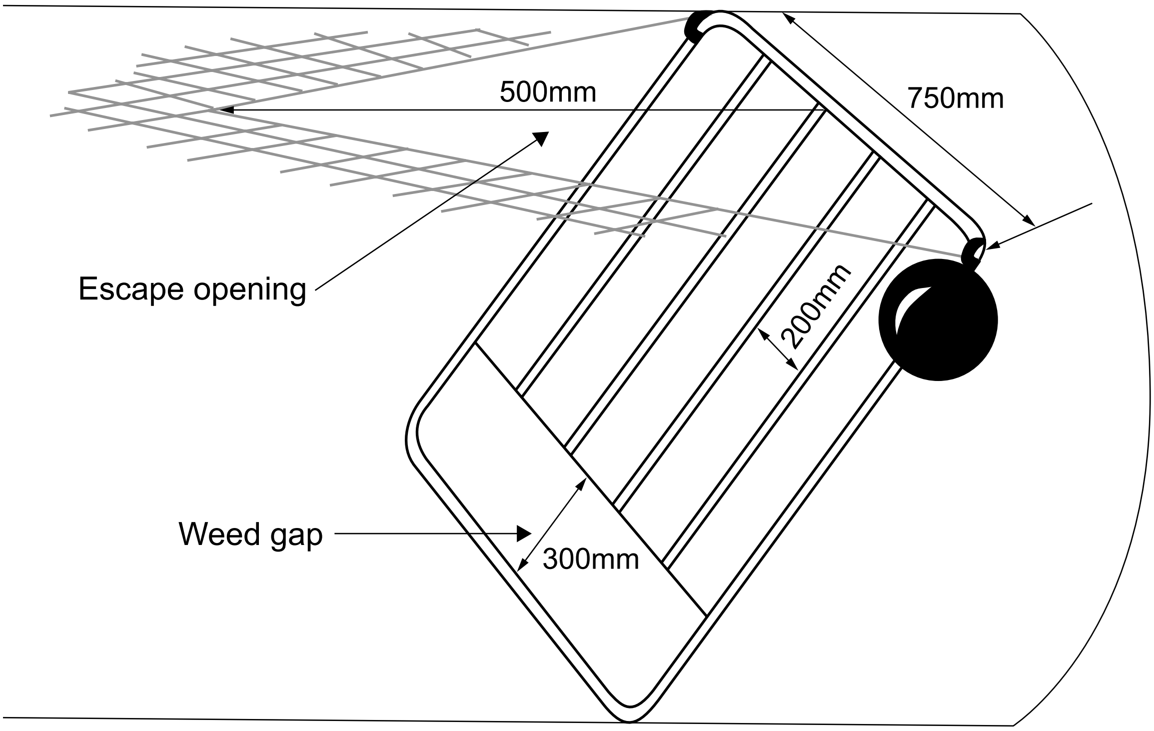


Figure 3.14 Current specifications of grid dimensions in place for trawl fisheries in Western Australia.

3.2 Objective 2 – Determine the effect of implementation on bycatch and fishing power

During the project, a total of 1567 trawl shots comprising 1969 hours of trawling were recorded by observers on board commercial vessels (Table 3.1).

Table 3.1 Summary of the number of trawl shots and hours of trawling monitored by observers in each fishery between 2000 and 2002.

Fishery	Shots	Total Duration (hr)
Shark Bay Prawn	1,180	1,236.5
Shark Bay Scallop	141	142.8
Exmouth Gulf Prawn	246	589.7
Total	**1,567**	**1,969.0**

3.2.1 Shark Bay Prawn Fishery Observer Program

3.2.1.1 Total prawn catch

Grid type was a significant factor in total prawn catch whereas prawn species and its interaction with grid type were not (Table 3.2). A fully reduced ANOVA indicates a significant grid effect (Table 3.3). The effect of various grids on prawn catch is gauged by comparing the catch of the grid side to that of the control side (Figure 3.15).

Table 3.2 ANOVA explaining the variation in the proportion of total prawn catch (kg) taken by a Shark Bay prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Species	2	1.22	0.60	0.60	0.55
Grid Type	9	18.54	2.06	2.05	0.03
Species*Grid Type	12	16.04	1.34	1.33	0.20
Residuals	619	621.64	1.01		

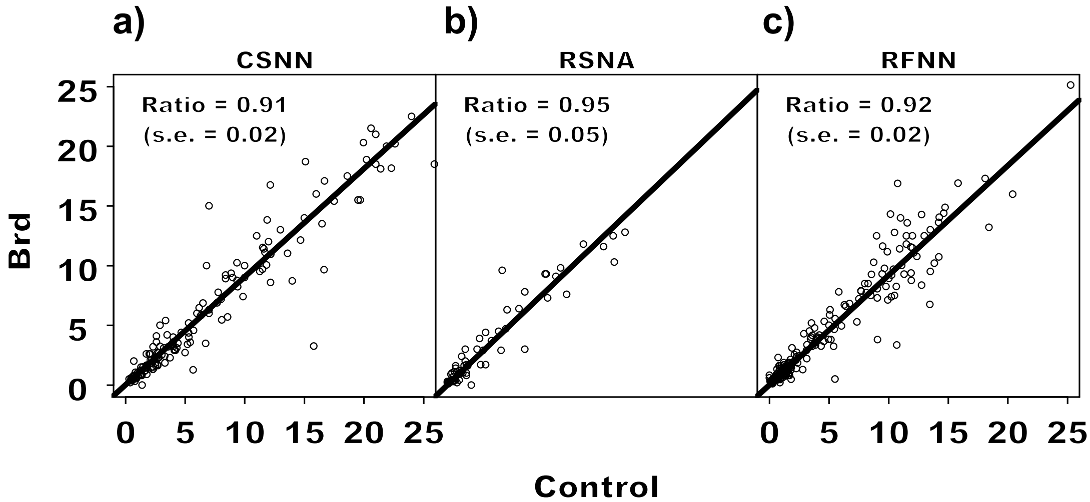


Figure 3.15 Plots of total prawn catch taken (kg) by the BRD versus the control side are presented for the three most commonly observed grid types (in terms of hours trawled) in the Shark Bay prawn fishery. The ratio of the BRD catch versus the control catch, along with the associated standard error (s.e.), is included.

Table 3.3 Optimally reduced ANOVA explaining the variation in the proportion of the total prawn catch (kg) taken by a trawler, by the control side in the Shark Bay prawn fishery. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	9	25.11	2.79	2.77	< 0.01
Residuals	633	637.73	1.01		

Linear regressions comparing total prawn catch (all species grouped together) on the grid side to control side indicate significant differences between the control and grid sides for most grid types (Table 3.4). Total prawn catch loss is variable between grid types with the most commonly observed grids showing a 5-9% loss whereas three grid types (FRNN, RFWA and RFNA) showed a 14-17% loss.

Table 3.4 The estimated ratio relating the various BRD's total prawn catch (kg) to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Grid Type	Secondary device	Shots	Duration (hr)	Ratio	s.e.	t-value	P
CSNN	-	82	198.8	0.91	0.02	-4.50	< 0.01
CSNN	Square mesh panel	9	28.5	0.87	0.05	-2.07	0.03
CSNA	-	5	7.6	1.13	0.05	2.60	0.06
RFWA	-	30	59.5	0.83	0.04	-4.25	< 0.01
RFNN	-	73	267.6	0.92	0.02	-4.00	< 0.01
RSNN	-	34	64.8	0.86	0.03	-4.67	< 0.01
RSNA	-	22	79.9	0.95	0.05	-1.00	0.33
RFNA	-	17	18.3	0.83	0.03	-5.67	< 0.01
RSNN*2	-	16	34.4	0.94	0.05	-1.20	0.25
RSNN*2	Square mesh panel	12	17.2	1.15	0.05	3.00	0.01

3.2.1.2 Soft and broken prawn catch

There was no significant difference between various grids or species type on soft and broken prawn catch (Table 3.5). Hence, a linear regression comparing the catch of soft and broken prawns is made for all grid types and prawn species combined. The reduction of soft and broken prawns was shown to be 15% (Table 3.6).

Table 3.5 ANOVA explaining the variation in the proportion of soft and broken prawn catch (kg) taken by a Shark Bay prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Species	1	6.69	6.69	3.34	0.07
Grid Type	8	16.50	2.06	1.03	0.41
Species*Grid Type	3	9.31	3.10	1.55	0.20
Residuals	314	629.61			

Table 3.6 The estimated ratio relating the various BRD's soft and broken prawn catch (kg) to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Shots	Duration (hr)	Ratio	s.e.	t-value	P
271	318.7	0.85	0.03	-5.00	< 0.01

3.2.1.3 Bycatch

Differences amongst grid types were significant on the amount of bycatch retained in nets compared to control nets (Table 3.7). Linear regressions comparing the grid side catch to control side indicates a general reduction in bycatch between 0 and 17% with the most commonly observed grid types showing 0-7% reduction in overall bycatch (Table 3.8, Figure 3.16).

Table 3.7 ANOVA explaining the variation in the proportion of the total bycatch (baskets) taken by a Shark Bay prawn trawler, on the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	10	22.78	2.78	4.22	< 0.01
Residuals	827	446.44	0.54		

Table 3.8 The estimated ratio relating the various BRD's total bycatch (baskets) to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Grid Type	Secondary device	Shots	Duration (hr)	Ratio	s.e.	t-value	P
CSNA	-	62	65.4	0.83	0.03	-5.67	< 0.01
CSNN	-	241	257.0	0.93	0.01	-7.00	< 0.01
CSNN	Square mesh panel	9	9.5	0.90	0.02	-5.00	< 0.01
RFNA	-	40	49.2	0.89	0.03	-3.67	< 0.01
RFNN	-	121	145.4	1.00	0.02	0.00	0.99
RFWA	-	95	87.2	0.95	0.03	-1.67	0.10
RFWN	-	33	27.0	0.96	0.03	-1.33	0.19
RSNA	-	22	28.3	0.90	0.03	-3.33	< 0.01
RSNN*2	-	52	61.9	0.87	0.02	-6.50	< 0.01
RSNN*2	Square mesh panel	18	23.6	0.93	0.02	-3.50	< 0.01
RSNN	-	143	141.5	0.99	0.01	-1.00	0.32

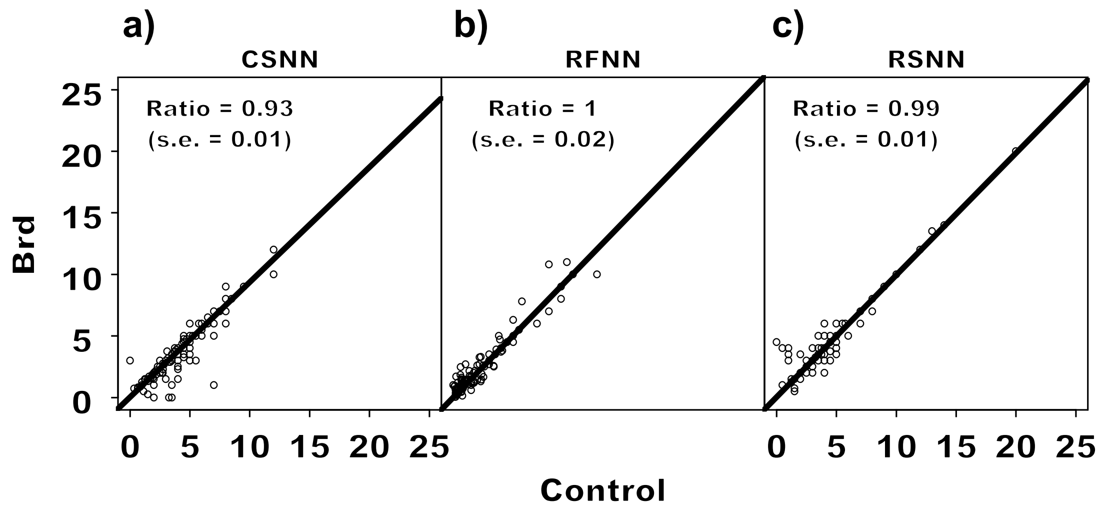


Figure 3.16 Plots of bycatch (baskets) taken by the BRD versus the control side are presented for the three most commonly observed grid types (in terms of hours trawled) in the Shark Bay prawn fishery. The ratio of the BRD catch versus the control catch, along with the associated standard error (s.e.), is included.

3.2.1.4 Turtles

From a total of 914 trawl shots (914 hours) with a grid on one side and the control net on the other, 20 turtle captures were observed in control side (no grid) and only one turtle capture was recorded with a BRD (type: RSNN*2). This represents a 95% reduction in the number of turtles caught. In a total of 266 trawls (273 hours) where grids were used on both nets no turtle captures were observed. All turtles captured were returned to the sea alive.

3.2.1.5 Pink snapper

Of the 1,377 trawls recorded by observers in Shark Bay of pink snapper catches, eighty four percent of trawls recorded no snapper whilst one trawl caught high numbers (> 400 individuals). This is a typical demersal trawl catch pattern for this species (Figure 3.17). The size composition of pink snapper (Figure 3.18) indicates that the snapper caught by trawlers were all juveniles, between 6 and 18 months old (Moran and Kangas 2003).

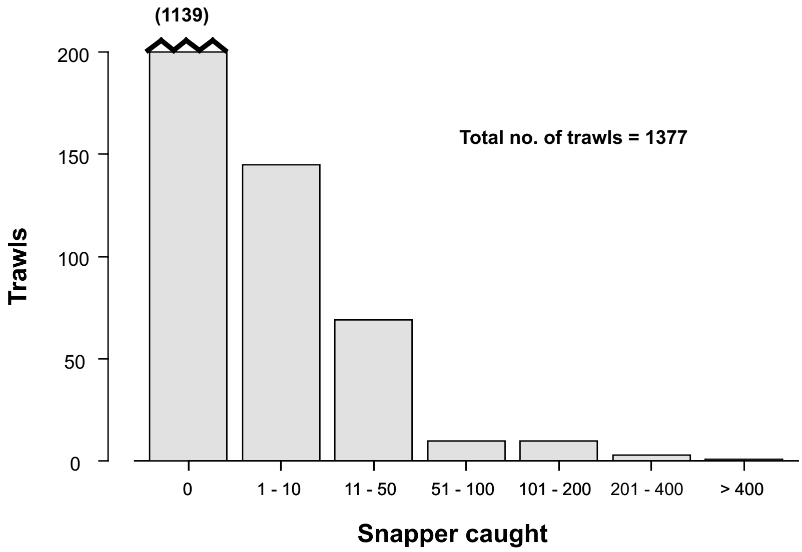


Figure 3.17 Number of trawl shots observed in Shark Bay prawn fishery that recorded pink snapper (*Pagrus auratus*) catches in various catch number categories.

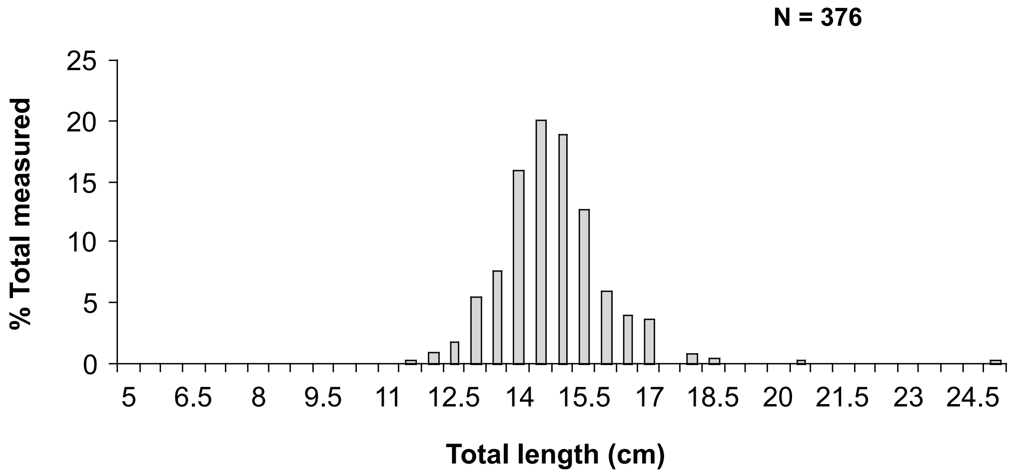


Figure 3.18 The general size composition of pink snapper (*Pagrus auratus)* caught in prawn trawl nets during the observer program.

The proportion of pink snapper catches taken by the control side did not vary amongst grid types (Table 3.9). A linear regression comparing the catch of the control and grid side indicates a 25% reduction of snapper in trawl nets using grids (Table 3.10).

Table 3.9 ANOVA explaining the variation in the proportion of pink snapper catch (numbers) taken by a Shark Bay prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	7	25.76	3.68	0.57	0.78
Residuals	188	1218.77	6.48		

Table 3.10 The estimated ratio relating the various BRD's pink snapper catch (numbers) to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Shots	Duration (hr)	Ratio	s.e.	t-value	P
196	205.2	0.75	0.04	-6.25	< 0.01

The effectiveness of secondary devices on snapper catches could not be made using the observer data as no snapper were caught during trawls with secondary devices in a net when observers were on board.

3.2.1.6 Sea snakes

The number of sea snakes caught in nets with grids was 42% lower than in control nets in the Shark Bay prawn fishery (Table 3.11, 125 trawls, paired t–test; $p < 0.01$, $t = 3.396$, $df = 124$).

Table 3.11 The number of sea snakes caught by the control net compared to the BRD net for various grid types in the Shark Bay prawn fishery.

Grid	Secondary	Shots	Duration (hr)	Control	BRD
CSNA	-	13	15.8	9	5
CSNN	-	45	47	40	13
CSNN	Square mesh panel	3	3	2	3
RFNA	-	5	7.1	4	2
RFNN	-	13	14.7	3	11
RFWA	-	20	17.6	14	10
RFWN	-	4	3.3	4	0
RSNA	-	2	2.8	0	2
RSNN*2	-	6	6.5	3	3
RSNN*2	Square mesh panel	4	5.6	4	2
RSNN	-	10	10.0	10	3
Total		**125**	**133.4**	**93**	**54**

3.2.1.7 Sharks

There was 87% less shark numbers retained by nets with grids compared to the control net (Table 3.12, 70 trawls, paired t–test; $p < 0.01$, $t = 8.88$, $df = 69$). The majority of sharks caught in the control net were >1m in length in the Shark Bay prawn fishery.

Table 3.12 The number of sharks caught by the control net compared to the BRD net for various grid types in the Shark Bay prawn fishery.

Grid	Secondary	Shots	Duration (hr)	Control	BRD
CSNA	-	7	8.2	6	1
CSNN	-	26	27.3	31	0
RFNA	-	2	2.6	2	0
RFNN	-	7	8	8	0
RFWA	-	7	6	7	0
RFWN	-	1	1.1	1	0
RSNA	-	6	7.8	8	2
RSNN*2	-	6	8	4	2
RSNN*2	Square mesh panel	2	3.2	1	1
RSNN	-	6	5.8	3	3
Total		**70**	**78**	**70**	**9**

3.2.1.8 Rays

There were 88% less rays retained in nets with grids compared to control nets in the Shark Bay prawn fishery (Table 3.13, 55 trawls, paired t-test; $p < 0.01$, $t = 9.42$, $df = 54$).

Table 3.13 The number of rays caught by the control net compared to the BRD net for various grid types in the Shark Bay prawn fishery.

Grid	Shots	Duration (hr)	Control	BRD
CSNA	3	2.4	3	0
CSNN	20	21.1	21	0
RFNA	1	1.5	1	0
RFNN	7	9.7	6	3
RFWA	4	3.5	6	1
RFWN	7	6	9	0
RSNA	2	2.2	4	2
RSNN*2	4	5.2	4	1
RSNN	7	7.6	11	1
Total	**55**	**59.2**	**65**	**8**

3.2.1.9 Tailor

A linear regression comparing the catch of the control net and grid side showed a 50% reduction in the number of tailor (*Pomatomus saltator)* caught in nets with grids (Table 3.14).

Table 3.14 The estimated ratio relating the various BRD's tailor catch (numbers) to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Shots	Duration (hr)	Ratio	s.e.	t-value	P
64	65.8	0.5	0.06	-8.33	< 0.01

3.2.1.10 Other Large Fin Fish

Only a marginal difference was observed with catches of other large finfish between nets with grids and the control net (Table 3.15, paired t-test; p = 0.08, t = 1.82, df = 18). Due to small number of trawls (19) with records of other large finfish however, the power of this test is questionable.

Table 3.15 The estimated ratio relating the various BRD's 'other large fin fish' catch (numbers) to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Grid	Shots	Duration (hr)	Control	BRD
CSNA	2	1.6	2	0
CSNN	9	8.7	10	4
RFWA	2	2	0	2
RSNN*2	5	7	7	1
RSNN	1	1.2	1	0
Total	**19**	**20.5**	**20**	**7**

3.2.1.11 Sponges

There was a significant difference between grid type on sponge catches (Table 3.16) with the reduction of sponges retained in nets with different grids varying between 79 and 100% (Table 3.17).

Table 3.16 ANOVA explaining the variation in the proportion of sponge catch (baskets) taken by a Shark Bay prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	8	118.34	14.79	3.54	< 0.01
Residuals	253	1058.70	4.18		

Table 3.17 The estimated ratio relating the various BRD's sponge catch to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Grid	Shots	Duration (hr)	Ratio	s.e.	t-value	P
RFWN	4	3.8	0.00	0.00	-Inf	< 0.01
CSNN	66	70.0	0.05	0.03	-31.67	< 0.01
CSNA	36	41.2	0.02	0.02	-19.60	< 0.01
RFWA	32	29.2	0.28	0.10	-7.20	< 0.01
RFNN	38	49.2	0.03	0.03	-32.33	< 0.01
RSNN	31	32.9	0.07	0.03	-31.00	< 0.01
RSNA	2	2.3	0.21	0.10	-7.90	0.08
RFNA	24	29.2	0.00	0.02	-50.00	< 0.01
RSNN*2	28	32.2	0.04	0.05	-19.20	< 0.01

3.2.1.12 Scallop

There was no significant difference between grid-types on scallop catches for the Shark Bay prawn boats (Table 3.18). Overall, there was a 9% reduction in scallop catch in nets with grids compared to the control net (Table 3.19).

Table 3.18 ANOVA explaining the variation in the proportion of scallop catch (baskets) taken by a Shark Bay prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	4	0.89	0.22	0.62	0.65
Residuals	71	25.63	0.36		

Table 3.19 The estimated ratio relating the various BRD's scallop catch (baskets) to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Shots	Duration (hr)	Ratio	s.e.	t-value	P
76	67.3	0.91	0.02	-4.5	< 0.01

3.2.1.13 Weed volume

Differences were observed between the proportion of weed retained by different grid types compared to control (Table 3.20) with between 79 and 96% reduction in the most commonly used grid types (Table 3.21).

Table 3.20 ANOVA explaining the variation in the proportion of total weed volume taken by a Shark Bay prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	9	166.04	18.45	4.83	< 0.01
Residuals	239	912.22	3.82		

Table 3.21 The estimated ratio relating the various BRD's total weed volume to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Grid Type	Secondary device	Shots	Duration (hr)	Ratio	s.e.	t-value	P
CSNA	-	7	8.0	0.03	0.07	-13.86	< 0.01
CSNN	-	44	46.8	0.15	0.05	-17.00	< 0.01
CSNN	Square mesh panel	4	4.0	0.00	0.00	-Inf	< 0.01
RFNA	-	6	7.0	0.00	0.01	-100.00	< 0.01
RFNN	-	55	67.1	0.04	0.09	-10.67	< 0.01
RFWA	-	58	55.2	0.21	0.03	-26.33	< 0.01
RFWN	-	15	11.7	0.43	0.07	-8.14	< 0.01
RSNA	-	5	6.3	0.82	0.19	-0.95	0.40
RSNN*2	-	12	12.6	0.75	0.46	-0.54	0.60
RSNN	-	43	42.6	0.13	0.03	-0.29	< 0.01

3.2.2 Shark Bay Scallop Fishery Observer Program

3.2.2.1 Scallop

The amount of target catch information from scallop boats was fairly limited. From the observations made, no significant differences between grids were observed (Table 3.22) and overall scallop catches were up by 12% in nets with grids compared to control nets (Table 3.23).

Table 3.22 ANOVA explaining the variation in the proportion of scallop catch (baskets) taken by a Shark Bay scallop trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	1	1.16	1.16	1.65	0.21
Residuals	29	20.46	0.71		

Table 3.23 The estimated ratio relating the various BRD's scallop catch (baskets) to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Shots	Duration (hr)	Ratio	s.e.	t-value	P
31	43.7	1.12	0.03	4.00	< 0.01

3.2.2.2 Bycatch

There was a significant difference in the amount of bycatch (baskets) recorded in nets with different grid types compared to the control net (Table 3.24). Bycatch was reduced by between 8 and 27% in nets with grids (Table 3.25). The few trawls conducted with a grid and secondary device combination indicated a 66% reduction in bycatch.

Table 3.24 ANOVA explaining the variation in the proportion of total bycatch (baskets) taken by a Shark Bay scallop trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	3	6.40	2.13	2.88	0.04
Residuals	96	71.03	0.74		

Table 3.25 The estimated ratio relating the various BRD's total bycatch to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Grid Type	Secondary	Shots	Duration (hr)	Ratio	s.e.	t-value	P
CSNN	-	41	43.0	0.92	0.03	-2.67	0.01
RFWN	-	27	45.1	0.78	0.04	-5.5	< 0.01
RSNA	-	28	25.2	0.73	0.08	-3.38	< 0.01
CSNN	Radial escape	4	4.2	0.34	0.16	-4.12	0.03

3.2.2.3 Turtles

Observed turtle captures on scallop trawlers were very low. From a total of 104 trawl shot observations (121.4 hours) with a grid on one side and a control net on the other, 2 turtle captures were observed on the control side and one in a net with a BRD (CSNN + radial escape section). In 37 trawls (21.4 hours) that had grids in all nets, no turtle captures were observed.

3.2.2.4 Pink snapper

There was no significant difference between numbers of pink snapper caught in the BRD nets compared to the control net (Table 3.26, paired t-test; $p = 0.48$, $t = -0.74$, $df = 10$). Based on a low number of shots (11) however, this result lacks power.

Table 3.26 The number of pink snapper caught in the nets with a grid compared to the control net in the Shark Bay scallop fishery.

Grid	Shots	Duration (hr)	Control	BRD
CSNN	8	9.5	43	85
RFWN	3	4.8	2	1
Total	11	14.3	45	86

3.2.2.5 Sea snakes

There was no significant difference in the number of sea snakes caught in a net with a grid compared to the control net. However, only nine trawl shots had sea snake observations (Table 3.27, paired t-test; $p = 0.73$, $t = 0.36$, $df = 8$).

Table 3.27 The number of sea snakes caught in the nets with grid compared to the control net in the Shark Bay scallop fishery.

Grid	Shots	Duration (hr)	Control	BRD
CSNN	7	4	8	9
RSNA	2	1.9	3	1
Total	**9**	**5.9**	**11**	**10**

3.2.2.6 Sharks

There was no significant difference in the numbers of sharks caught in a net with a grid compared to the control net in the Shark Bay scallop fishery. However, only seven trawl shots had shark observations (Table 3.28, paired t-test; $p = 0.29$, $t = 1.16$, $df = 6$).

Table 3.28 The number of sharks caught by the control net compared to the BRD net for various grid types in the Shark Bay scallop fishery.

Grid	Shots	Duration (hr)	Control	BRD
CSNN	1	1.0	1	0
RFWN	2	2.9	2	0
RSNA	4	2.8	2	2
Total	**7**	**6.7**	**5**	**2**

3.2.2.7 Rays

No rays were caught whilst observers (141 trawls) were on board scallop boats.

3.2.2.8 Tailor

Only one tailor was reported as being caught whilst observers were on board scallop boats and it was caught on the grid side (CSNN).

3.2.2.9 Other Large Fin-fish

Only six individuals of ‘other fin-fish’ were caught (in 2 shots totaling 6 hours of trawling); all these were caught on the control side.

3.2.2.10 Sponges

There were no significant differences in sponge catches between grid types (Table 3.29). A linear regression comparing grid side catch to control side catch indicates that 62% of sponges are reduced on the grid side compared to the control (Table 3.30).

Table 3.29 ANOVA explaining the variation in the proportion of sponge catch (baskets) taken by a Shark Bay scallop trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	2	36.79	18.40	3.04	0.06
Residuals	47	284.25	6.05		

Table 3.30 The estimated ratio relating the various BRD's sponge catch to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Shots	Duration (hr)	Ratio	s.e.	t-value	P
50	76.8	0.38	0.04	-15.5	< 0.01

3.2.2.11 Weed

No significant differences were observed between grid types (CSNN, FRWN and RSNA) and the amount of weed retained (Table 3.31) with an overall reduction of 85% in the amount of weed retained in nets with grids (Table 3.32). The areas of operation by the scallop boats did not have high volumes of weed during the project.

Table 3.31 ANOVA explaining the variation in the proportion of total weed volume (baskets) taken by a Shark Bay scallop trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	2	4.77	2.38	0.32	0.72
Residuals	43	315.20	7.33		

Table 3.32 The estimated ratio relating the various BRD's total weed volume to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Shots	Duration (hr)	Ratio	s.e.	t-value	P
46	57.2	0.15	0.05	-17.00	< 0.01

3.2.3 Exmouth Gulf Prawn Fishery Observer Program

3.2.3.1 Total prawn catch

There were differences in the proportion of total prawn catch between grid types but not with the species of prawn (Table 3.33). A fully reduced ANOVA indicates that grid type is still significant (Table 3.34). Linear regressions comparing grid to control side catch with species being combined indicates total prawn catches are variable from being reduced by 8% to being up by 3% (Table 3.35).

Table 3.33 ANOVA explaining the variation in the proportion of total prawn catch (kg) taken by an Exmouth Gulf prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Species	4	2.48	0.62	1.39	0.24
Grid Type	2	3.76	1.88	4.20	0.02
Species*Grid Type	3	0.45	0.15	0.34	0.80
Residuals	451	201.64	0.45		

Table 3.34 Optimally reduced ANOVA explaining the variation in total catch taken by an Exmouth Gulf prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	2	3.79	1.89	4.22	0.02
Residuals	458	205.61	0.45		

Table 3.35 The estimated ratio relating the various BRD's total prawn catch to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Grid Type	Opening	Shots	Duration (hr)	Ratio	s.e.	t-value	P
CSNN	Bottom	178	430.1	0.92	0.01	-8.00	< 0.01
CFWN	Top	6	16.5	1.03	0.03	1.00	0.36
CFNN	Top	3	9.0	0.93	0.07	-1.00	0.42

3.2.3.2 Soft and broken prawn catch

No significant differences were observed between grid types or species for the proportion of soft and broken prawn catch taken by the control net (Table 3.36). Hence, a linear regression comparing the proportion of soft and broken catch is made independently of species and grid type and indicates a 5% reduction in soft and broken prawns using grids (Table 3.37).

Table 3.36 ANOVA explaining the variation of the proportion of soft and broken prawn catch (kg) taken by an Exmouth Gulf prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Species	2	3.92	1.96	0.57	0.56
Grid Type	2	1.18	0.59	0.17	0.84
Residuals	245	838.91	3.42		

Table 3.37 The estimated ratio relating the various BRD's soft and broken prawn catch (kg) to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Shots	Duration (hr)	Ratio	s.e.	t-value	P
138	334.1	0.95	0.03	-1.67	< 0.01

3.2.3.3 Bycatch

There were significant differences between grid-types for the proportion of total bycatch (baskets) taken on the grid side to that of the control side (Table 3.38). A linear regression comparing grid side catch to control side catch indicates a 9% reduction in overall bycatch for the most commonly used grid compared to the control net (Table 3.39).

Table 3.38 ANOVA explaining the variation in the proportion of total bycatch (baskets) taken by an Exmouth Gulf prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	2	4.29	2.14	8.62	< 0.01
Residuals	195	48.55	0.25		

Table 3.39 The estimated ratio relating the various BRD's total bycatch to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Grid Type	Opening	Shots	Duration (hr)	Ratio	s.e.	t-value	P
CSNN	Bottom	188	455.2	0.91	0.01	-9.00	< 0.01
CFWN	Top	6	16.5	1.15	0.07	2.14	0.09
CFNN	Top	4	11.5	0.74	0.02	-13.0	< 0.01

3.2.3.4 Turtles

From a total of 231 trawl shot observations (548.9 hours), 6 turtle captures were observed. All six turtles were caught on the control side. This equates to a 100% reduction in turtle captures. In 15 trawls (40.8 hours) where observers were on board and grids were installed in all nets, there were no observed turtle captures.

3.2.3.5 Pink snapper

Pink snapper are rarely caught in Exmouth Gulf. Only one pink snapper was recorded (control net) during the whole observer program.

3.2.3.6 Sea snakes

There was no significant difference between sea snake catches in nets with a grid compared to the control nets in the Exmouth Gulf prawn fishery (Table 3.40, paired t-test; $p = 0.88$, $t = 0.15$, $df = 35$).

Table 3.40 The number of sea snakes caught by the control net compared to the net with a grid in the Exmouth Gulf prawn fishery.

Grid	Opening	Shots	Duration (hr)	Control	BRD
CFNN	Top	1	2.5	2	0
CFWN	Top	3	8.2	0	3
CSNN	Bottom	31	70.6	20	17
CSNN	Top	1	2.5	0	1
Total		**36**	**83.8**	**22**	**21**

3.2.3.7 Sharks

There was no significant difference between shark catches in nets with a grid and the control nets in the Exmouth Gulf prawn fishery (Table 3.41, paired t-test; $p = 0.48$, $t = 0.72$, $df = 21$). The sharks caught in this fishery are generally less than 1.5m in length.

Table 3.41 The number of sharks caught in the control nets compared to nets with grids in the Exmouth Gulf prawn fishery.

Grid	Opening	Shots	Duration (hr)	Control	BRD
CSNN	Bottom	16	38.6	11	8
CSNN	Top	6	12	6	5
Total		**22**	**50.6**	**17**	**13**

3.2.3.8 Rays

Ray catches were reduced by 56% in nets with grids compared to control nets (Table 3.42, paired t-test; $p = 0.03$, $t = 2.31$, $df = 16$).

Table 3.42 The estimated ratio relating the various BRD's ray catch to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Grid	Opening	Shots	Duration (hr)	Control	BRD
CSNN	Bottom	12	25.5	9	4
CSNN	Top	5	12.5	7	3
Total		**17**	**38.0**	**16**	**7**

3.2.3.9 Tailor

There were no observed catches of tailor in the Exmouth Gulf prawn fishery whilst observers were on board vessels.

3.2.3.10 Other Large Fin-fish

There were no observed catches of other finfish species in the Exmouth Gulf prawn fishery whilst observers were on board vessels.

3.2.3.11 Sponges

No significant differences were observed between grid types for the proportion of sponges taken (Table 3.43). A linear regression comparing grid side catch to control side catch indicated a 95% reduction in the catch of sponges on the nets with grids compared to control nets (Table 3.44).

Table 3.43 ANOVA explaining the variation in the proportion of sponge catch (baskets) taken by an Exmouth Gulf prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Grid Type	3	12.84	4.28	0.44	0.72
Residuals	156	1506.84	9.66		

Table 3.44 The estimated ratio relating the various BRD's sponge catch to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Shots	Duration (hr)	Ratio	s.e.	t-value	P
160	393.5	0.05	0.04	-23.75	< 0.01

3.2.3.12 Scallop

No scallops were caught in the Exmouth Gulf prawn fishery whilst observers were on board and generally scallops are rarely caught in this fishery.

3.2.4 Shark Bay Prawn Fishery, commercial fishers voluntary bycatch log books

Shark Bay prawn fishers provided prawn catch and very limited bycatch data for 625 trawl shots (759.8 hrs) between March and May 2000. Grids used were CSNN, RSNN, RFNN and RFNA; all of which were top opening and had no secondary devices. Due to the small amount of bycatch data only prawn catches could be analysed.

3.2.4.1 Total prawn catch

There were no significant differences in total prawn catch between grid types (Table 3.45) so all grid types were combined. A linear regression comparing the proportion of the grid side catch to control side catch indicated a 16% reduction in prawn catch (Table 3.46).

Table 3.45 ANOVA explaining the variation in the proportion of the total prawn catch (kg) taken by a Shark Bay prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Species	2	0.84	0.42	0.40	0.67
Grid Type	3	3.71	1.24	1.19	0.31
Species*Grid Type	3	3.64	1.21	1.16	0.32
Residuals	954	993.09	1.04		

Table 3.46 The estimated ratio relating the various BRD's total prawn catch to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Shots	Duration (hr)	Ratio	s.e.	t-value	P
559	582.3	0.84	0.01	-16.00	< 0.01

3.2.4.2 Soft and broken prawn catch

There were significant differences in the proportion of soft and broken prawns for species but not for grid type. (Tables 3.47 and 3.48). A linear regression comparing individual prawn species catch on the grid side catch to control side indicated a 26% reduction in soft and broken king prawns but a 15% increase in soft and broken tiger prawns (Table 3.49).

Table 3.47 ANOVA explaining the variation in the proportion of soft and broken prawn catch (kg) taken by a Shark Bay prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Species	1	8.59	8.59	3.85	0.05
Grid Type	3	1.23	0.41	0.18	0.91
Residuals	558	1243.64	2.23		

Table 3.48 Optimally reduced ANOVA explaining the variation in the proportion of soft and broken prawn (kg) taken by a Shark Bay prawn trawler, by the control side. Type 3 sum of squares have been presented.

Factor	Df	SS	MS	F	P
Species	1	8.42	8.42	3.80	0.05
Residuals	561	1244.86	2.22		

Table 3.49 The estimated ratio relating the various BRD's soft and broken prawn catch to that taken by the control net, as determined by the weighted (duration) – least squares regression with no intercept.

Species	Shots	Duration (hr)	Ratio	s.e.	t-value	P
King	362	372.3	0.74	0.01	-26.00	< 0.01
Tiger	178	186.2	1.15	0.03	5.00	< 0.01

3.2.5 Shark Bay and Exmouth Gulf Prawn Fishery grid and secondary BRD experimental trials

3.2.5.1 Evaluation of a grid and the CSMPA as a secondary BRD in Shark Bay

Compared to the control, the grid only and the grid with the CSMPF and CSMPA codends significantly reduced the weights of total prawns by similar amounts (12.5, 14.0 and 12.0%, respectively, Table 3.50) and the numbers (19.6, 19.3 and 16.1%, respectively) and weights (by 14.8, 18.8 and 13.5%, respectively) of king prawns (Table 3.50; Figure 3.19a, b and c). The grid in combination with the CSMPA codend also significantly reduced the weight of bycatch (by 48.9%) and the numbers and weights of leatherjacket (55.6 and 58.6%, respectively), sardine (by 57.4 and 70.3%), bar-tailed flathead (by 75.7 and 73.4%) and small-toothed flounder (by 50.0 and 46.5%) (Table 3.50; Figure 3.19g, k, o, q and r).

While not significant, this combination of BRDs also reduced the numbers and weights of trumpeter whiting, butterfish, trumpeter, threadfin and heart-headed flathead (differences of between 8.3 and 68.2%) (Figure 3.19 i, j, m, n and p). No other significant differences were detected (Table 3.50 and Figure 3.19), although the grid only and the grid in combination with the CSMPF codend showed some reduction in the weight of bycatch (by 4.9 and 15.5%, respectively) and the numbers and weights of butterfish, trumpeter, heart-headed flathead and small-toothed flounder (by between 14.4 and 44.4%) (Table 3.50; Figures 3.19g, j, m, p and r). Further, the numbers and weights of trumpeter whiting, leatherjacket, threadfin were also reduced by the grid and CSMPF codend (by between 15.8 and 57.5%), however these catches were not significantly different from the control codend (Table 3.50; Fig. 3.19 i, k, n, 1 and s).

Table 3.50 Summaries of paired *t*-tests comparing 3 BRDs (grid – NG only, Grid and composite square mesh panel forward – CSMPF and grid and composite square-mesh panel aft – CSMPA) codends against the control codend in shark Bay. All variables were analysed using one-tailed paired *t*-test. % diff = % difference between grid side and control, Pt-v = paired *t*-value; *n* = number of replicates; blank = insufficient data. * = p <0.05; ** = p<0.01.

	Grid only vs control				Grid and CSMPF vs control				Grid and CSMPA vs control			
	% diff	Pt-v	p	*n*	% diff	Pt-v	*p*	*n*	% diff	Pt-v	*p*	*n*
Wt. of total prawns	**12.5**	-2.616	0.014*	10	**14.1**	-2.263	0.045*	10	**12.0**	-3.132	0.006**	10
No. of king prawns	**19.6**	-3.580	0.003**	10	**19.3**	-3.302	0.005**	10	**16.1**	-3.336	0.004**	10
Wt.. of king prawns	**14.8**	-3.801	0.002**	10	**18.8**	-2.682	0.013*	10	**13.5**	-3.39	0.004**	10
No. of tiger prawns	11.7	-0.460	0.328	10	-2.3	0.992	0.826	10	11.9	-0.996	0.173	10
Wt. of tiger prawns	13.8	-0.582	0.287	10	-7.1	0.689	0.746	10	13.8	-0.896	0.196	10
Wt. of coral prawns	-10.1	0.785	0.771	8	5.1	-0.558	0.297	8	8.6	-.987	0.175	10
Wt. of bycatch	4.9	-0.675	0.258	10	15.5	-1.666	0.065	10	49.48.90	-2.431	0.019*	10
No. of trumpeter whiting					17.7	-0.338	0.372	8	52.9	-1.163	0.144	7
Wt. of trumpeter whiting					15.8	-0.334	0.374	8	56.3	-1.236	0.131	7
No. of butterfish	32.9	-1.013	0.17	10	24.1	-0.634	0.273	8	9.4	-0.344	0.369	9
Wt. of butterfish	28.6	-0.725	0.245	10	37.2	-1.24	0.127	8	27.4	-1.257	0.122	9
No. of leatherjacket	-1.6	-0.079	0.531	10	23.5	-1.643	0.067	10	**55.6**	-3.611	0.003**	10
Wt. of leatherjacket	-6.7	0.410	0.654	10	24.2	-0.921	0.191	10	**58.6**	-3.515	0.003**	10
No. of goatfish	-93.4	4.088	0.999	10	-88.1	3.529	0.997	10	17.	-0.098	0.462	10
Wt. of goatfish	-66.9	3.616	0.997	10	-53.3	1.847	0.951	10	3.0	-0.162	0.438	10
No. of trumpeter	16.6	-1.656	0.066	10	25.5	-1.287	0.123	7	67.9	-1.668	0.073	7
Wt. of trumpeter	24.0	-1.582	0.074	10	21.8	-0.922	0.196	7	68.2	-1.621	0.078	7
No. of threadfin					57.5	-1.364	0.111	7	61.7	-1.678	0.072	7
Wt. of threadfin					32.2	-1.147	0.147	7	50.4	-1.833	0.058	7
No. of sardine	-174.4	1.62	0.925	8					**57.4**	-2.066	0.039*	8
Wt. of sardine	-138.9	1.792	0.942	8					70.3	-2.032	0.041*	8
No. of heart-headed flathead	34.0	-0.856	0.212	7	14.4	-0.341	0.371	8	40.3	-1.11	0.152	8
Wt. of heart-headed flathead	22.1	-0.637	0.274	7	44.8	-0.815	0.221	8	27.3	-0.536	0.304	8
No. of bar-tailed flathead					-55.7	-0.514	0.313	7	**75.7**	-3.103	0.007**	8
Wt. of bar-tailed flathead					-189.8	-0.42	0.345	7	**73.4**	-3.5	0.004**	9
No. of small-toothed flounder	32.1	-1.36	0.105	9	38.3	-1.021	0.167	10	**50.0**	-2.731	0.013*	9
Wt. of small-toothed flounder	7.1	-0.367	0.362	9	44.4	*1.321	0.109	10	**46.5**	-2.548	0.017*	9
No. of blue swimmer crab	-90.9	2.375	0.972	7	18.5	-0.432	0.338	10	-2.2	0.043	0.516	8
Wt. of blue swimmer crab	-134.4	2.691	0.982	7	20.5	-0.379	0.357	10	2.8	-0.041	0.484	8

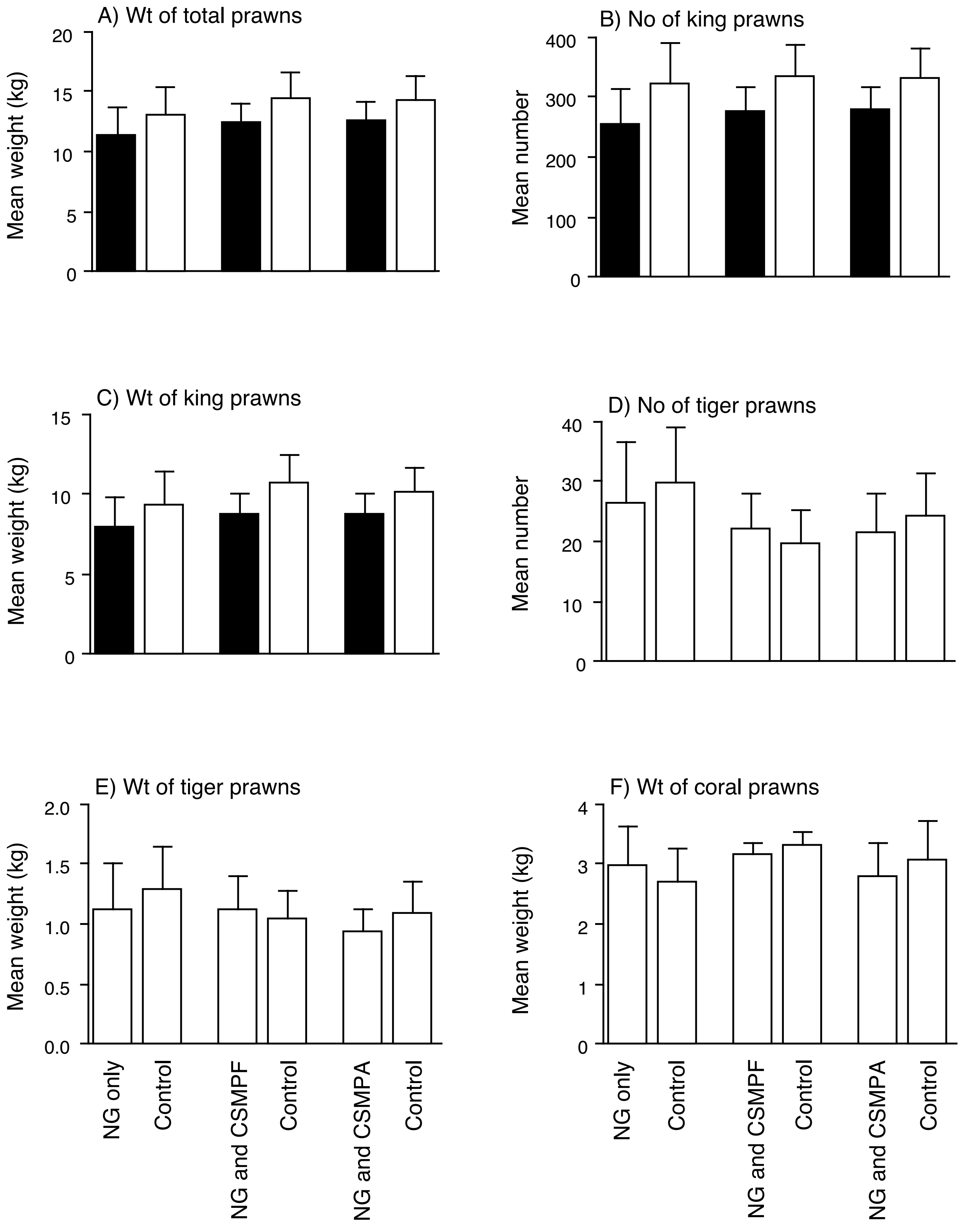


Figure 3.19 Differences in mean catch (± SE) of species between the BRDs and the control in Shark Bay. Histograms in black represent significant reductions NG = Nordmøre-grid, CSMPF = composite square-mesh panel forward codend. CSMPA = composite square-mesh panel aft codend.

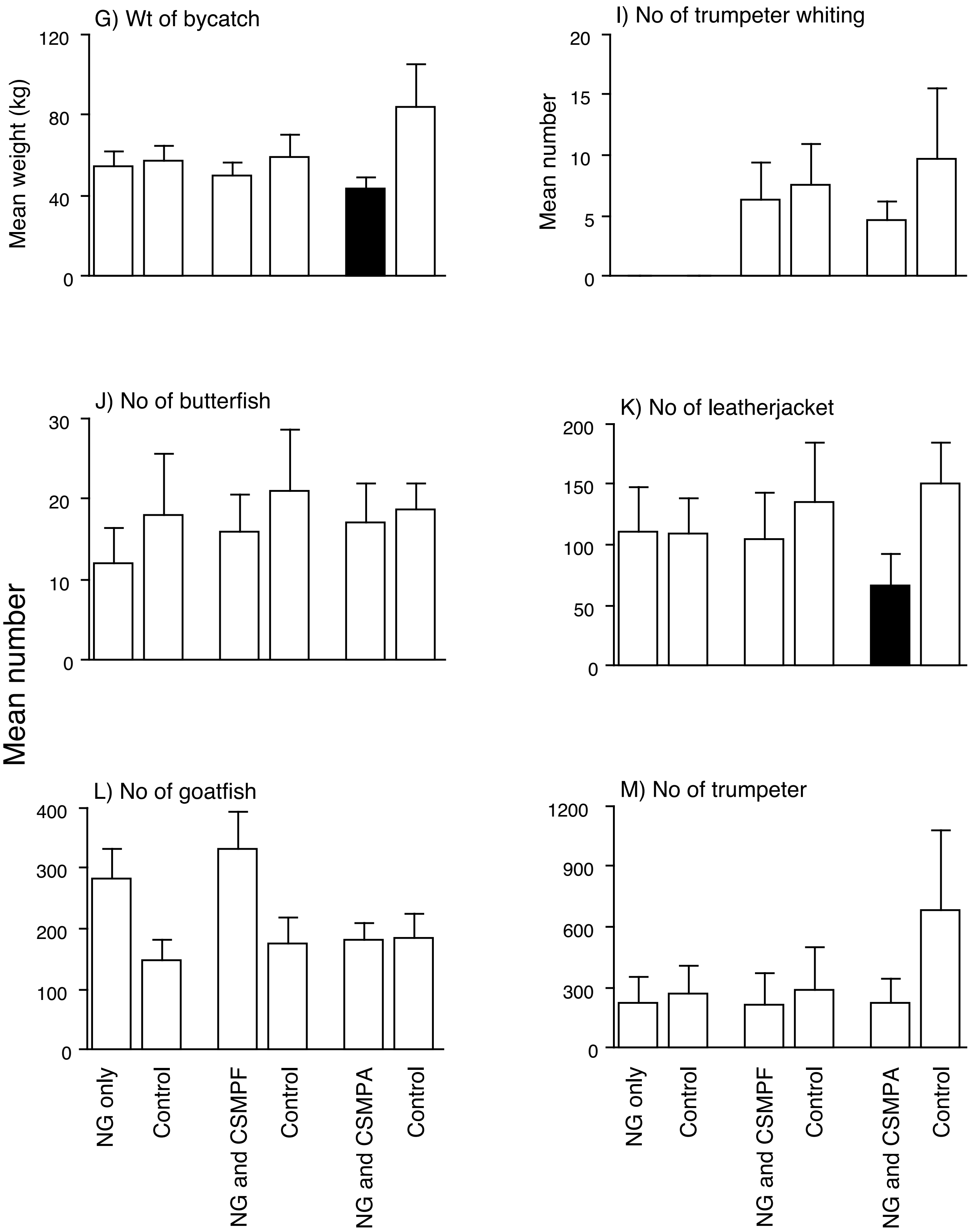


Figure 3.19 cont.

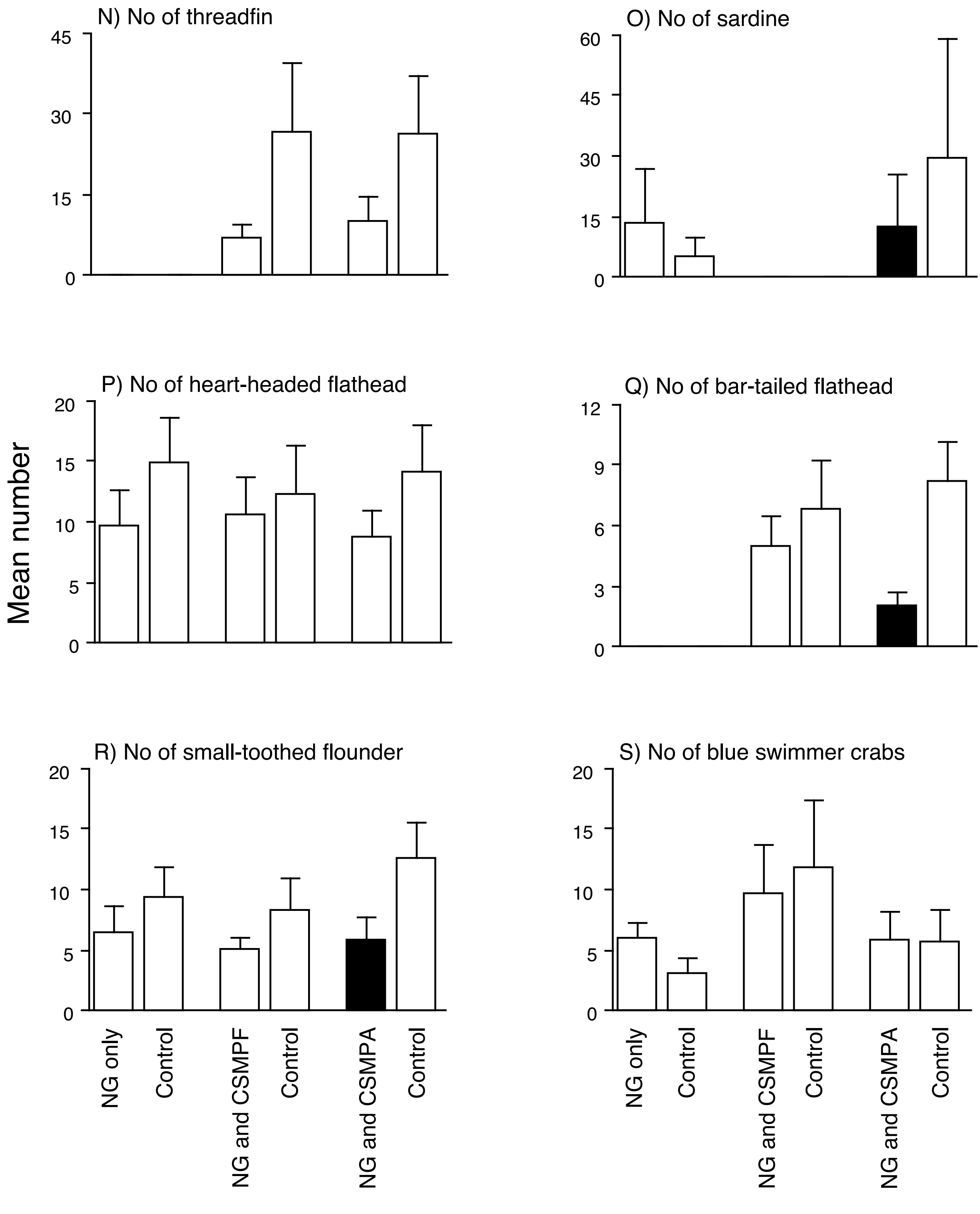


Figure 3.19 cont.

3.2.5.2 Evaluation of a grid and the CSMPA as a secondary BRD in Exmouth Gulf

Compared to the control, a grid only and a grid in combination with the CSMPA codend significantly reduced the weights of bycatch (by 8 and 53.5%, respectively), numbers (by 62 and 97.9%, respectively) and weights (by 67.6 and 97.2%, respectively) of leatherjacket and the numbers of heart-headed flathead (by 46.3 and 51.3%, respectively) and small-toothed flounder (by 57.1 and 50%, respectively) (Table 3.51; Figures 3.20 g, k, n and p). The grid in combination with the CSMPA codend also significantly reduced the numbers and weights of tiger prawns (by 16.6 and 11.3%), trumpeter whiting (by 50.9 and 47.3%), goatfish (by 71.8 and 66.2%) and trumpeter (by 98.1 and 90.2%) (Table 3.51; Figures 3.20 d, e, j, l and m), while the grid only significantly reduced the numbers and weights of ponyfish (by 40 and 22.7%) and the weights of small-toothed flounder (by 52.9%) (Table 3.51; Figures 3.20 h and q). No other significant differences were detected, although the numbers of stout whiting and 3 spot crab were reduced by the super shooter grid with the CSMPA (by 39.4% and 42.8%, respectively) while the numbers of blue swimmer crabs were reduced by the super shooter grid only (by 33%) (Figures 3.20 i, s and r). Further, slightly fewer total prawns were retained in both the codends with the BRDs than in the controls (up to 7% less) (Figure 3.20 a).

Table 3.51 Summaries of paired t-test comparing the grid and grid and CSMPA (composite square mesh panel aft) combination against the control in Exmouth Gulf. All variable were analysed using one-tailed paired t-tests. % diff. = % difference between grid and control nets, Pt-v = paired t-test value; number of replicates = 6, * = p<0.05, ** = p<0.01.

	Grid vs control			Grid and CSMPA vs control		
	% diff.	pt-v	P	% diff.	pt-v	p
Wt of total prawns	5.4	-1.387	0.112	7.4	-1.876	0.059
No. of king prawns	-3.1	0.298	0.611	25.1	-1.733	0.072
Wt. of king prawns	-9.7	0.771	0.762	24.3	-1.596	0.086
No. of tiger prawns	8.7	-1.539	0.092	**16.6**	-3.393	0.009**
Wt. of tiger prawns	6.8	-1.383	0.113	**11.4**	-3.586	0.008**
Wt of endeavours	6.5	-0.521	0.312	-30.3	3.436	0.991
Wt of bycatch	**8.0**	2.484	0.028*	**53.5**	-20.132	0.0001**
No. of ponyfish	**40.0**	-2.236	0.038*	35.7		
Wt. of ponyfish	**22.7**	-2.996	0.015*	60.0		
No. of stout whiting				39.5	-1.908	0.057
Wt. of stout whiting				49.4	-2.012	0.051
No. of trumpeter whiting	-13.6	1.773	0.932	**51.0**	-2.483	0.028*
Wt. of trumpeter whiting	-9.6	0.839	0.780	**47.3**	-2.306	0.035*
No. of leatherjacket	**62.1**	-2.756	0.020*	**97.9**	-5.604	0.001**
Wt. of leatherjacket	**67.6**	-2.712	0.021*	**97.2**	-4.165	0.004**
No. of goatfish	14.5	-0.506	0.317	**71.9**	-3.799	0.006**
Wt. of goatfish	-17.0	0.810	0.773	**66.2**	-4.726	0.003**
No. of trumpeter	-8.0	0.235	0.588	**98.1**	-5.238	0.002**
Wt. of trumpeter	4.9	-0.273	0.398	**90.2**	-6.745	0.0005**
No. of heart-headed flathead	**46.3**	-2.433	0.029*	**51.4**	-3.124	0.013*
Wt. of heart-headed flathead	84.7	-1.208	0.141	34.6	-1.567	0.089
No. of small-toothed flounder	**57.1**	-2.609	0.024*	**50.0**	-2.183	0.040*
Wt. of small-toothed flounder	**52.9**	-3.354	0.010**	75.9	-1.072	0.166
No. of blue swimmer crab	33.0	-1.142	0.152	-3.8	0.237	0.411
Wt. of blue swimmer crab	43.1	-1.607	0.084	2.4	-0.084	0.468
No. of 3 spot crab	-57.1	0.955	0.808	42.9	-1.406	0.109
Wt of 3 spot crab	3.4	-0.094	0.464	36.6	-1.156	0.15

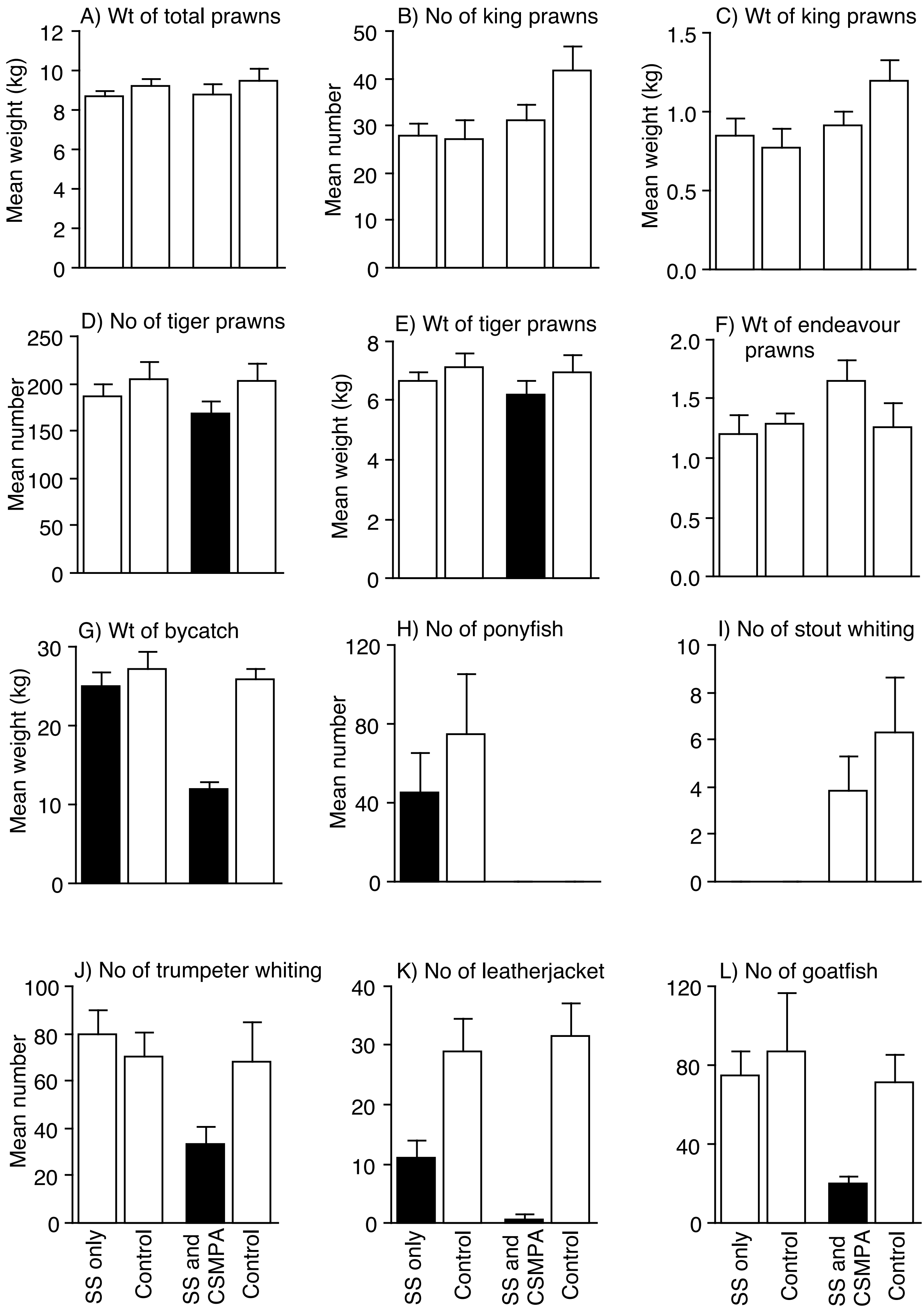


Figure 3.20 Differences in mean catches (± SE) of species between the BRD and the control net in Exmouth Gulf. Histograms in black represent significant reductions. SS – grid, CSMPA – composite square-mesh panel aft codend.

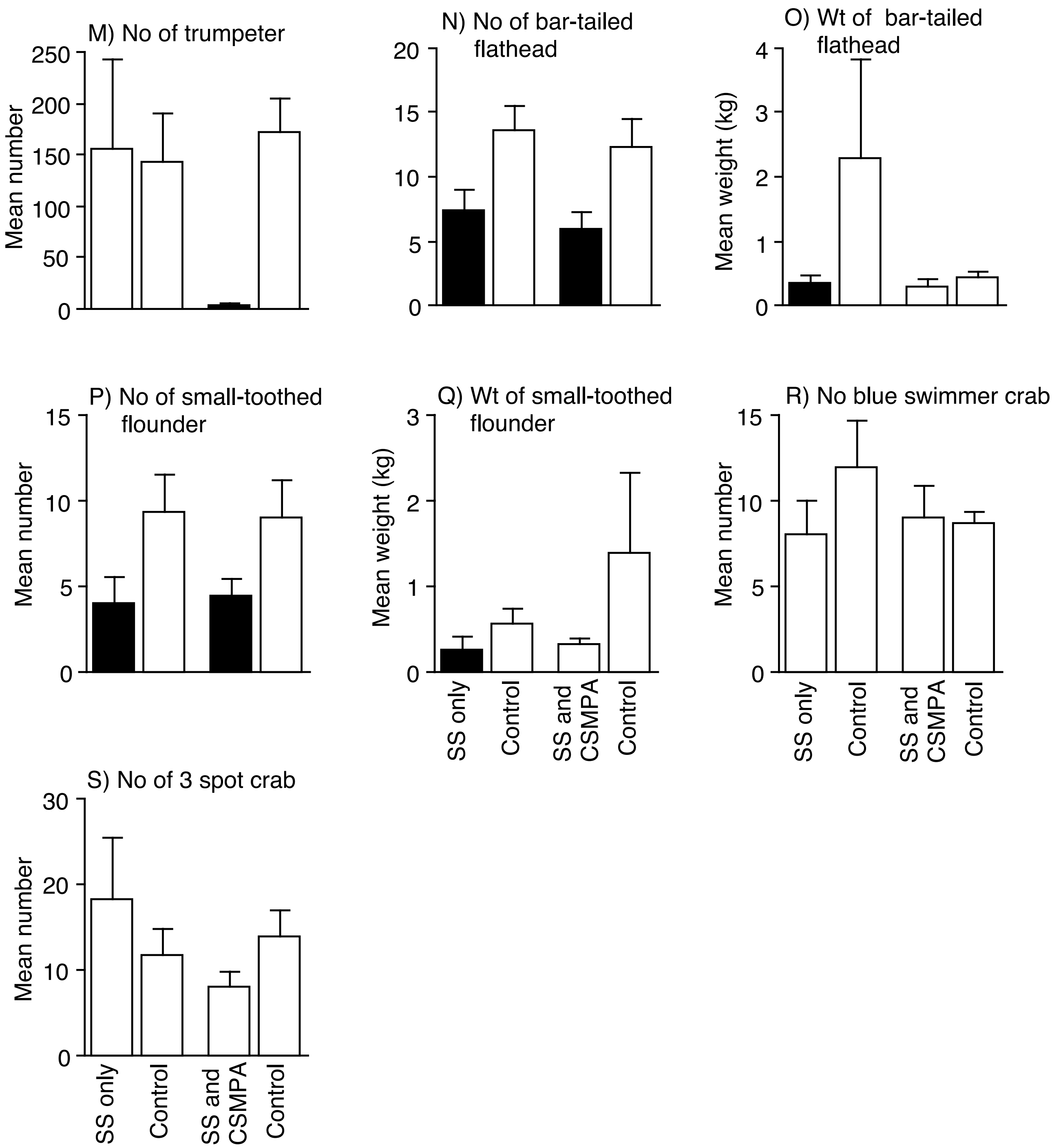


Figure 3.20 cont.

ANOVA of the differences in catches between the two BRDs and their controls detected significant differences in weights of bycatch, goatfish and numbers of blue swimmer crab for the main effect of BRDs (Table 3.52). Subsequent SNK tests of these means showed that the grid with the CSMPA codend caught less bycatch and goatfish, but more blue swimmer crab than the grid on its own.

Table 3.52 Summaries of *F* ratios from two-factor analyses of variance to determine effects on variables due to fishing with 2 different BRDs on different nights in Exmouth Gulf. The transforms used to stabilise the variances where required are listed. *= p<0.05; ** = p<0.01.

		Total Prawns	King prawns		Tiger prawns		Endeavour prawns	Bycatch
Treatment	df	Wt	No.	Wt.	No.	Wt.	Wt.	Wt.
Nights	1	0.87	1.11	3.00	0.21	0.003	0.40	5.16
BRDs	1	0.24	23.59	5.93	11.33	0.420	21.77	7748.50**
Interaction	1	0.65	0.11	06.10	0.08	1.220	0.23	0.02
Residual	8							

		Trumpeter Whiting		Leatherjacket		Goatfish		Trumpeter	
Treatment	df	No.(ln(x+1000))	Wt.	No.(ln(x+1000))	Wt.	No.	Wt.	No.	Wt.
Nights	1	6.06*	3.18	4.78	3.83	0.35	0.05	0.005	0.198
BRDs	1	13.63	14.76	9.54	1.57	4.74	1365.00**	2.04	4.00
Interaction	1	1.08	0.46	0.32	0.50	0.34	0.006	6.95*	1.57
Residual	8								

		Heart-headed flathead		Small-toothed flounder		Blue Swimmer crab		3 spot crab	
Treatment	df	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Nights	1	0.13	0.82	1.25	0.40	0.006	1.03	0.93	0.50
BRDs	1	0.00	1.51	0.07	0.67	169.17*	1.27	29.47	1.10
Interaction	1	0.06	0.78	1.25	0.80	0.006	0.89	0.07	0.50
Residual	8								

3.2.6 Shark Bay Scallop Fishery grid experimental trials

A total of 36 trawl shots were completed. Several shots were discounted due to blocking of nets/grid with weed and/or sponge and these shots were redone to provide a minimum of 10 trawl shots per combination. The grid and standard net were changed from port to starboard side during the 10 trawl shots.

3.2.6.1 Scallops

No significant difference was observed between the catch of scallops between the standard net and either grid type (paired t-test, RFNA; p =0.42, df = 14, RF2NA; p = 0.81, df = 13) or when the two grids were used side-by-side (paired t-test, p= 0.61, df = 9).

3.2.6.2 Bycatch composition

Bycatch to catch ratio for the scallop fishery is around 0.5:1. The major component of the bycatch (75-95% of total) was crabs, primarily blue swimmer crabs (*Portunus pelagicus*). Under normal fishing operations, fishers retain some large crabs but most are discarded. Small sponges were the next common item. Very few fish were caught overall with all individuals of fish caught being small in size (less than 15cm). The main species caught were; goatfish, large scaled grinners, flathead and a few gurnard. Less than 20 individuals of fish were usually caught per side.

For overall bycatch, a significant difference was observed between the RFNA grid and control net (paired t-test, p = 0.04, df= 13) with a 25% reduction in overall bycatch volume whereas no reduction was observed with the RF2NA grid and control net (paired t-test, p =0.20, df = 14).

3.2.6.3 Turtles

No turtles were caught in any shot during the trials.

3.2.6.4 Sharks and rays

From 34 trawls undertaken in total comparing the grid and control nets, no sharks or rays were caught in the side with a grid whilst 9 were caught in the control net.

3.2.6.5 Pink Snapper

From 34 trawls undertaken in total comparing the grid and control nets, one snapper was caught on the grid side and 7 (1 in each of seven trawls) were caught on the control side. This was a reduction of 87%.

3.2.6.6 Sponges

From 34 trawls undertaken in total comparing the grid and control nets, 33 sponges were caught in control nets and 16 were caught in the nets with grids. This was a reduction of 52%.

4.0 DISCUSSION

The process of incorporating BRD devices into trawl fisheries was on a progressive basis. The work to be undertaken needed to provide for both the ability to collect important catch efficiency and selectivity information for nets with BRDs and traditional fishing gear whilst allowing scope for innovation and industry application for effective BRD development. The main focus of this research was in determining the effects of BRDs on by catch and on the relative fishing power (on target species) of the boats. The process for the smaller prawn and scallop fisheries has followed the parameters established for the major fisheries. Implementation of BRDs was a two-step process. Initially the focus was on grid implementation and once accepted by industry, secondary device implementation would proceed. However, implementation of both devices was being trialled on one side initially then implemented into all the gear. This provided for a process allowing the gear to be tuned and refined by fishers and for research data to be collected on comparisons of old (standard) gear and new gear.

In terms of grids, in Shark Bay, for both the prawn and scallop fleets, in general two types of grids are now being used; the CSWA (circular, straight vertical bars, wide bar spacing and accelerator) and RSNA (rectangular, straight vertical bards, narrow bar spacing and accelerator). Some grids are still being used with a horizontal gap (up to 300mm) in the bottom (known locally as a flounder gap, RFN Figure 3.6 an FRWN Figure 3.7) to aid in the movement of weed into the cod-end. Grids with wider bar spacing (up to 265mm) were also trialled for a period of time to allow weed to pass through to the cod-end more freely. However, these are being phased out as they have not proved to be significantly superior to the simpler designs and for a majority of the grids, the bar spacing now used is 160-200mm. As the nets used in Shark Bay are 2 x 8 fathom nets for prawn boats and 2 x 7 fathom nets for the scallop boats, the overall grid dimensions are around 1 m wide and 1.3 metres high. The grids are sewn it at an angle of 45 degrees and the escape opening is generally around 780-800 mm wide. In Exmouth Gulf a smaller grid is used in each net as the fleet utilise quad gear (4 x 4.5 fathom nets). These are RSNN grids with a rectangular shape (81 x 85 cm in size), straight vertical bars with 98mm bar spacing and no accelerator. The Exmouth Gulf fleet are currently ensuring all their grids comply with United States (US) TED regulations as they were accredited in 2004 to export to the US.

Although the research focus on implementation in this project has been the Shark Bay and Exmouth Gulf trawl fisheries, the intent was for full implementation in all the prawn and scallop fisheries in WA and this implementation program has occurred in parallel to this project.

The square mesh panel has been the main secondary bycatch reduction device trialled by fishers during the implementation program. Experimental research trials using grid and square mesh panel combinations in Shark Bay (Broadhurst et al. 2001) significantly reduced the weight of bycatch (by 49%) and the numbers and weights of several commercially and non-commercially important species (by up to 75%). Preliminary trials on commercial boats indicate around 20-30% reduction of overall bycatch with up to 70% reduction of an individual fish species (e.g. trumpeter, *Pelates quadrilineatus* and banded grunter, *Terapon theraps*) from trawls. The main species with significant reductions seen in either the research or commercial trials were; hair-finned leatherjacket (*Paramonacanthus choirocephalus*), gold-striped sardine (*Sardinella gibbosa*), bar-tailed flathead (*Platycephalus endrachtensis*), small-toothed flounder (*Pseudorhombus jenynsii*), trumpeter whiting (*Sillago burrus*), robust whiting (*S. robusta*), goatfish (*Upeneus asymmetricus*), trumpeter (*Pelates quadrilineatus*), orange spotted toadfish (*Torquigener pallimaculatus*), large scaled grinner (*Saurida undosquamis*) and Goodlads stinkfish (*Callionymus goodladi*).

These initial experimental trials using composite square mesh panels provided encouragement to fishers to try these devices in Shark Bay and Exmouth Gulf prawn fisheries and trialling by commercial operators. In particular, one or two keen skippers in each fishery have provided information that can be passed onto other fishers in order to make the secondary devices more effective (with regard to position, size, colour, water flow etc.) in reducing fish numbers. Large panels were originally used (i.e. 6 x 6 meshes of 100mm mesh), however most fishers now are using smaller sections sewn into the trawl nets of around 3 x 4 meshes (100mm mesh). In Exmouth Gulf, small square mesh panels were sewn onto frames and these were inserted into the nets. These stainless steel frames tend to bend and became distorted during trawling and it is considered more appropriate to sew the square mesh panel straight into the net.

The development of appropriate BRDs required a lengthy process of experimentation and evaluation in order for industry to feel confident in their use and effectiveness. This extended period was also due to the difficulties encountered with high volumes of weed in Shark Bay and this has not been fully resolved. During this period, grids with larger bar spacing (up to 200mm spacing) and grids with a horizontal gap (up to 300mm) at the base of the grid (RFNN and RFWN) were trialled to see if some of the weed would flow though the bars of the grid and into the cod-end alleviating the blockage problems. These grids provided some benefits but not sufficient enough to continue being used. This has resulted in an exemption period for the use of grids during the peak fishing time in Shark Bay to ensure the major catch of the season is not compromised. This exemption covered areas prone to high weed volume and where turtles are not common. During this time, trawl duration is less than 60 minutes ensuring turtle survival if any are caught.

As part of the implementation process, the mandatory use of grids has been enacted, as part of a condition of license and the use of secondary BRDs will also be a condition of license when it becomes mandatory in 2005. For both devices, the overall specifications will remain fairly generic allowing for innovation so that trialling continues by those that wish to do so.

The observer program was the primary method of collecting the bycatch and effectiveness of grid implementation data for this project. Experimental trials were completed to supplement the observer program and to allow for finer detailed information on individual species when commercial fishing imperatives were not the focus.

The observer program involved research observers accompanying commercial operators on their boats, collecting bycatch, catch and other information during commercial operations. At the commencement of the trials, in Shark Bay, boats towed one net with a grid and one without allowing for comparisons between sides. In Exmouth Gulf as boats tow quad gear, two nets on one side had grids inserted. Due to the commercial nature of the boats activities, only general catch and by catch data could be collected so that data collection fitted in with the commercial operations of the boats. Target species weights, overall bycatch volume, numbers of large animals (identified to the lowest level possible) and specific fish species were recorded. Overall volume of bycatch as ‘prawn baskets’ was used for ease of operation.

Comparisons were made between the catch of the net(s) without a grid compared to the net(s) with a grid. Overall, 265 nights were spent on board boats by observers. A total of 1,180 trawl shots were recorded in the Shark Bay prawn fishery, 141 trawls in the Shark Bay scallop fishery and 246 in the Exmouth Gulf prawn fishery. The lesser number of nights spent on scallop boats in Shark Bay was due to the low number of days this fishery is open and the boats often having a full complement of crew on board (13) so there was no accommodation available for observers until in the latter parts of the season once crew numbers were reduced. For Exmouth Gulf prawn fishery, although the number of trawls observed were less, longer trawl durations occur in this fishery and the overall hours spent in the fishery was approximately half of that spent in Shark Bay prawn fishery even though the number of trawls observed was only 20% of those in Shark Bay.

The key results form the observer program is that there was no variation in the effect of grids on prawn catches between the two main species of prawns caught in these fisheries, the western king prawn *Penaeus latisulcatus* and the brown tiger prawn *Penaeus esculentus.* The use of grids show a marked reduction of soft and broken prawns of between 5% (Exmouth Gulf) and 15% (Shark Bay) providing a better quality product overall. Higher improved product quality may be related to the length of the trawl shots in each fishery as boats in Shark Bay rarely trawl more than 60 minutes whilst in Exmouth trawls vary between one and three hours. Approximately 5-9% of prawns were lost on a trawl pass, however, early in the development process in adjusting the grids, up to 14-17% of prawn loss was observed. As the prawns lost are still available for capture, losses less than 10% are not considered to be significant in its affect on overall catch. However, on occasion in Shark Bay, when high weed volumes are prevalent, most prawns can be lost if the grid is blocked and they exit out of the net via the escape opening. Operational difficulties are also encountered as the crew need to get inside the net to clear a blocked grid and this results in lost fishing time and potential safety issues when stinging fish are entangled in the weed. Under these circumstances, boats often move away from these areas, however, the weed in Shark Bay is drifting and unattached and hence its occurrence and problem for boats is variable. In low to moderate weed conditions, grids reduced the volume of weed by 79-96%. No one grid substantially outperformed another under moderate weed conditions.

The bycatch (smaller fish and invertebrate species) to catch ratio for prawns in Shark Bay was seen to be around 4-8:1 and in Exmouth Gulf 2-5:1. Bycatch was reduced by 0-9% overall by grids alone and the variation may be related to the size of some of the bycatch species that may be deflected out of the net rather than passing through the bar spacings.

In the scallop fishery, grids did not produce a significant loss of scallops overall. The problem with weed that has been encountered by prawn boats will also be an issue for scallop boats in years when weed is found on the scallop trawl grounds, however during the duration of the observer program this did not occur. Scallop boats tow nets with 100 mm mesh size and therefore bycatch volume is much reduced compared to prawn trawling (50-60mm mesh). The bycatch to catch ratio in the scallop

fishery in Shark Bay was 0.5:1. Secondary bycatch reduction devices are not considered necessary as the net already acts as a fish exclusion device.

Grids reduced the number of turtles by 95-100% in all fisheries and sharks and rays by 87% in Shark Bay. In Exmouth Gulf, which has a higher number of sharks and rays that are less than 1.5m in length, the reduction in numbers was not significant, as they tend to pass through the grid into the cod-end. These are generally returned to the sea alive. Sea snakes were reduced in the Shark Bay prawn fishery by 42%, which may have been related to the movement of weed and snakes out of the escape opening. For the scallop and Exmouth Gulf prawn fishery, that do not have the problems associated with weed, there was no difference in sea snake numbers in nets with or without grids as the sea snakes generally pass through the grid spacings and into the cod-end. The amount of sponges retained in nets was reduced by 79-100% with grids although deleterious impacts on sponges may still occur as they are pushed over or broken off.

5.0 CHANGES FROM THE ORIGINAL PROPOSAL

The project was to finish at the end of June 2002 but was extended until December 2003 due to high weed volume in Shark Bay causing initial delays in the development of the final grid design.

6.0 BENEFITS

The WA trawl industry, the environment and the general community has benefited from the project overall. There are economic, environmental and social benefits to the introduction of BRDs. Economic benefits include better quality product and higher value of product. In the Exmouth Gulf fishery, prawn catches have improved slightly with the use of grids. Also, the exclusion of large and some threatened species and the reduction in level of overall bycatch volumes has been one of the factors (in addition to spatial and temporal management regimes and catch rate threshold management of vulnerable target species) resulting in the export accreditation of the Shark Bay prawn and scallop and Exmouth Gulf prawn fisheries by Department of Environment and Heritage (previously Environment Australia).

Environmental benefits are the reduced retention of unwanted animals. Large animals are excluded from trawl nets and overall bycatch reduction is between 20 and 50%. Increased survival is expected for animals that are excluded and not brought to the surface in nets. Social benefits include improved work conditions, with the low retention of large animals resulting in less lifting and hazardous working conditions as well as faster sorting times. The general public benefits from the knowledge that overall trawling impacts are reduced and increased survival of bycatch species is achieved.

7.0 FURTHER DEVELOPMENTS

Further refinement of secondary BRDs and improved use of grids will occur with the innovation and keen interest of some members of industry. The innovations developed will flow on to other fishers and the smaller trawl fisheries within WA and interstate, over time. A low-level observer presence will be retained in Shark Bay and Exmouth Gulf to monitor BRD effectiveness over the next few years and to document further innovations.

8.0 PLANNED OUTCOMES

1. & 4. Grids have been successfully implemented into the Shark Bay prawn and scallop and the Exmouth Gulf prawn fisheries as well as the smaller prawn and scallop fisheries within WA, namely Onslow, Nickol Bay, Broome and Kimberley prawn fisheries and the Abrolhos Islands scallop fishery. Each fishery is using grids most suitable for their fishing operations but all fit within generic specifications as part of a condition on their fishery licences.

In Shark Bay however, due to a re-occurring presence of moderate to large volumes of drift weed (primarily *Amphibolis antractica* and *Posidonia australis*) grids are exempt during peak catching periods within specified areas. During this time boats restrict their trawl duration to ≤ 60 minutes to ensure turtle survival if any are caught.

Secondary BRDs have been voluntarily trialled since the commencement of the 2002 fishing seasons and were compulsory in one side of the gear in Exmouth and Shark Bay prawn fishery during 2004. They will be mandatory in all gear in these two fisheries and compulsory in the other prawn fisheries for one side of the trawl gear in 2005.

2. An assessment of the impacts of grid introduction on prawn catches indicate that although 5-9% of prawns may be lost during one trawl pass (and much more if the grid is fully blocked by weed), these prawns are still available for capture and the overall reduction in prawn catch due to grids under low and moderate weed levels in negligible. However, under high weed conditions prawn loss is substantial and effectively working the gear with grids becomes impractical. This has resulted in some modification of fishing activities and at times can reduce the effective trawl areas of the fleet, which may result in more concentration of fishing effort in the remaining trawl areas. Spatial and temporal modification of trawl patterns will need to be monitored over the next few years to deduce the consequences of any changes to sustainability of prawn stocks.

For the scallop fishery, limited experimental trials indicated no significant difference between scallop catch with nets with grids and those without. For scallop caught by prawn boats, scallop catches were reduced by 9% in the side towing a grid similar to the losses seen in prawn catch.

Experimental trials of secondary bycatch reduction devices indicated a reduction of overall bycatch by 49% and up to 75% reduction of some individual species whilst preliminary trials on commercial boats indicate around 20-30% reduction of overall bycatch with up to 90% reduction of an individual fish species from trawls. Further trialling of secondary BRDs is continuing with full implementation into Shark Bay and Exmouth prawn fisheries in 2005.

3. In general, fishers have accepted that grids are beneficial under most circumstances. They recognize improved work conditions with less sorting time, reduced hazards in handling large animals and improved product quality. However, some new hazards have also been identified in the form of weed blockage and the need for crew members to go inside nets to clear the blockage encountering poisonous fish hidden in the weed as well as rocks getting stuck on grids and being dislodged whilst the gear is being hoisted on board, falling on the deck/sorting table. This has required some modifications to operating practices on boats to reduce potential for accidents.

5. A communication strategy was developed in consultation with the trawl industry and the outcomes of the research and industry innovation has been disseminated to the broader fishing community and the public.

9.0 CONCLUSION

The BRD implementation program in WA has been a progressive and step-wise process that has involved obtaining an overall acceptance in the main prawn and scallop trawl fisheries before introducing any legislation to the smaller trawl fisheries. Fishers were given the opportunity to test gear on one side before having to use them on both sides so that they could have confidence that the gear was working appropriately without significant loss of product. The initial grid types were not strong enough for shark encounters and subsequent grid models were made more robust. In general two shapes of grids are being used, oval or rectangular, with or without an inclined accelerator at the top (CSWA, RSNA Figure 3.2, 3.4, Figure 3.5). Some grids are still being used with a horizontal gap in the bottom (known locally as a flounder gap, RFNN Figure 3.6 and RFWN Figure 3.7) to aid in the movement of weed into the codend, however, these are being phased out. The performance of all the grids overall are fairly similar and loss of prawn species is between 5 and 9% on average in Shark Bay and with no appreciable loss of prawns in recent times in Exmouth Gulf. All grid types resulted in a 5-15% reduction of soft and broken prawns, which is beneficial to industry with improved quality (and value) of prawns caught.

Under these circumstances it is considered that in general, fishing efficiency is only slightly reduced (up to 5%) overall as prawns lost in one trawl remain on the trawl grounds and should be available for capture during subsequent trawling activities. Thus, reducing the net loss of prawn catches to insignificant levels.

Grids were shown to reduce the number of turtles captured by 95-100% in the Shark Bay and Exmouth Gulf fisheries, although the numbers caught was always low. In Shark Bay, shark and ray numbers were reduced by 87-88%, however in Exmouth Gulf the number of sharks passing through grids was higher with only a minor reduction in overall catches. This is due to the generally smaller size of the sharks and rays in Exmouth Gulf with many of them passing through the grid bar-spacings.

In Shark Bay however, there are still periods of time and areas when grids do not allow fishing as grids become blocked with drift weed (*Posidonia australis* and/or *Amphibolis antarctica*) and create health and safety issues for the crew. These blockages can result in total loss of product as nothing can pass through the grid. It also causes a working hazard to crew who need to physically get in the net to remove the weed. To overcome this issue, which often occurs in the peak catching period and main fishing area for king prawns (king prawns constitute ~70% of total prawn catch in the fishery), grid exemptions are in place for two fishing periods with a total fishing time around 40 nights per year. The areas for this exemption are known for their high weed concentration and where turtles are uncommon.

Once grid styles were developed, secondary devices were trialed on a voluntary basis. The square mesh panel, radial escape devices and fish eyes were trialed. The secondary devices were again introduced to one side again to allow fishers to trial position and types against their standard gear in order to be able to assess their efficiency. No significant reduction in prawn catch was observed with the secondary BRDs that have been trialed.

Several individual skippers have put in considerable time and effort to improve secondary BRD designs. However, this process has resulted in a slower overall uptake but will ensure that the gear is effective in its objectives. In 2004 it will be compulsory for all boats to trial secondary BRDs on one side with full implementation in 2005. Information gathered during the last three years has been provided for information to all skippers and license holders to assist with this final implementation process.

In addition to the current BRD implementation program, which will certainly reduce trawl impacts on bycatch, other additional measures need to be considered to reduce trawl impacts. Not all bycatch can be eliminated from trawls using grids and secondary devices because of the physical and behavioural characteristics of certain species. Other mitigation measures which are employed in the WA trawl fisheries are spatial and seasonal closures and permanent closures of sensitive areas or areas with known occurrences of vulnerable species. Secondly the uptake and the use of hoppers (in-water sorting devices) will enhance survival of some bycatch species which are still captured (Dell et al. 2003, Carrick (pers. comm.)). In Shark Bay, one scallop and prawn boat and 5 boats in Exmouth Gulf are currently using hoppers with plans for two more boats to have hoppers installed in 2004.

10.0 ACKNOWLEDGEMENTS

We would like to thank the Shark Bay prawn and scallop and Exmouth Gulf prawn fishers and licence holders for their collaboration, innovation and interest in BRD trials, in particular Tony Pittorini and skippers; Peter Rooney, Mark Scriven and Dean Fletcher, Norm Stevens (NW Seafoods) skipper Kevin Dodge and, M G Kailis Group and skippers, Tony Tomlinson and Garth Brookes and to Alan Butler and crew on the FV Conway (NW Seafoods) for assisting with scallop experimental trials.

Numerous Department of Fisheries personnel assisted with the project; Errol Sporer facilitated and coordinated the observer program, observers were Scott Bickford, Andrew Prindiville, Dave Harris, Phil Unsworth, Josh Brown, Gareth Parry and Samantha Richards (EG trawl industry). Nick Caputi, Jim Penn and Peter Stephenson provided valuable comments on drafts of this report.

11.0 REFERENCES

Alverson, D.L., Freeberg, M.H., Pope, J.G. and Murawski, S.A. (1994) A global assessment of fisheries bycatch and discards. *FAO Fisheries Technical paper* No. **339**, 233 pp.

Andrew, N.L. and Pepperell, J.G. (1992) The bycatch of shrimp trawl fisheries. *Oceanography and Marine Biology an Annual Review* **30,** 527-565.

Bensançon, H.C. (1973) Review of the development of the selective shrimp trawl in The Netherlands. In; Report of the expert consultation on selective shrimp trawls. Ijmuiden, The Netherlands, 12-14 June. *FAO Fisheries Research Report* **13**:21-25.

Boddeke, R. (1973) Developments in the Dutch shrimp (Crangon crangon) fisheries. In; Report of the expert consultation on selective shrimp trawls. Ijmuiden, The Netherlands, 12-14 June. *FAO Fisheries Research Report* **13**:16-20.

Broadhurst, MK. (2000) Modifications to reduce bycatch in prawn trawls: A review and framework for development. *Reviews in Fish Biology and Fisheries* **10**:27-60.

Broadhurst and Kennelly, (1996a) Rigid and flexible separator-panels in trawls that reduce the by-catch of small fish in the Clarence River prawn-trawl fishery, Australia. *Marine Freshwater Research* **47**: 991-998.

Broadhurst and Kennelly, (1996b) Effects of the circumference of codends and a new design of square-mesh panel in reducing unwanted by-catch in the New South Wales oceanic prawn-trawl fishery, Australia. *Fisheries Research* **27**: 203-214.

Broadhurst, M.K., Kangas, M.I., Damiano, C., Bickford, S.A. and Kennelly, S.J. (2002) Using composite square-mesh panels and the Nordmøre-grid to reduce bycatch in the Shark Bay prawn-trawl fishery, Western Australia. *Fisheries Research,* **58**: 349-365.

Broadhurst, M.K., Kennelly, S.J., Watson, J. and Workman, I. (1997a) Evaluations of the Nordmøre-grid and secondary by-catch reducing devices (BRDs) in the Hunter River prawn-trawl fishery, Australia. *Fisheries Bulletin* **95**: 210-219.

Broadhurst, M.K., Kennelly, S.J. and O'Doherty, G. (1997b) Specifications for the construction and installation of two by-catch reducing devices (BRDs) in New South Wales prawn-trawl fisheries. *Marine and Freshwater Research* **48**: 485-489.

Broadhurst, M.K., Larsen, R.B., Kennelly, S.J. and McShane, P. (1999a) Composite square-mesh codends: size-selectivity of prawn, reduction of by-catch and rapid industry adoption in Gulf St Vincent, South Australia. *Fisheries Bulletin* **97**: 434-448.

Broadhurst, M.K., Kennelly, S.J. and Eayrs, S. (1999b) Flow-related effects in prawn-trawl codends: potential for increasing the escape of unwanted fish through square-mesh panels. *Fisheries Bulletin* **97**: 1-8.

Brunenmeister, S.L. (1984) Standardization of fishing effort and production models for brown, white and pink shrimp stocks fished in US waters of the Gulf of Mexico. In: Penaeid Shrimps - their biology and management. Eds. J.A Gulland and B.J. Rothschild, 187-210.

Bunting, J. (2002) Draft Bycatch Action Plan for the Shark Bay Prawn Managed Fishery. *Fisheries Management Paper* No. **147,** 82pp. Department of Fisheries, Western Australia.

De Groot, S.J. (1984) The impact of bottom trawling on benthic fauna of the North Sea. *Ocean Management*, **9**:177-190.

Dell, Q., Gribble, N., Foster, S. and Ballam, D. (2003) Evaluation of "Hoppers" for reduction of bycatch mortality in the Queensland East Coast Prawn Trawl Fishery" FRDC 2001/098 p 68.

Diamond, S.L., Cowell, L.G. and Crowder, L.B. (2000) Population effects of shrimp trawl bycatch on Atlantic croaker. *Canadian Journal of Fisheries and Aquatic Sciences* **57**:2010-2021.

Gunter, G. (1936) Studies of the destruction of marine fish by shrimp trawlers in Louisiana. Louisiana Department of Conservation, New Orleans.

High W.L., Ellis, I.E. and Lusz L.D. (1969) A progress report on the development of a shrimp trawl to separate shrimp from fish and bottom-dwelling organisms. *Commercial Fisheries Review.* **31**: 20-32.

Hutchings, P. (1990) Review of the effects of trawling on macrobenthic epifaunal communities. *Australian Journal of Marine and Freshwater Research,* **41:** 53-64.

Isaksen, B., Valdemarsen, J.W., Larsen, R.B., Karlsen, L. (1992) Reduction of fish by-catch in shrimp trawl using a rigid separator grid in the aft belly. *Fisheries Research* **13**: 335-352.

Jones, J.B. (1992) Environmental impact of trawling on the seabed: a review. *New Zealand Journal of Marine and Freshwater Research,* **26**, 59-67.

Kennelly, S.J. (1995) The issue of bycatch in Australia's demersal trawl fisheries. *Reviews in Fish Biology and Fisheries,* **5**, 213-234.

McGilvray, J.G., Mounsey, R.P., MacCartie, J., (1998) The AusTED II, an improved trawl efficiency device. 1. Design theories.

Moran, M. and Kangas M., (2003) The effects of the trawl fishery on the stock of pink snapper, *Pagrus auratus*, in Denham Sound, Shark Bay. *Fisheries Research Bulletin* **31**:52 pp.

Mounsey, R.P., Baulch, G.A., Buckworth, R.C., (1995) Development of a trawl efficiency device for Australian prawn trawl fisheries. I. The AusTED design. *Fisheries Research* **22**: 99-105.

Olsen, S. (1999) Recent developments in shrimp sorting trawls. First Edition. Institute of Fishery Technology Research. Bergen, Norway.

Robins-Troeger, J.B., Buckworth, R.C. and Dredge, M.C.L. (1995) Development of a trawl efficiency device (TED) for Australian prawn fisheries. II. Field evaluations of the AusTED. *Fisheries Research* **22**:107-117.

Robins, J.B. and McGilvray, J.G. (1999) The AusTED II, an improved trawl efficiency device 2. Commercial performance. *Fisheries Research* **40**:29-41.

Saila, S.B. (1983) Importance and assessment of discards in commercial fisheries. *FAO Fisheries Circular* No. 765, 62 pp.

Standing Committee on Fisheries and Aquaculture (SCFA) 1998 National Policy on Fisheries Bycatch.

Thorsteinsson, G. (1992) The use of square mesh codend in Icelandic shrimp (*Pandalus borealis*) fishery. *Fisheries Research* **13**: 255-266.

Watson, J.W. and Taylor, C.W. (1986) General contribution on research on selective shrimp trawl designs for penaeid shrimps in the United States. Presented at FAO Expert Consultation on Selective Shrimp Trawl Development. Maztlan, Mexico, 24-28 November 1986. Mimeo, available from FAO: http://ww/fao.org/fi.

Watson, J.W. and Taylor, C.W. (1996) Technical specifications and minimum requirements for the extended funnel, expanded mesh and fishery BRDs. NOAA, MS Lab P.O. Drawer 1207, Pascagoula. MS 39567.

12.0 APPENDICES

APPENDIX 1 – Intellectual Property

N/A

APPENDIX 2 – Staff

Principal Investigator:	Mervi Kangas
Co-Investigators:	Steve Kennelly Matt Broadhurt
Statistician:	Adrian Thomson
Senior Technical Officer:	Errol Sporer
Observers:	Phil Unsworth Scott Bickford Andrew Prindiville Josh Brown Gareth Parry
Casual observer:	Sam Richards

APPENDIX 3 – Data Sheets

a) Shark Bay prawn BRD observer log sheet

	DATE	FISHERY	OBSERVER

BRD Type		BRD Side P or S		BRD : AL / STEEL	

Suffix **B** for Baskets.

Shot No	Side	Catch Vol	Weed Vol	Sponges	Sea Snakes	Large Animals	Pink Snapper			Prawns					
										King	King S&B	Tiger	Tiger S&B	Endeav	Corals
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														

PTO FOR POSITION/DURATION/COMMENTS/LENGTH FREQUENCY

b) Scallop fishery observer log sheet

VESSEL	DATE	FISHERY	OBSERVER

BRD Type		BRD Side P or S		BRD : AL / STEEL	

Suffix **B** for Baskets.

Shot No	Side	Catch Vol	Weed Vol	Sponges	Sea Snakes	Large Animals	Pink Snapper	Blue Crabs	Scallops (baskets)						
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														
	P														
	S														

PTO FOR POSITION/DURATION/COMMENTS/LENGTH FREQUENCY

c) Shot details for either prawn or scallop fishery

SHOT No	Duration minutes	Start Latitude	Start Longitude	**Comments**

Length Frequency: **Species:** ………………………………………………… **Units:** …………

← - - - - - - - - - - - - - - L e n g t h - - - - - - - - - - - - - - →

Shot No																			

d) Exmouth gulf BRD observer data sheet

Vessel		Date		Skipper		Observer

Grid Type		Grid side P or S		Other BRD	Port / Starboard	

Shot No	Start Lat	Start Long	Shot Duration	Side	Bycatch (baskets)	Large sharks	Large rays	Sea snakes	Sponges	Turtles	King	Kings S/B (kg)	Tiger	Tigers S/B (kg)	Endeav (kg)	Endeav S/B (kg)
				P												
				S												
Co mm																
				P												
				S												
Co mm																
				P												
				S												
Co mm																
				P												
				S												

COMMENTS:____

e) Commercial fisher BRD log sheet

Date Date of the Day Trawling Commences	Vessel Name of Vessel	Responsibility of the Skipper Provide information on the weight of: By product- baskets, Prawns - cartons or kg's caught in the control net and indicate the catch difference ie 25%, 50%, 75% in the BRD net

	PORT NET STANDARD NET OR BRD NET (PLEASE CIRCLE)					STARBOARD NET STANDARD NET OR BRD NET (PLEASE CIRCLE)				
	BYPRODUCT			PRAWNS		BYPRODUCT			PRAWNS	
SHOT NO.	FISH	TURTLES	WEED	KINGS	TIGERS	FISH	TURTLES	WEED	KINGS	TIGERS
01										
02										
04										
05										
06										
07										
08										
09										
10										
11										
12										
13										
14										
15										

COMMENTS:

APPENDIX 4 – Publications

Broadhurst, M.K., Kangas, M.I., Damiano, C., Bickford, S.A. and Kennelly, S.J. (2002) Using composite square-mesh panels and the Nordmøre-grid to reduce bycatch in the Shark Bay prawn-trawl fishery, Western Australia. *Fisheries Research,* **58**: 349-365.

Kangas, M.I., Joll, L. and Shaw, J. (in prep.) Progressive Bycatch Reduction Device Implementation for Western Australian Demersal Trawl Fisheries. (to be submitted to *Marine Policy*).

Presentation at Conferences and Workshops

Joll, L. and Kangas M.I. 'Development & implementation of bycatch reduction gear in Western Australian trawl fisheries'. Presentation at a BRD Workshop in Brisbane (QDPI and QFS) in May 2002.

Kangas M.I. and Thomson, A. BRD Implementation in Western Australian trawl fisheries. 2001 ASFB Conference, Bunbury, WA, September 2001.