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Effects of Trawl Design on Bycatch and Benthos in Prawn and Finfish Fisheries

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Bibliography
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1. Bycatches (Fisheries) - Queensland.
2. Trawls and trawling - Queensland.
3 Fishery management - Queensland.
4. Benthos - Queensland.
5. Shrimp fisheries - Queensland - Management.
   I. Blaber, S.J.M.
   II. CSIRO Marine Research.

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1. NON-TECHNICAL SUMMARY

Trawl fisheries are among Australia's most valuable fisheries (Kailola *et al.* 1993). However, concern is increasing about the impacts of trawling on other marine life, such as turtles and the multitude of small fish caught as a bycatch in the Northern Prawn Fishery. On Australia's North West Shelf it was found that fish trawling also decreases the number of animals and plants on the sea bed. This, in turn, changes the make-up of the fish community. Concerns about impacts such as these has made the 'effects of fishing' a high priority area for research.

The main aims of this project were to:

(i) develop and test fish-trawl gear that minimises the impact on the sea bed while maintaining catches of red snapper in Australia's Northern Fish-trawl Fishery;

(ii) develop and test Bycatch Reduction Devices suitable for Australia's Northern Prawn Fishery;

(iii) describe the damage to, and survival of, animals that escape through Bycatch Reduction Devices;

(iv) describe the behaviour of fish and prawns in trawl nets to help develop gear that minimises catches of unwanted bycatch species;

(v) develop and maintain a literature data base, accessible to other Australian research organisations on research into environmentally friendly trawl gear;

(vi) promote the results of the project to the fishing industry.

The first objective of the project was to develop a 'sea-bed-friendly' fish trawl. It followed and complemented earlier studies by the Northern Territory Department of Primary Industry and Fisheries (NTDPIF) on the "Julie Anne" environmentally friendly trawl. A standard demersal wing trawl (McKenna wing trawl) was rigged to test three different ways of fishing: (i) with the footrope on the sea bed (demersal fish trawling), (ii) with the footrope 40–50 cm above the sea bed (semi-pelagic fish trawling), and (iii) with the footrope 80–90 cm above the sea bed (semi-pelagic fish trawling). These heights were achieved by attaching a combination of headline floats and steel weights to the footrope, which makes this style of rig simple and easy to use.

Weights of red snapper caught in the three trawl rigs were not statistically different, but the trawl rigged to operate 40–50 cm above the sea bed caught slightly more than the other two. The two semi-pelagic trawls caught substantially fewer stingrays, unwanted small fish and animals that live on the sea bed, as well as fewer squid and Moreton Bay bugs. Furthermore, they did less damage to the sea bed. The semi-pelagic trawl rigs are easy to sue, cost the same as the demersal rig, fish the target species equally well, but do less damage to the marine life.

The second objective was to assess the suitability of Bycatch Reduction Devices (BRDs) for use in Australia's Northern Prawn Fishery (NPF). The research complemented a similar study in northern NSW by the NSW Fisheries Research Institute and another by the Queensland Department of Primary Industry and Fisheries (QDPIF) and the NTDPIF, who developed a Bycatch Reduction Device known as the "AusTED".

A total of 17 different BRDs or combinations of BRDs were tested during three cruises in the Gulf of Carpentaria. We made the choices by testing devices already being used around the world that seemed to have the most potential for use in the NPF, interviewing fishers in the NPF to find out what their most important bycatch issues were, and gathering information from flume-tank observations and research cruises.

The first cruise assessed two sizes of square-mesh codend (38 mm and 45 mm) in standard 14 fathom prawn trawls by comparing catches with a standard diamond-mesh codend. Codend covers were used to catch the animals that escaped from the codends. The second cruise assessed eight different BRDs in 30 min trawls . The most suitable devices from this cruise were then assessed during a third cruise. Fishers in the NPF usually trawl for between 2 and 5 h, so on the third cruise, the eight best BRDs were tested on two-hour trawls .

Compared with the standard diamond-mesh codend, one of the square-mesh codends (45 mm) reduced the amount of unwanted bycatch by 28.4 percent and lost only 3.1 percent of commercial sized-prawns. It also had the advantage of allowing between 58 and 98 percent of small tiger prawns ('over 30s') to escape and enhance future stocks. The 38 mm square-mesh codend was less successful : it excluded 4 percent of unwanted fish bycatch and lost 0.4 percent of prawns.

Cruises two and three tested two types of BRDs: inclined grids used mainly to exclude large animals in the NPF, and other devices used mainly to exclude fish. Improvements were made to most of the devices between cruises two and three. The results can be summarised as follows. All three inclined grids (Super Shooter, Nordmøre grid and AusTED) were extremely effective at excluding large animals such as sea turtles, large sharks and large rays. They were also effective at excluding some of the unwanted small fish catch, especially when used in combination with other BRDs such as a fisheye or square-mesh window. This fish exclusion ranged between 0 and 39 percent, depending on the device.

The ability of the inclined grids to catch prawns varied. The Super Shooter had the best prawn retention rate, losing only between 2 percent and 12 percent of prawns. The higher rates of prawn loss (>2 percent) occurred either in the early trials or when the Super Shooter was combined with a fisheye in very poor weather. The Super Shooter also performs well in areas where the other inclined grids tend to clog with sponges or other large objects. The Nordmøre grid lost substantial numbers of prawns, but modifications could greatly improve its performance. The AusTED lost 22 percent of prawns but gave much better results in other trials during a QDPIF and NTDPIF project.

The performances of the specialist fish excluders (fisheye, square-mesh windows, radial escape section) were strongly affected by the weather and haulback delay: much higher levels of fish and prawn loss were measured when the weather exceeded Force 7 or 8. A delay in haulback on the second cruise also seemed to cause extra loss of fish and prawns for most fish excluder devices. The fisheye lost only up to 11 percent of fish, but its prawn catches ranged between a 30 percent loss (in bad weather) and a 22 percent gain. The positioning of this device seems to be critical; these results are likely to be improved with further trials. The radial escape section excluded only up to 8 percent of fish, and prawn catches ranged between a 43 percent loss (bad weather) and a 5 percent gain. Video evidence suggested that the version used in this trial was effective at excluding strong-swimming fish, but not small fish with poor swimming ability. Square-mesh windows were used alone, with fish-stimulator devices to encourage escape, or in conjunction with the Nordmøre grid. The four versions of the square-mesh windows used on the second cruise excluded between 3 percent and 7 percent of fish and lost between 8 percent and 14 percent of prawns in good weather, but up to 49 percent in very poor weather. Square-mesh windows also show promise as sea-snake excluders.

These results are from a set of trials that gave only two or three opportunities to improve the performance of the BRDs over the course of the project. Future trials on commercial boats will allow improvements to be made much faster and under commercial operating conditions. Although we have already described some very promising results for exclusion of large marine animals (Super Shooter) and fish (square-mesh codend) without substantial prawn loss, the results of these and other devices can be improved.

The third objective of the research project was to describe the damage to fish escaping from BRDs and to assess whether they survive after they escape. These two studies were made with square-mesh codends. Damage to fish was assessed by collecting fish that escaped from a 38 mm or 45 mm square-mesh codend into a fine-mesh codend cover. A large, water-filled scoop was used to bring the fish onto the boat with minimal additional damage. The fish were anaesthetised with MS222 and then examined for damage to their head, fins and body. Most fish escaping from 45 mm diamond or square-mesh codends suffered little damage, but those escaping from 38 mm square-mesh codends were more severely damaged.

The survival experiments compared the rate of survival of escapees from 45 mm diamond mesh with 45 mm square-mesh codends. Codend escapees were retained in fine-mesh codend covers and quickly transferred into either sea cages or swimming pools. Here their survival was monitored for eight to ten days. For most of the species tested, survival rates were higher in the pool than the sea cages and more than 80 percent of fish survived.

The fourth objective of the research project was to describe the way the fish and prawns enter trawls. We used a multi-level beam trawl to find out whether fishes and prawns enter a prawn trawl from the top, from the middle, or from the lower area of the trawl mouth. This information could suggest modifications to the trawl mouth to substantially reduce bycatch without loss of prawns. Although follow-up experiments are needed, the research has shown that the highest percentage of fish (40 percent) and prawns (81 percent) entered the trawl no higher than 600 mm above the sea bed. The top compartment of the trawl (1200 mm to 1800 mm above the sea bed) caught the second highest percentage of fish (39 percent) and prawns (14 percent). A lead-ahead panel of netting stopped animals escaping over the top of the trawl mouth; these animals were forced into the top section of our trawl. The middle compartment of the trawl (600 mm to 1200 mm above the sea bed) caught the lowest percentage of fish (20 percent) and prawns (5 percent).

The fifth objective of the project was to develop an ongoing literature data base on environmentally friendly trawl-gear research that can be accessed by other Australian research organisations. This database already has over 300 records, including titles, authors, keywords and abstracts. Entry of new records is continuing at the CSIRO, Australian Maritime College (AMC) and NTDPIF.

The final objective of the project was to promote the results to the fishing industry. In some ways, this is the most important part of the project if we want to encourage voluntary adoption of the most suitable BRDs. To this end, we reported the results of the project in fishing industry magazines, at fishing industry meetings and in newsletters to industry participants. Our results were also published in scientific journals and, oral and poster presentations at scientific conferences, and were reported in newspaper and television articles, community magazines and through radio interviews.

Two new FRDC-funded projects have arisen from this work. One of these investigates the composition and sustainability of bycatch populations of the NPF and Queensland East Coast Fishery. The other will promote and develop BRDs in these fisheries through workshops and voluntary sea trialing. Additional projects that could encourage BRD adoption and improve BRD performance include (i) a study of the economic values of using BRDs; (ii) demonstration and training in fitting and using BRDs, (iii) investigation of methods for manufacturing BRDs in Australia, and (iv) further detailed behavioural studies of prawn and fish bycatch in trawl nets.

BACKGROUND

Trawl fisheries are among Australia's most valuable fisheries (Kailola *et al.* 1993). However, recent studies have highlighted the impacts that trawling can have on non-target species such as the benthic and bycatch populations. Although in most cases the consequences of these impacts are unknown, under the precautionary principle, it is widely recognised that they should be minimised to ensure the long-term maintenance of biodiversity in our marine ecosystems.

Some impacts of trawling in northern Australia's multi-species demersal fish-trawl fishery were studied by Sainsbury (1988). Like others in tropical waters, this fishery has a large bycatch component (mainly fish), which is usually discarded at sea. Demersal fish trawling on the Australian North West Shelf in the 1960s and 1970s also significantly reduced the abundances of sponges and associated benthos such as alcyonarians and gorgonians. This was thought to have led to a reduction in catches of the main target species, *Lethrinus* and *Lutjanus* (Sainsbury, 1988). New regulations for the Northern Fish-trawl Fishery, introduced in 1991, allow use of only semi-pelagic fish trawls. These are trawls rigged to operate with sweeps, bridles and net clear of the sea bed, though with the otterboards on the sea bed. This project further developed trawl design to provide user-friendly trawls for this and similar fisheries.

Australia's northern prawn trawl fisheries identified impacts on bycatch as a priority area for research because they catch very large amounts of bycatch: typically, less than 20 percent of the catch consists of prawns. Nearly all of the rest — mainly fish and crustaceans — is discarded. Pender and Willing (1989) estimated the bycatch in the NPF at around 70,000 t. Most of these animals are dead when discarded (Wassenberg and Hill 1989).

Concerns about the impacts of trawling on non-target communities and the environment are growing and it is appropriate that trawl-fishing industries support research into trawl designs that minimise these impacts. Inaction in this area would probably lead to continued and mounting criticism, followed by increasing pressure from non-governmental and community groups to protect the ecosystems in question.

NEED

The effect of trawling on non-target species and the marine environment is a subject of growing world-wide concern. It can threaten the viability or profitability of many fisheries (Pauly 1979, Boonyubol and Pramokchutima 1984, Sainsbury 1987). It is particularly relevant to trawl fisheries in Australia, where issues of long-term ecological sustainability, the maintenance of biodiversity and community structure, and the protection of critical fisheries habitats must be incorporated in future management planning. If many of Australia's tropical fisheries are to remain viable it is vital that they address the issue of bycatch. In the northern hemisphere, there have been recent advances in the technology to reduce bycatch and damage to both non-target species and the environment. However, differences between single-species, cold-water fisheries and specialised tropical penaeid trawl fisheries or multispecies fin-fish trawling have made direct technology transfer impossible.

There have been some similar advances in gear technology in Australian fisheries. Research on development and testing of an inclined grid to reduce bycatch in prawn trawls, known as the AusTED (to exclude turtles and other large bycatch), was being undertaken by QDPI / NT. Fisheries. This and other Bycatch Reduction Devices were considered. We also considered other issues, such as the survival of bycatch, which are equally important to maintaining long-term biodiversity, and hence, the fishery. There is evidence, for example, that belly funnels in combination with square-mesh are more effective than grids in promoting escape of the smaller size classes of prawns (Valdemarsen 1988). The current proposed study complemented the QDPI / NT. Fisheries "AusTED" study by comparing the performance of Bycatch Reduction Devices and quantifying the survival rate of animals that escape through these devices. By providing managers with information on bycatch reduction and survival from Bycatch Reduction Devices the QDPI / NT study and ours will enable technology transfer that best suits industry needs.

Another development in gear technology is new NT Fisheries' environmentally friendly fish trawl (the "Julie Anne trawl"). Such trawls will enable the Northern Fish-trawl Fishery to be developed without a parallel increase in damage to benthic habitats. The present study will advance the known technology of environmentally friendly fish trawls for northern Australian waters by testing this and other trawls.

Descriptions of the behaviour of each target and the main non-target species in relation to various trawl rigs were essential to our understanding of how standard and modified trawl rigs operate and can be modified to reduce bycatch. The video footage generated from these studies will also be useful for assisting technology transfer within the industry.

The sophisticated vessels and underwater monitoring techniques and equipment, advanced biological knowledge and gear technology skills of the CSIRO Division of Fisheries, Australian Maritime College and NT Fisheries ensured that the necessary expertise was available to the project.

OBJECTIVES

Objective 1. To develop and test trawl gear that minimises impact on the sea bed while maintaining catches of target species in Australia's Northern Fish-trawl Fishery.

Objective 2. To develop and test Bycatch Reduction Devices suitable for Australia's Northern Prawn Trawl fishery.

Objective 3. To investigate the damage to and survival of animals that escape using Bycatch Reduction Devices.

Objective 4. To describe the reaction of fish and prawns to trawls in order to enhance our ability to develop trawls that minimise catches of unwanted species.

Objective 5. To develop an ongoing literature data base on environmentally friendly trawl gear research that can be accessed by other Australian research organisations.

Objective 6. To promote the results of the project to the fishing industry.

OBJECTIVE 1

- **To develop and test trawl gear that minimises impact on the sea bed while maintaining catches of target species in Australia's Northern Fish-trawl Fishery**

INTRODUCTION

Northern Australian waters on the continental shelf between 114° and 140° E support a multi-species demersal fish-trawl fishery (for descriptions, see Edwards 1983; Sainsbury 1987; Blaber *et al.* 1994) that, like others in Australian tropical waters, has a large bycatch component (mainly fish), which is usually discarded at sea. Demersal fish trawling on the Australian North West Shelf in the 1960s and 1970s significantly reduced the abundances of sponges and associated benthos such as alcyonarians and gorgonians. This was thought to have led to a reduction in catches of the main target species, *Lethrinus* and *Lutjanus* (Sainsbury, 1988). New regulations for the Northern Fish-trawl Fishery, introduced in 1991, allow use of only semi-pelagic fish trawls - trawls rigged to operate with sweeps, bridles and net clear of the sea bed, though with the otterboards on the sea bed.

An earlier version of this style of trawl caught adequate catches of commercially important fish, had less impact on the substrate and retained fewer unwanted species (Ramm *et al.*, 1993). The resultant cleaner catches of the commercially important fish resulted in a higher quality product. The trawl, known as the 'Julie Anne trawl', is a fork-rigged, semi-pelagic, four-seam box trawl that uses fly-wires (upper bridles) and floats to lift the headline. This, combined with the absence of a groundrope, raises the whole trawl off the sea bed (Ramm *et al.* 1993)

Although the initial trials of the "Julie Anne" trawl gave promising results, in subsequent tests it was found that the trawl's geometry was sensitive to changes in towing conditions, including towing speed, water depth and length of warp. The trawl required constant monitoring and adjustment and took longer to deploy and retrieve.

An alternative semi-pelagic trawl was designed. We fished this demersal wing trawl (the "McKenna wing trawl") on the sea bed and semi-pelagically, with the groundrope removed and footrope set at one of two heights above the sea bed. The results are further evidence that semi-pelagic trawls can be environmentally friendly and that they may be viable alternatives to standard demersal fish trawls.

METHODS

Trawl design

Two identical wing trawls were used in the trials: each had a headline length of 25.6 m, a fishing circle of 48.8 m, and 50 mm stretch-mesh polyethylene netting throughout the codend (Figure 1). Commercial trawlers use 110 mm mesh codends, but the 50 mm mesh size enabled us to study a greater range of species. Trawl 1 was rigged for standard demersal operation and was used as a control to test the effect of footrope height on commercial fish catches. Its groundrope weighed 170 kg in air and total headline flotation was 157 kg. Trawl 2 had the groundrope removed and was rigged to operate at 0.4 - 0.5 m (Trawl 2a) and 0.8 - 0.9 m (Trawl 2b) above the sea bed. The desired heights were achieved through a combination of headline flotation and steel weights (10, 20 and 40 kg) attached to the footrope (Table 1). Figure 1 shows the position of floats and footrope weights to operate the trawl at 0.4 - 0.5 m above the sea bed. Bridle and sweep lengths for all trawls were 50 and 40 m respectively. Single slot Polyvalent otterboards were used throughout the trials. Each otterboard weighed 1000 kg and had a surface area of 3.8 m^2.

Figure 1. The wing trawl used in this study, here rigged to fish semi-pelagically with its footrope at 0.4 - 0.5 m above the sea bed.

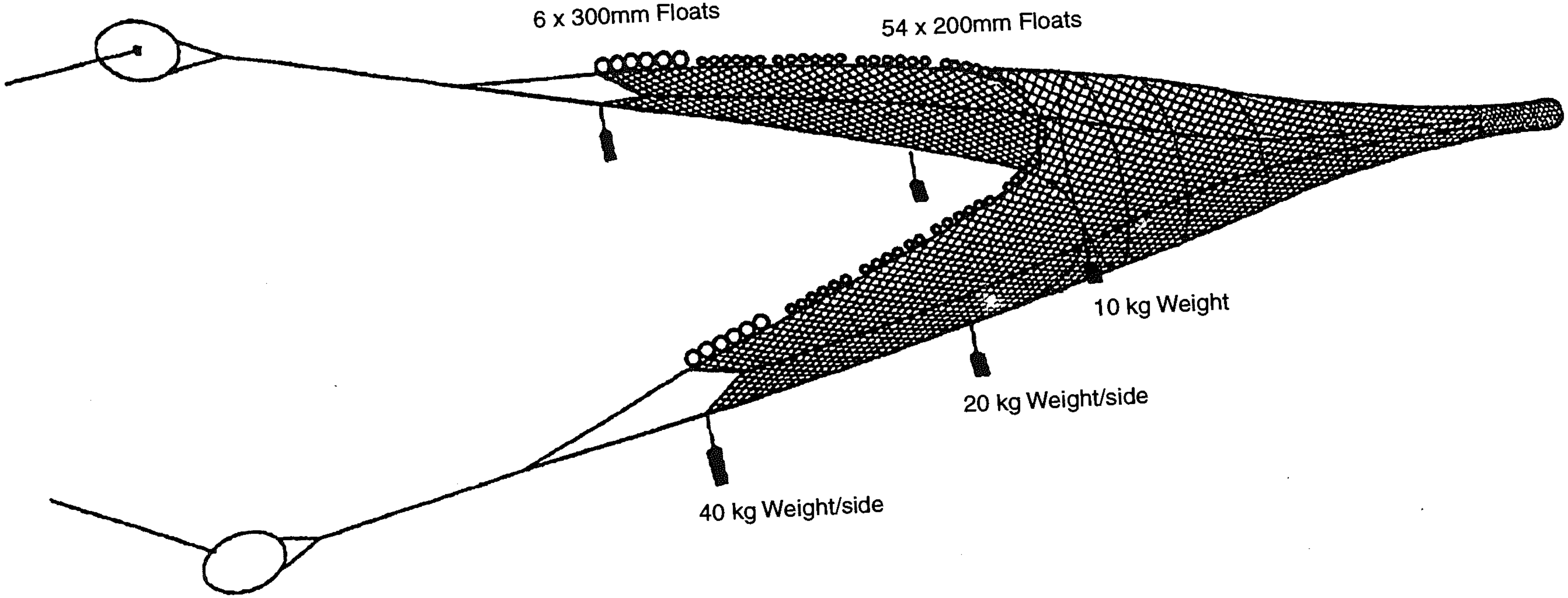


Table 1.

Total groundrope weight, footrope weight, headline flotation and footrope height for the three trawl types.

Trawl No.	Groundrope weight (kg	Footrope weight (kg)	Headline flotation (kg	Footrope height (m)
1	170	0	157	0.0
2a	0	130	245	0.4 - 0.5
2b	0	110	262	0.8 - 0.9

Trawl performance monitoring

The distance between the otterboards on all trawls was measured by 'Scanmar' acoustic sensors housed in brackets attached to the otterboards. Wing-end spread measurements of Trawl 1 were obtained by placing the sensors on the upper wing-ends, 0.3 m ahead of the netting. These were not measured for trawls 2a and 2b. Headline height was monitored with a 'Scanmar' height sensor attached to the second row of meshes behind the centre of the headline.

At the Australian Maritime College flume tank before the cruise, a small beam trawl (net removed) was towed with 2.5 m lengths of 10 mm 'dropper' chains attached at known vertical heights. The number of polished links was recorded at the end of tows at a range of speeds, A plot of vertical height against number of unpolished links was generated. The footrope on the field nets was also fitted with the dropper chains. The number of unpolished links was then compared with the plot to determine footrope height.

Warp tension during sea trials was measured by recording hydraulic oil pressure of each winch with an A/S Hydraulik Brattvaag 'Synchro 2000' automatic trawl-control system. Video footage was recorded on a 'Sony Hi 8 Handycam' in an underwater housing attached to the trawl. All tows were made at 1.8 m s^{-1}, using a warp-to-depth ratio of 3:1. Tow duration was 30 minutes and trawl performance data were recorded midway through each tow. Trawl speed was recorded with a 'JRC' doppler log.

Study area and sampling strategy

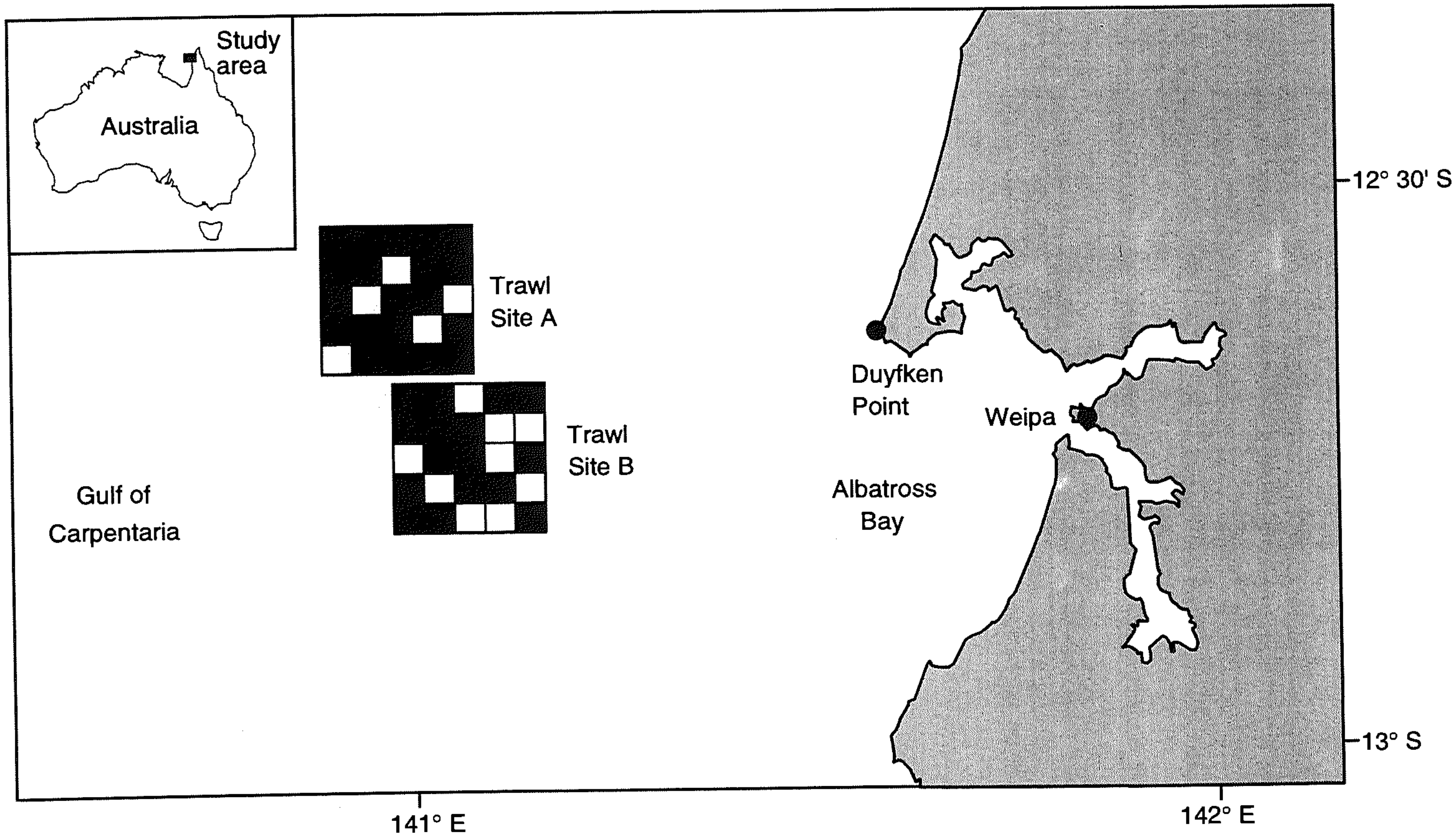
The area chosen for trawl comparisons (Figure 2) was within the waters of the Northern Fish-trawl Fishery Management Zone (described in Newton *et al.* 1994). It was chosen because previous studies had shown it had the two key components required for our comparison: commercial quantities of red snappers (Lutjanidae) and structural benthos (= macro-benthos protruding above the sea bed) (CSIRO unpublished data).

The trawl area was divided into two 18x18 km sites (A and B, Figure 2), each of which was divided into 25, 2 x 2 nautical mile grids. Sites were sampled alternately and for three days at a time (each day a different trawl gear type). Site A was sampled four times (4 visits x 5 grids x 3 trawl types = 60 tows), while Site B was sampled three times (3 visits x 5 grids x 3 trawl types = 45 tows), with one extra grid sampled by each trawl type at Site B; this gave a total of 108 trawls (Figure 2). The net type was randomly re-ordered for each site visit. Each day's trawling consisted of five trawls, in five separate grids, one in each of five time slots (0800-1000, 1000-1200, 1200-1400, 1400-1600 and 1600-1800). These gave comparisons of each net type in the same grid (physical area) at the same time of day. The same five (randomly chosen) grids were used for each set of three trawl types before a new set of five grids was chosen. Depth in the sampling areas ranged between 41 and 58 m (mean = 50.6 m, n=108).

DATA COLLECTION AND ANALYSES

We identified all fish to species, weighed each species group, counted individuals and measured the lengths of the smallest and largest in each catch. Fishes (including elasmobranchs) that were longer than about 500 mm, and all commercially important fishes, were measured and weighed individually (commercially important fishes were regarded as those currently marketed by commercial fishers or either targeted or kept by recreational or traditional fishers).

Figure 2. North-east Gulf of Carpentaria showing the sites and grids sampled during trials of semi-pelagic fish trawls. Each grid was sampled by all three trawl types.



Where catches of smaller fishes were large (> about 50 kg), a subsample (usually around 30 percent) was taken and processed, and the remainder was weighed. For these trawls, the data for the total catch were calculated by multiplying up the sub-sample values to a total weight of smaller fish.

Invertebrates were treated in the same way as fish, with all large specimens measured and large numbers of smaller organisms subsampled. Invertebrates were often only identified to class.

The analyses described below were applied to all species individually and to the following categories of combined species:

- 'sharks' - free swimming and usually pelagic (mostly Carcharhinidae)
- 'other elasmobranchs' (mainly rays and shovelnose rays)
- 'fish bycatch' (mainly small fishes)
- 'sponges'
- 'other invertebrates' (excluding sponges, squid and *Thenus orientalis* [Moreton Bay bugs], which were analysed separately).

Only species caught in 5 or more trawls were included in the analyses.

This study aims to test the null hypothesis that catches from the two semi-pelagic fish trawls (0.4m and 0.8m above the sea bed) are the same as those from the demersal version of the trawl (footrope on the sea bed).

Dunnett's t-tests in PROC GLM (SAS Institute Inc., 1988) were used for each animal group to test for catch differences between each semi-pelagic trawl and the demersal trawl.

While the objective was to describe the difference in catches between these trawl gears, the catches can also be affected by site differences, time of day and grid series. These factors were included in a linear model to enable us to compare catches, after accounting for any variation caused by these factors. Thus,

Catch = gear + site + time + gear x site + gear x time + site x time + gear x time x site + grid (site x time) + e,

where gear was the trawl gear type used (footrope of the net at 0.0, 0.4 - 0.5 or 0.8 - 0.9 m above the sea bed); site was the trawl area A or B (Figure 2); time was the diurnal time window in which the trawl was made (0800-1000, 1000-1200, 1200-1400, 1400-1600 or 1600-1800); grid represented the 36 individual grids (3 for each combination of site and time) trawled by each gear; and e was the error term or gear x grid (site x time). All factors used in the model, except 'grid', are assumed to have fixed effects. Site was used as a fixed factor in the model because of the limited choice of the specific habitat required (see above).

Plots of residual versus fitted values of weights and numbers data from the model showed very little difference whether log or square-root transformed. Square-root transformed data were chosen to stabilise the variance of catch weights, which were then used separately in the model.

The significance tests for each effect in the model are based on the appropriate error terms as determined by the expected mean squares (type III). This was determined using a 'Random' statement with the 'test' option in PROC GLM (SAS Institute Inc., 1988).

RESULTS

Trawl performance

Essential details of the trawls' performance are given in Table 2. Trawl 2a produced the largest average distance between otterboards: 71.1 m. The wing-end spread of Trawl 1 was measured for only three tows, resulting in a mean spread of 14.7 m or 57 percent of headline length. From the mean otterboard spread of this trawl, the sweep and bridle angle to the direction of tow was calculated as 18°. No difference was detected in warp tension (total trawl drag) between trawls with or without the groundrope (Table 2). Trawl 1 was rigged for demersal operation and its headline height (2.3 +/- 0.09 m) was equivalent to its vertical opening (i.e. the difference between headline and footrope heights). Based on observed footrope heights and mean headline heights, the vertical opening of trawls 2a and 2b was 3.0 and 3.15 m respectively.

Table 2. Means and standard errors (in brackets) of otterboard spread, headline height and warp tension for the three trawl types.

Trawl No.	Mean otterboard spread (m)	Mean headline height (m)	Mean warp tension (t)
1	66.8 (0.75)	2.3 (0.09)	2.0 (0.03)
2a	71.1 (0.39)	3.5 (0.09)	1.97 (0.03)
2b	68.7 (0.74)	4.1 (0.08)	1.98 (0.03)

Videos of trawls during the trials showed wide footrope spread. The footropes of trawls 2a and 2b were observed to be uniformly clear of the sea bed for their entire length, with little change from the desired height.

Trawl catches

A total of 277 440 fish (196 species) weighing 12 413 kg was caught during the study. A total weight of 1680 kg of epibenthic invertebrates (34 species or species groups) was also taken. Trawl 1 caught 219 285 fish (190 species) weighing 8 515 kg, and 1 638 kg of epibenthic invertebrates (32 species or species groups); trawl 2a caught 33 704 fish (109 species) weighing 3 153 kg, and 35.2 kg of epibenthic invertebrates (11 species or species groups); trawl 2b caught 24 451 fish (82 species) weighing 745 kg, and 7.7 kg of epibenthic invertebrates (10 species or species groups).

Catch comparisons

The catches of 20 selected animal groups (main commercially important species and other groups of interest) are described in Table 3 and nine of these are presented in Figure 3 (a-i). There were significant differences between the catches of the three trawl types for seven of these nine species groups. Trawl 1 caught more fish bycatch, more epibenthic invertebrate groups (sponge, other benthic invertebrates and *T. orientalis*) and more squid than either of the semi-pelagic trawls. Squid also showed a significant interaction between gear, time of day and trawl site, indicating that catch differences between gears were also affected by specific times of day and trawl sites.

Although the difference in catches between trawl gear type was particularly striking for the invertebrates, carcharhinid sharks and 'other elasmobranchs' were also caught in significantly higher abundance in trawl 1. The results for all of these animal groups were the same whether analysed by weights or numbers.

The two target species — *Lutjanus malabaricus* and *L. erythropterus* — showed no significant differences in catches between the trawl types. However, both species appear to be caught ion greater abundance in trawl 2a. The lack of significance between these catches from trawl 2a and the other two trawl types shows the high degree of variability between catches of these two species during this study. This is demonstrated by the fact that *L. erythropterus* and *L. malabaricus* were represented in only 17.6 percent and 33.3 percent of trawls respectively.

Ten other species of commercially important fish species and penaeid prawns also showed no difference in catches between the three trawl types (Table 3). Most of these were less abundant and less frequently caught than the two main target fishes.

Only four of the 20 selected animal groups (Table 3) showed differences in catches due to factors other than gear. Catches of sponges and the Mackerel, *Scomberomorus queenslandicus*, both showed differences between trawl sites, while catches of carcharhinid sharks and squid differed between sites but depending on the time of day (showed significant time by site interactions).

In total, 107 fish species and 15 invertebrate taxa were caught in more than four tows, and so were analysed for differences in catches between trawl types.

There were significant differences ($p<0.05$) between trawl types in the catches of 68 (63.5 percent) species of fishes. For a further 6 species of fish, the probability values were between 0.05 and 0.1. All except 7 of these 68 species were caught in greater abundance in trawl 1; these seven had highest catches in trawl 2a. All of these (*Dussumieria elopsoides, Arius thalassinus, Echeneis naucrates, Scomberoides tol, Selar crumenophthalmus, Parastromateus niger* and *Rastrelliger kanagurta*) are described by Smith and Heemstra (1986) as pelagic in

Figure 3. Mean catches (and standard errors) of nine species from groups of particular interest. The three trawl types represented are as follows: 0 = demersal trawl (trawl 1); 0.4 = trawl fished semi-pelagically at 0.4-0.5 m above the sea bed (trawl 2a); and 0.8 = trawl fished semi-pelagically at 0.8-0.9 m above the sea bed (trawl 2b).

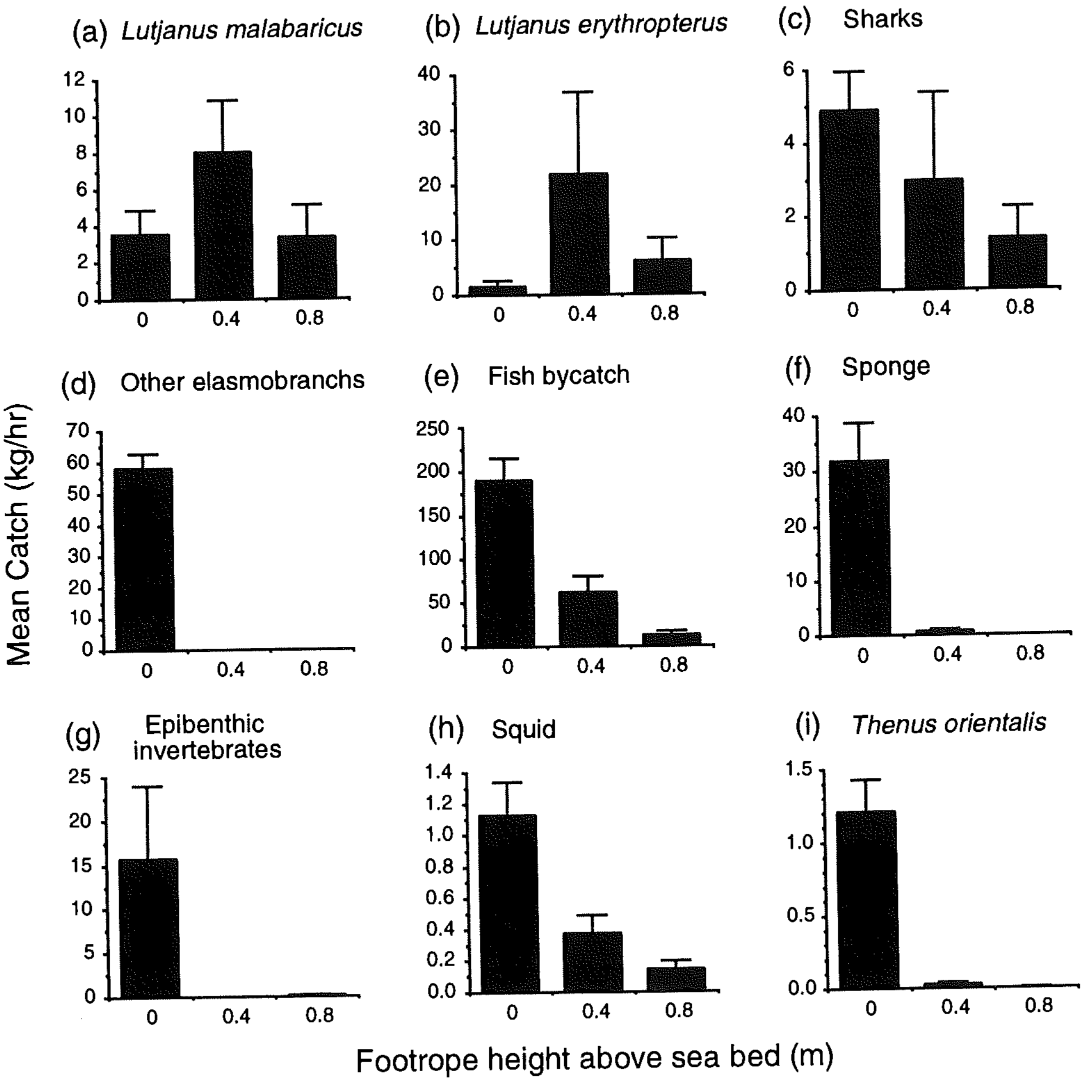


Table 3. Mean and standard errors of catches (kg h^{-1}) of animals in demersal wing trawls from the Gulf of Carpentaria site in November 1993. The trawls were rigged with their footropes 0.0 (trawl 1), 0.4 (trawl 2a) or 0.8 m (trawl 2b) above the sea bed. Only species caught in >4 trawls are included. The total number of individuals caught and their percentage occurrence in trawls are also presented. F ratios and probability statistics are presented from the test for differences between these catches. * = p<0.05, ** = p<0.01, *** = p<0.001, + = p>0.05 but<0.1. Commercially or recreationally important species are denoted thus: (C).

Taxon	Species	Total Catch	% of trawls	Trawl type 1		2a		2b				
		(n)		Mean	s.e.	Mean	s.e.	Mean	s.e.	*F*	*P*	
Carcharhinid sharks		116	25	4.9	1.1	2.9	2.4	1.4	0.86	6.8	0.003	**
Other elasmobranchs		159	26.8	58.0	16.3	-	-	-	-	26.4	<0.001	***
Fish bycatch		275097	100	189.7	25.5	61.6	18.2	12.4	4.7	66.5	<0.001	***
Benthic invertebrates (except sponges)		4049	43.5	15.7	8.3	0.03	0.02	0.10	0.08	12.4	<0.001	***
Carcharhinidae	*Carcharhinus dussumieri*	36	14.8	2.68	0.7	0.07	0.07	-	-	18.6	<0.001	***
	Hemigaleus microstoma	13	4.6	0.84	0.44	-	-	-	-	4.8	0.014	*
	Rhizoprionodon acutus	59	4.6	0.35	0.21	1.93	1.93	-	-	0.62	0.54	
Rhynchobatidae	*Rhynchobatus djiddensis*	17	12.0	18.05	8.68	-	-	-	-	7.4	0.002	**
Dasyatididae	*Dasyatis leylandi*	49	4.6	0.40	0.29	-	-	-	-	2.5	0.09	+
	Himantura toshi	28	13.0	4.56	1.62	-	-	-	-	11.2	<0.001	***
Gymnuridae	*Gymnura australis*	20	8.3	0.55	0.20	-	-	-	-	8.2	0.001	**
Clupeidae	*Dussumieria elopsoides*	8	5.6	-	-	0.02	0.01	0.003	0.003	3.3	0.047	*
	Herklotsichthys lippa	686	13.9	0.05	0.03	0.11	0.06	0.94	0.86	1.04	0.36	
	Pellona ditchela	106	9.3	0.09	0.05	0.01	0.01	0.05	0.04	1.75	0.19	
Chirocentridae	*Chirocentris dorab*	7	4.6	0.03	0.03	0.05	0.04	0.01	0.01	0.62	0.54	

Synodontidae	*Saurida micropectoralis*	1377	31.5	7.53	1.20	-	-	0.04	0.04	219.2	<0.001	***
	Saurida sp. 2	8195	55.6	13.28	2.36	0.43	0.10	0.33	0.08	81.2	<0.001	***
	Saurida undosquamis	5152	37.9	6.29	2.09	0.29	0.12	0.16	0.05	21.1	<0.001	***
	Synodus hoshinonis	32	7.4	0.01	0.01	0.001	0.001	-	-	3.8	0.03	*
Ariidae	*Arius thalassinus*	231	17.6	2.81	0.78	4.73	4.73	-	-	4.3	0.02	*
Holocentridae	*Sargocentron rubrum*	110	6.5	0.64	0.36	0.01	0.01	-	-	2.5	0.098	+
Fistulariidae	*Fistularia petimba*	979	28.7	0.40	0.06	-	-	-	-	98.1	<0.001	***
Centriscidae	*Centriscus scutatus*	100	4.6	0.02	0.009	-	-	-	-	5.2	0.01	*
Scorpaenidae	*Apistus carinatus*	49	5.6	0.04	0.02	-	-	-	-	6.5	0.004	**
Triglidae	*Lepidotrigla* sp. 2	89	6.5	0.001	0.001	-	-	-	-	6.8	0.003	**
Platycephalidae	*Elates ransonetti*	378	25.0	0.17	0.04	-	-	-	-	55.6	<0.001	***
	Rogadius asper	153	9.3	0.08	0.04	-	-	-	-	8.6	<0.001	***
	Suggrundus isacanthus	53	5.6	0.10	0.05	-	-	-	-	6.6	0.003	**
	Suggrundus macracanthus	678	27.8	0.87	0.16	-	-	-	-	98.1	<0.001	***
	Suggrundus rodericensis	45	4.6	0.022	0.018	-	-	-	-	1.7	0.19	
Dactylopteridae	*Dactyloptena papilio*	209	21.3	0.11	0.03	-	-	-	-	20.2	<0.001	***
Serranidae	*Epinephelus areolatus*	49	5.6	0.61	0.37	-	-	-	-	3.4	0.044	*
	Epinephelus sexfasciatus	51	9.3	0.11	0.05	-	-	-	-	6.6	0.003	**
Teraponidae	*Terapon jarbua*	29	4.6	0.03	0.02	-	-	0.001	0.001	2.1	0.13	
	Terapon theraps	1076	4.6	2.21	1.29	0.01	0.01	-	-	5.1	0.01	*
Priacanthidae	*Priacanthus tayenus*	15530	52.8	8.14	1.14	0.12	0.07	0.22	0.20	105.1	<0.001	***
Apogonidae	*Apogon quadrifasciatus*	303	14.8	0.10	0.03	-	-	-	-	21.7	<0.001	***
	Apogon septemstriatus	88	9.3	0.01	0.009	-	-	0.001	0.001	3.3	0.049	*

	Rhabdamia gracilis	161	6.5	<0.001	<0.001	0.002	0.002	-	-	0.95	0.39	
Rachycentridae	*Rachycentron canadus* (C)	15	6.5	0.07	0.07	0.54	0.38	0.04	0.04	1.1	0.34	
Echeneidae	*Echeneis naucrates*	65	21.3	0.06	0.03	0.40	0.12	0.14	0.08	4.7	0.015	*
Carangidae	*Alepes* sp.	195	19.4	0.37	0.23	0.07	0.03	0.02	0.02	1.8	0.19	
	Atule mate	307	32.4	0.28	0.12	0.34	0.117	0.33	0.21	0.39	0.68	
	Carangoides caeruleopinnatus	838	37.0	1.64	0.57	0.32	0.12	0.31	0.27	10.4	<0.001	***
	Carangoides chrysophrys	165	19.4	0.56	0.27	1.79	1.59	0.05	0.04	1.2	0.31	
	Carangoides fulvoguttatus	10	4.6	0.07	0.07	0.08	0.05	0.08	0.08	0.15	0.86	
	Carangoides humerosus	152	8.3	0.45	0.26	0.02	0.01	0.003	0.003	3.2	0.05	+
	Carangoides malabaricus	2542	38.9	2.73	0.70	0.23	0.14	1.20	1.13	13.3	<0.001	***
	Carangoides talamparoides	424	23.2	0.20	0.05	0.11	0.06	0.13	0.13	2.7	0.083	+
	Caranx bucculentus	820	16.7	2.71	1.13	0.52	0.47	0.17	0.15	6.5	0.004	**
	Decapterus macrosoma	5038	25.9	0.78	0.65	2.34	1.88	0.09	0.07	1.4	0.25	
	Decapterus russellii	3437	45.4	3.06	2.57	1.7	0.77	0.34	0.22	1.5	0.24	
	Gnathanodon speciosus (C)	253	10.2	0.67	0.61	19.08	14.56	0.41	0.34	2.2	0.13	
	Megalaspis cordyla	616	6.5	1.61	1.57	3.57	3.57	0.07	0.07	0.37	0.7	
	Scomberoides tol	477	28.7	0.26	0.12	0.78	0.27	0.17	0.08	5.0	0.011	*
	Selar crumenophthalmus	2992	62.0	1.68	0.66	4.14	1.22	1.35	0.71	3.6	0.036	*
	Selaroides leptolepis	4184	47.2	5.16	2.15	2.72	1.03	0.08	0.05	11.0	<0.001	***
	Seriolina nigrofasciata	134	13.9	1.60	0.59	-	-	0.002	0.002	20.5	<0.001	***
Formionidae	*Parastromateus niger*	567	28.7	0.5	0.28	2.43	0.96	0.41	0.19	5.3	0.009	**
Leiognathidae	*Gazza minuta*	78	5.6	0.10	0.07	-	-	0.004	0.004	2.5	0.09	+
	Leiognathus bindus	36941	50.9	8.27	1.60	0.43	0.28	0.42	0.28	61.2	<0.001	***

	Leiognathus equulus	1963	9.3	3.82	2.49	1.10	1.10	0.12	0.12	2.4	0.1	
	Leiognathus moretoniensis	5126	33.3	1.14	0.18	-	-	-	-	72.9	<0.001	***
	Leiognathus splendens	656	6.5	0.97	0.57	-	-	-	-	6.7	0.003	**
	Secutor insidiator	1082	26.8	0.26	0.09	0.07	0.04	0.10	0.08	9.9	<0.001	***
Lutjanidae	*Lutjanus argentimaculatus* (C)	38	7.4	0.80	0.58	1.86	1.36	0.16	0.16	1.5	0.24	
	Lutjanus erythropterus (C)	845	17.6	1.43	1.10	21.89	14.92	5.94	4.15	1.4	0.25	
	Lutjanus malabaricus (C)	219	33.3	3.53	1.33	8.0	2.84	3.31	1.80	1.4	0.24	
	Lutjanus russelli (C)	244	16.7	2.21	1.25	0.28	0.14	0.18	0.15	1.2	0.31	
	Lutjanus sebae (C)	219	13.0	1.47	0.72	0.72	0.44	0.68	0.68	1.1	0.35	
	Lutjanus vittus	511	32.4	0.78	0.34	0.78	0.43	0.57	0.43	0.39	0.68	
	Pterocaesio diagramma	120	10.2	0.004	0.003	0.002	0.002	0.04	0.04	0.46	0.63	
Nemipteridae	*Nemipterus celebicus*	6075	29.6	13.46	3.02	0.01	0.01	-	-	208.4	<0.001	***
	Nemipterus furcosus	1665	25.0	5.79	2.46	0.03	0.02	0.004	0.004	19.8	<0.001	***
	Nemipterus hexodon	1826	32.4	3.03	0.51	-	-	-	-	108.6	<0.001	***
	Nemipterus nematopus	3791	35.2	4.54	0.54	-	-	-	-	184.6	<0.001	***
	Nemipterus peronii	788	25.0	1.79	0.33	0.005	0.005	-	-	126.5	<0.001	***
	Scolopsis taeniopterus	1002	30.6	2.03	0.47	-	-	-	-	59.9	<0.001	***
Gerreidae	*Gerres filamentosus*	267	19.4	0.38	0.11	-	-	-	-	22.9	<0.001	***
	Pentaprion longimanus	16627	38.9	9.69	1.56	0.003	0.002	0.001	0.001	128.5	<0.001	***
Haemulidae	*Diagramma pictum* (C)	201	16.7	6.96	3.34	3.31	2.71	-	-	3.1	0.058	+
	Pomadasys maculatum	13944	23.1	23.05	11.89	2.37	2.01	0.02	0.01	7.3	0.002	**
Lethrinidae	*Lethrinus laticaudus* (C)	32	6.5	1.18	0.87	0.11	0.11	-	-	2.4	0.1	
	Lethrinus lentjan (C)	129	9.3	1.41	1.02	0.63	0.46	0.03	0.03	1.4	0.27	

Sparidae	*Argyrops spinifer* (C)	17	4.6	0.13	0.07	0.10	0.08	-	-	1.5	0.24	
Mullidae	*Upeneus* sp. 2	927	18.5	1.12	0.22	0.01	0.008	-	-	85.2	<0.001	***
	Upeneus sulphureus	8358	45.4	5.11	1.04	0.78	0.41	0.91	0.88	17.8	<0.001	***
Ephippididae	*Platax batavianus*	74	4.6	0.75	0.56	1.49	1.16	-	-	1.4	0.26	
Chaetodontidae	*Parachaetodon ocellatus*	117	9.3	0.18	0.07	-	-	-	-	10.7	<0.001	***
Pomacentridae	*Pristotis jerdoni*	503	14.8	0.24	0.14	0.04	0.02	-	-	5.7	0.007	**
Sphyraenidae	*Sphyraena forsteri*	201	16.7	0.44	0.17	0.05	0.04	0.006	0.006	10.5	<0.001	***
	Sphyraena putnamiae	23	6.5	0.24	0.14	0.29	0.19	-	-	1.7	0.19	
Labridae	*Choerodon monostigma*	128	13.9	0.30	0.09	-	-	-	-	18.6	<0.001	***
Uranoscopidae	*Uranoscopus cognatus*	34	8.3	0.02	0.01	-	-	-	-	5.9	0.006	**
Callionymidae	*Callionymus japonicus*	63	6.5	0.03	0.01	-	-	-	-	6.3	0.004	**
Siganidae	*Siganus canaliculatus*	78	6.5	0.31	0.23	0.01	0.01	0.009	0.009	2.5	0.09	+
	Siganus fuscescens	20	7.4	0.09	0.06	0.06	0.06	0.01	0.01	1.03	0.37	
Trichiuridae	*Trichiurus lepturus*	35	8.3	-	-	0.008	0.006	0.02	0.02	1.04	0.36	
Scombridae	*Rastrelliger kanagurta*	2604	39.8	0.51	0.14	2.78	1.12	0.19	0.10	5.98	0.005	**
	Scomberomorus queenslandicus (C)	17	8.3	0.31	0.15	0.15	0.10	0.08	0.06	0.74	0.48	
Psettodidae	*Psettodes erumei*	121	12.0	1.22	0.40	-	-	-	-	13.6	<0.001	***
Bothidae	*Grammatobothus polyophthalmus*	207	17.6	0.19	0.06	-	-	-	-	18.7	<0.001	***
	Pseudorhombus diplospilus	261	24.1	0.92	0.21	-	-	-	-	39.2	<0.001	***
	Pseudorhombus elevatus	384	25.0	0.33	0.08	-	-	-	-	46.7	<0.001	***
	Pseudorhombus spinosis	107	11.1	0.19	0.07	-	-	-	-	11.4	<0.001	***
Triacanthidae	*Trixiphichthys weberi*	364	19.4	0.70	0.22	0.02	0.01	-	-	18.5	<0.001	***
Balistidae	*Abalistes stellaris*	193	27.8	2.6	0.77	0.32	0.10	0.01	0.01	14.8	<0.001	***

Monacanthidae	*Paramonacanthus filicauda*	106195	40.7	22.3	7.0	2.7	1.2	2.6	2.3	11.9	<0.001	***
Ostraciidae	*Rhynchostracion nasus*	37.2	6.5	0.13	0.06	-	-	-	-	5.0	0.011	*
Tetraodontidae	*Lagocephalus sceleratus*	161	16.7	0.22	0.06	-	-	-	-	23.3	<0.001	***
Diodontidae	*Cyclichthys jaculiferus*	49	7.4	0.30	0.14	-	-	-	-	6.7	0.003	**
Porifera		164	30.6	28.5	5.7	0.70	0.42	-	-	63.6	<0.001	***
Anthozoa	Gorgonacea	13	6.5	0.61	0.57	0.005	0.005	<0.001	<0.001	1.7	0.19	
	Alcyonaria	50	6.5	0.04	0.03	0.002	0.002	-	-	2.3	0.11	
Zoantharia	Scleractinia	11	4.6	0.12	0.08	-	-	-	-	3.8	0.03	*
Crustacea	Brachyura	128	11.1	0.05	0.02	-	-	<0.001	<0.001	6.4	0.004	**
	Peneiodea (C)	271	8.3	0.45	0.45	-	-	<0.001	<0.001	1.04	0.36	
Scyllaridae	*Thenus orientalis* (C)	146	13.0	1.2	0.23	0.03	0.02	0.002	0.002	49.6	<0.001	***
Mollusca	Scallops	249	17.6	0.12	0.04	-	-	-	-	22.2	<0.001	***
	Cuttlefish	897	31.5	2.39	0.39	-	-	-	-	76.6	<0.001	***
	Squid (C)	1734	78.7	1.13	0.21	0.37	0.12	0.14	0.06	32.8	<0.001	***
	Octopus	38	7.4	0.03	0.02	-	-	-	-	4.7	0.014	*
Bryozoa		7	6.5	0.02	0.007	-	-	-	-	4.8	0.013	*
Echinodermata	Asteriodea	76	13.9	0.90	0.30	-	-	-	-	12.8	<0.001	***
	Echinoidea	265	9.3	0.17	0.10	-	-	-	-	4.4	0.018	*
Ascidiacea		1295	20.3	1.96	0.52	0.001	0.001	-	-	26.3	<0.001	***

habit, which would make them more likely to be caught higher in the water column. No species had highest catches in trawl 2b.

The 68 species that were caught in greatest abundance in trawl 1 came from 40 different families. Several families had many species caught mainly in this trawl type: three of the four carcharhinid sharks, two of three rays, all four synodontids, four of the five platycephalids, seven of the 17 carangids, four of the six leiognathids, all six nemipterids, both species of gerreids and mullids, all four species of bothids but none of the six species of lutjanid. The only representatives analysed, of 19 families, were caught in greatest abundance in trawl 1.

There were significant differences ($p<0.05$) between net types in catches of 12 of 15 groups of epibenthic invertebrates: they were all caught in greatest abundance in trawl 1.

DISCUSSION

Trawl performance

The trials demonstrated the effectiveness of a demersal wing trawl rigged for semi-pelagic operation in maintaining catch rates of *L. malabaricus* and *L. erythropterus* while passing over most benthic species. The handling problems of the fork-rigged Julie Anne trawl had been overcome by using the sweep and bridle configuration used in most demersal operations. When rigged semi-pelagically, the wing trawl is relatively simple to operate and consequently more likely to gain industry acceptance. Its onboard handling was little different to a standard demersal trawl: the footrope weights had to be removed before storing the net drum to prevent fouling of meshes. The use of a groundrope of similar total weight to the five footrope weights might eliminate this.

The small amount of otterboard spread and headline height variation in all trawls suggests the trawl was stabile during the fishing operation. This was confirmed by video observations and the consistent number of polished 'dropper' chain links. Its stability was attributable to the large spreading forces generated by the otterboards, which were bigger than normally required to spread this size of demersal trawl.

Trawl 1 attained a wingend spread of 57 percent of headline length. While wingend spread was not recorded for trawls 2a and 2b, their otterboard spread measurements implied their wingend spreads were greater than that of trawl 1. Trawls operated with large distances between wingends are often considered to be overspread, which, according to Engås & Godø (1986), increases footrope tension and reduces trawl contact with the sea bed. As one of the criteria examined by these trials was minimal trawl impact on the benthic community, reduced sea bed contact is a desirable characteristic of this trawl. The use of appropriately sized otterboards to generate large wingend spreads, combined with the selective use of floats and footrope weights may be necessary to achieve desired footrope clearances.

The larger wingend spreads in the semi-pelagic trawls may explain the higher catches of some species in trawl 2a. Alternatively, these fish may simply occur higher off the sea bed than the species that had higher catches in the demersal trawl. The fishes with the highest catches in trawl 2a (0.4 - 0.5 m above the sea bed) were always caught in lower abundance in the trawl raised to 0.8 - 0.9 m (trawl 2b). The obvious explanation is that when the footrope is raised to this height it gives enough clearance between it and the sea bed to enable the fish to escape. However, the behavioural reaction of fish to such trawls is largely unknown.

Fish catches

Catches of all fishes combined were considerably larger in the demersal fish trawl (trawl 1) than the A large proportion of bycatch reduction information (in particular, the most recent advances) is not reported in the literature. It was considered that first hand discussions with people at the major semi-pelagic versions (trawls 2a and 2b) of the same trawl. Trawl 1 caught 6.5 times more fish (by number) than trawl 2a (0.4 - 0.5 m above the sea bed) and 9.0 times more than trawl 2b (0.8 - 0.9 m). The fish biomass was 2.7 and 11.4 times higher than in trawls 2a and 2b, respectively. The catches are higher than are likely in the commercial fishery because the legal codend mesh size is 110 mm, whereas we used 50 mm mesh, but the difference would nonetheless be substantial.

When the whole trawl rig is lifted off the sea bed, much less small fish bycatch is caught. As the only difference between the demersal and semi-pelagic rigs is the raising of the trawl, it is likely that many of these fish escape under the footrope, sweeps or bridles.

The greatest concern to the fishing industry when introducing new gear is its ability to maintain catches of the target species. Our results support those of Ramm *et al.* (1993) that catches of both red snappers (*L. malabaricus* and *L. erythropterus*) and two other commercially important snappers —*L. argentimaculatus* and *L. russelli* — are not decreased by using a semi-pelagic trawl. Further, we found that the catches of all other lutjanids (including L. sebae) were essentially the same in the demersal and semi-pelagic trawls. In fact, the mean catches of *L. malabaricus*, *L. erythropterus* and *L. argentimaculatus* were higher in the trawl at 0.4 - 0.5 m above the sea bed, although these were due to one or two unusually large catches. Most of these commercial species of Lutjanus appear to be aggregated and so this type of non-targeted sampling regime is likely to result in high variability between catches. Consequently, although the highest catches of the main target species were clearly highest in the trawl at 0.4-0.5 m above the sea bed, it is difficult to be confident of this result from this study.

We can be confident, however, that the semi-pelagic trawls do not decrease catches of the target species. It appears these species do not escape en masse under the footrope when it is raised to 0.4 - 0.5 m, but that raising the whole trawl results in catches of more individuals that swim higher in the water column. The trawl fished at this height caught more of the target fishes than the 0.8-0.9 m trawl rig.

The species of fishes that are not caught by the semi-pelagic trawls are from a range of families. They include benthic groups (e.g. rays, synodontids, platycephalids, mullids and bothids), and many common epi-benthic groups (e.g. carcharhinid sharks, leiognathids, nemipterids and gerreids). Our results clearly show that by using semi-pelagic instead of demersal trawls, catches of many of these common non-target trawl species are reduced.

Invertebrate catches

Catches of epibenthic invertebrates are dramatically lower in the semi-pelagic version of the fish trawl. Trawl 1 caught 46 and 213 times more benthos (by weight) than trawls 2a and 2b, respectively. The footrope of the semi-pelagic trawls simply passes over most of the benthos, with only the highest forms being captured. Personal observation also suggests that some benthos is picked up by the sweeps and bridles (in contact with the sea bed) and a proportion of this ends up in the net. The amount of damage to the benthos from this cause was not measured. Neither semi-pelagic trawl caught many benthic invertebrates.

Other commercially valuable species, which are often kept as a byproduct, were seldom caught in the semi-pelagic trawls (e.g. squid, *Thenus orientalis*).

BENEFITS

Relatively simple modifications to a demersal wing trawl enabled it to fish semi-pelagically and conform to the regulations for the Northern Fish-trawl Fishery, while maintaining its ability to catch the target species. The main advantages over a demersal trawl are:

- catches of the target species (red snappers) are the same or greater
- catches of unwanted bycatch of small fishes and benthic invertebrates are very much smaller
- catches contain fewer non-target species and therefore are of a higher quality
- the trawl is less likely to be damaged on rough sections of the sea bed.

The semi-pelagic wing trawl we tested is an improvement on the earlier 'Julie Anne trawl'. The problems experienced with the 'Julie Anne trawl' have been largely overcome and handling of the trawl is much simpler. The rigging arrangement used in the trials could be easily and cheaply adapted to most demersal fish trawls.

Semi-pelagic versions of fish trawls, such as that described here, have also been used to benefit other demersal trawl fisheries. A semi-pelagic version of a demersal trawl was developed to improve catches of squid and butterfish when they move off the bottom at certain times in the fishing season (Goudey 1987). A semi-pelagic trawl tested by Alshuth (1989) caught more 8 cm sprats (*Sprattus sprattus* L) at night than a bottom trawl; the converse applied to 9 cm sprats during the day. In some circumstances there may, therefore, be advantages of being able to convert from a demersal to a semi-pelagic style trawl depending on the fishing requirements.

Direct links between preserving the benthos (and other non-target communities) and sustaining a fishery have not been proven. However, by minimising the impact of trawling on non-target animals it is more likely that the marine community will be retained in its original form and therefore better able to sustain the fishery resource in the long-term. The more conservative 'preserve just in case' approach has been increasingly adopted by fishers in the last decade and is seen more and more as 'smart fishing'. This will become more important in the next few years as more boats are granted access to the Northern Fish-trawl Fishery (Newton *et al.* 1994).

Many other trawl fisheries that currently use demersal trawls could use semi-pelagic fish trawls. This includes the South East (about 125 boats) (Kailola *et al.*, 1993); North West Slope (about 12 boats) and Western Deepwater (about 15 boats) Trawl Fisheries on Australia's continental shelf. The advantages of using more environmentally friendly trawls could well apply to these and other trawl fisheries in Australia and elsewhere.

OBJECTIVE 2

- **Develop and test Bycatch Reduction Devices suitable for Australia's Northern Prawn Trawl fishery**

A. Review and evaluation of existing strategies

(a) Visits to main centres of bycatch-reduction research

Much of the work on bycatch reduction (in particular, the most recent advances) has not been reported in the literature. CSIRO and AMC therefore funded a visit to the main centres of research into bycatch reduction for two key project staff in February 1994. The trip is reported in Appendix A; the centres and people visited are listed in Appendix B.

The information gathered from this three-week trip put the project in a position to speed up the development and testing of BRDs for the NPF. Some of the benefits are listed below:

- first-hand experience of the many BRDs being used around the world
- several of these devices were viewed in flume tanks in Hirtshals (Denmark) and Hull (England)
- practical discussions with scientists and fisheries technologists about the performance and handling of BRDs, and ultimately their suitability for the NPF
- discussions with scientists about techniques and pitfalls of survival studies on bycatch escapees from trawls
- discussions with scientists and fisheries technologists about techniques and pitfalls of underwater video studies of animals in trawls nets
- received feedback on many aspects of the project
- broadened the profile of Australian BRD research by presenting preliminary results in seminars at each site

The information gathered during this trip greatly streamlined many aspects of the development and testing of BRDs and the other associated research, such as obtaining video data, conducting survival experiments, and industry liaison. Many of these benefits are difficult to measure, but some results are mentioned below.

The devices selected for testing were two inclined grids (Super Shooter, Nordmøre) and four other BRDs (Radial Escape Section, Fisheyes, Square-mesh panels and Square-mesh codends). Fish-stimulator devices, used in conjunction with BRDs; were also chosen: 'hummer-wire stimulator', ' black cylinder stimulator' or 'fish-mouth stimulus' and 'glow netting'. These are designed to orient captured fish to the escape device and so enhance escapement. They are described in more detail in the BRD research report below.

(b) Review of literature

Background information on bycatch reduction technology and research was obtained from the international literature, much of which is cited in this report.

(c) Survey of fishers' views

During the 1994 closed season, a questionnaire was sent to 32 skippers, five skipper/owners and one owner in Cairns, Darwin and Brisbane to find out their views and their concerns about bycatch.

A second questionnaire was used to collect information about bycatch caught during trawling for tiger prawns. The questions focussed on: how often different bycatch groups were caught; problems caused by the capture of each species; and the bycatch groups the fishermen would most like to exclude from their catch. This information was then used in selecting which BRDs to test.

For the purpose of this study bycatch was grouped in the following categories: fish; large animals such as rays, shovelnose sharks, other sharks and turtles; area-specific benthic organisms including heart urchins ('sea eggs'), sponges and corals; and seasonally occurring animals such as jellyfish. Squid, bugs and scallops were classified as byproduct rather than bycatch, because they have a commercial value to the fishermen.

The fishers' stressed that many of the bycatch categories were generally found in specific areas. For example, catches from the Weipa area are dominated by fish, while more sponges are taken around Bountiful Island. Hence, it is difficult to generalise about the occurrence of different bycatch groups in catches throughout the NPF. Fishers also commented that areas that have been regularly fished over the years have been cleared of much of the large benthic material.

RESULTS OF THE SURVEY

Small fish are apparently the most common components of bycatch; 97 percent of fishers reported them in every haul of the net. Their capture often caused delays in sorting the catch, and large hauls resulted in loss of prawns, because their weight closes the gear. A 'try-net', a small trawl that can be hauled in after a short time can be used to monitor the composition of the catch. If there are large numbers of fish, skippers generally shorten the length of the tow.

Small fish bycatch caused no problems to 26 percent of fishers. These skippers have sorting hoppers on their vessels, which reduces delays, and thereby improves product quality (due to less time on deck).

Large animals were caught in every shot according to 10 percent of fishers, or in every second to tenth shot (55 percent of fishers). However, some skippers observed that the number of large animals caught in nets had declined in recent years.

The biggest problem with the large animals (the "monsters") is the damage they inflict on the prawns during capture. Their sheer size and weight squash the prawns as they tumble around in the codend and crush others as they hit the sorting table. Live "monsters" can also sweep prawns over the side of the boat when they thrash about on the table.

Large animals can also damage nets during capture. Shovelnose sharks, considered by fishers to be the strongest and most violent of the group, are a particular problem. Several skippers reported that sharks could also force their snouts through the codend exit and loosen the securing knot, creating an opening through which the prawns are lost. Sharks in the water bite holes in nets while attempting to steal catch, and sawfish can split open the side of a net with their blade-like snouts.

"Monsters" may even injure crew while on deck. The serrated stinging spines on the tails of rays can inflict severe wounds, and the thrashing of large sharks can turn prawns and small fish into dangerous projectiles. The extra care required to deal with these animals results in delays with sorting the catch.

The number of benthic organisms captured, including heart urchins (sea eggs), corals and sponges, depended on the area fished, according to the skippers. Where abundant, they might be caught in every shot; in other areas, none are caught. Large sponges and corals crush prawns, their weight closes the gear and can cause further loss through the build-up in bycatch weight, which reduces the efficiency of the gear and sometimes the damage the nets.

Sea eggs are seen as a growing problem; their abundance appears to have increased over recent years. In some areas they occur in such large numbers that they can quickly fill a trawl and cause the net to 'blow out', resulting in the loss of both prawns and fishing time. Nets suffered more 'chaffing' when they were towed through beds of hard urchins.

Large quantities of sea eggs also cause delays in processing the catch, and leave behind a trail of sore fingers among crew members who have to sort them. The spines responsible for this also damage the prawns.

Catches of sea eggs can be reduced by regular monitoring of the try net. Most skippers reported that they avoid areas where sea eggs occur in large numbers. However, when no alternative fishing areas are available fishers in the NPF make the gear fish 'lighter' to avoid the sea eggs, although there was some loss of prawns.

Large numbers of jellyfish can occur sporadically in the Gulf; the year of 1985 was most vividly remembered by fishers. If a careful eye is not kept on the build-up of jellyfish, or 'blubber' as they are called by operators in the fishery, their weight can split the net open. 'Blubber' shoots have been incorporated in gear to try to alleviate this problem, but generally skippers look for alternative fishing grounds.

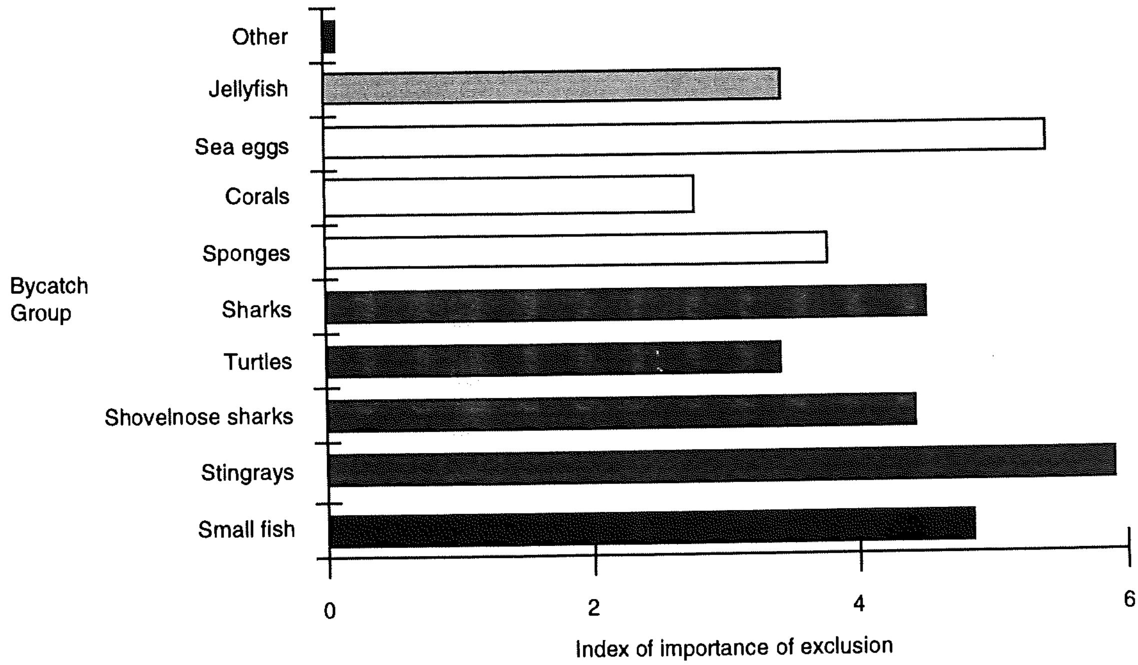
Less than five percent of bycatch is retained as byproduct. This includes scallops, bugs, squid and some larger fish; they make a useful contribution to the vessel's earnings (Pender *et al*; 1992). Other products such as shark fins and trunks, and ray wings are sold by some fishers. The value of such byproducts influence fishers' views as to which animals they label "unwanted" and wish to be excluded from their catch.

Skippers and owners were asked which of the bycatch groups they would most like to exclude from their catch if the technology were available. Fishers assigned priorities to each group and we then calculated an overall index of priority of exclusion for each group.

The group skippers would most like to exclude from their catch stingrays (Figure 4) followed by sea eggs . Sea eggs were next although 47 percent of fishers did not see them as a problem. Small fish rated third, followed by sharks, shovelnose sharks, sponges, jellyfish, turtles and corals. Overall, large animals and fish were identified as the bycatch components fishers most wanted to be excluded. This finding influenced the selection of BRDs to be tested during the research cruise in February and March 1995.

Fishers generally agreed that there would be advantages in reducing bycatch as long as there was no associated loss of prawns. The main benefits would be improved quality of product, due to reduced damage to the prawns and shorter sorting times; increased gear efficiency with smaller amounts of bycatch to tow around; and reduced net damage. As one skipper stated, 'a reduction in bycatch would produce a better quality product and a happier crew'.

Figure 4. Priorities for exclusion of bycatch group assigned by Northern Prawn Fishery operators. Shading indicates the groupings we used.



B. Developing and testing Bycatch Reduction Devices for Australia's Northern Prawn Trawl Fishery

Trawl fisheries throughout the world are now being required to use Bycatch Reduction Devices as a result of pressure from several sources. Conservation organisations have successfully lobbied governments to introduce measures to protect endangered or vulnerable marine species such as dolphins and sea turtles (e.g. Watson and Seidel 1980, Watson and Taylor 1988, Watson *et al.* 1993). Scientific research has also influenced fisheries managers to legislate for trawl gear that minimises impact on non-target marine organisms. In Australia's Northern Fish-trawl Fishery (Newton *et al.* 1994). After Sainsbury *et al.* (1987) showed that trawling removed structured benthos, which affected the species composition of the fish community on Australia's North West Shelf and introduced management required fish trawling to be semi-pelagic BRDs to decrease catches of unwanted bycatch that are target species for other fisheries (e.g Watson and Taylor 1988, Watson *et al.* 1993, Broadhurst and Kennelly 1995) or juveniles of the same fishery (Isaksen *et al.* 1992). In the latter case, the use of a separator panel has helped fishing to continue on prawn grounds that otherwise would have been closed to trawling. Although the impetus for the introduction of BRDs has differed between fisheries, the result is a growing trend towards increasing the selectivity of trawls by decreasing the amount of unwanted bycatch.

So far, all management procedures in Australia's Northern Prawn Fishery (NPF hereafter, Figure 5) e.g. seasonal, spatial and daytime closures, limited entry and gear (size and number) restrictions — have been developed to control the effort of individual operators to maximise long-term prawn yields. Despite the government's requirement for ecologically sustainable management, no specific regulations have been promulgated to help protect non-target species in this ecosystem.

There are many advantages to decreasing the amount of unwanted bycatch in prawn trawls. Firstly, it would minimise changes to the marine community, including disturbing the sea bed and deaths to species that are vulnerable or endangered. Secondly, fishers would benefit from higher catch values (because the product would suffer less damage), shorter sorting times, lower fuel costs (reduced net drag) and longer tow times (the codend would fill more slowly) — and fishers would hear less criticism from community groups. Thirdly, recreational and other commercial fisheries would benefit from a reduced impact on species they target. Despite these advantages the fishing industry is concerned that changes to trawl gear that reduce the unwanted bycatch might also reduce prawn catch rates. Hence, the acceptance of BRDs in Australia's NPF will depend on their ability to maintain prawn catches as well as reduce unwanted bycatch.

Pressures from conservation groups and the government's policy to develop ecologically sustainable fishing practices have prompted the funding of several other projects to develop and test BRDs. The 'AusTED' developed by Mounsey *et al.* (1995) was independently tested by Robins-Troeger *et al.* (1995). They reported it significantly reduced bycatch, including turtles, without significant losses in prawn catch at 5 different sites in coastal trawl grounds of south-east Queensland. In New South Wales' estuarine and offshore prawn-trawl fisheries, several BRDs, including the Morrison soft TED, square-mesh panels (offshore) and the Nordmøre grid (estuary) were tested (Andrew *et a*l. 1993, Broadhurst and Kennelly 1995, 1996a, 1996c). The last two BRDs have been widely adopted in these fisheries (pers comm, M. Broadhurst).

The NPF is Australia's largest prawn fishery and one of the most valuable fisheries in Australia, with an annual production between 8 000 and 10 000 tonnes (Somers, 1994). It is estimated that greater than 30 000 tonnes of bycatch are taken from the NPF each year (Pender *et al.*, 1992; Ramm *et al.*, 1990). Despite this, there has been very little previous research into bycatch reduction technology in the NPF.

In this section we report the first trials of Bycatch Reduction Devices in Australia's tropical NPF. The report is in two sub-sections: one reporting a set of tests of the performance of two sizes of square-mesh codend and a second reporting comparisons of a variety of other BRD devices. The same general method was used to study BRD performance throughout the project (see Figure 6) and described in detail in Objective 2 section B2.

Figure 5. Sketch map of Australia's Northern Prawn Fishery (Source: *The AFMA Northern Prawn Fishery 1996 Information Booklet*)

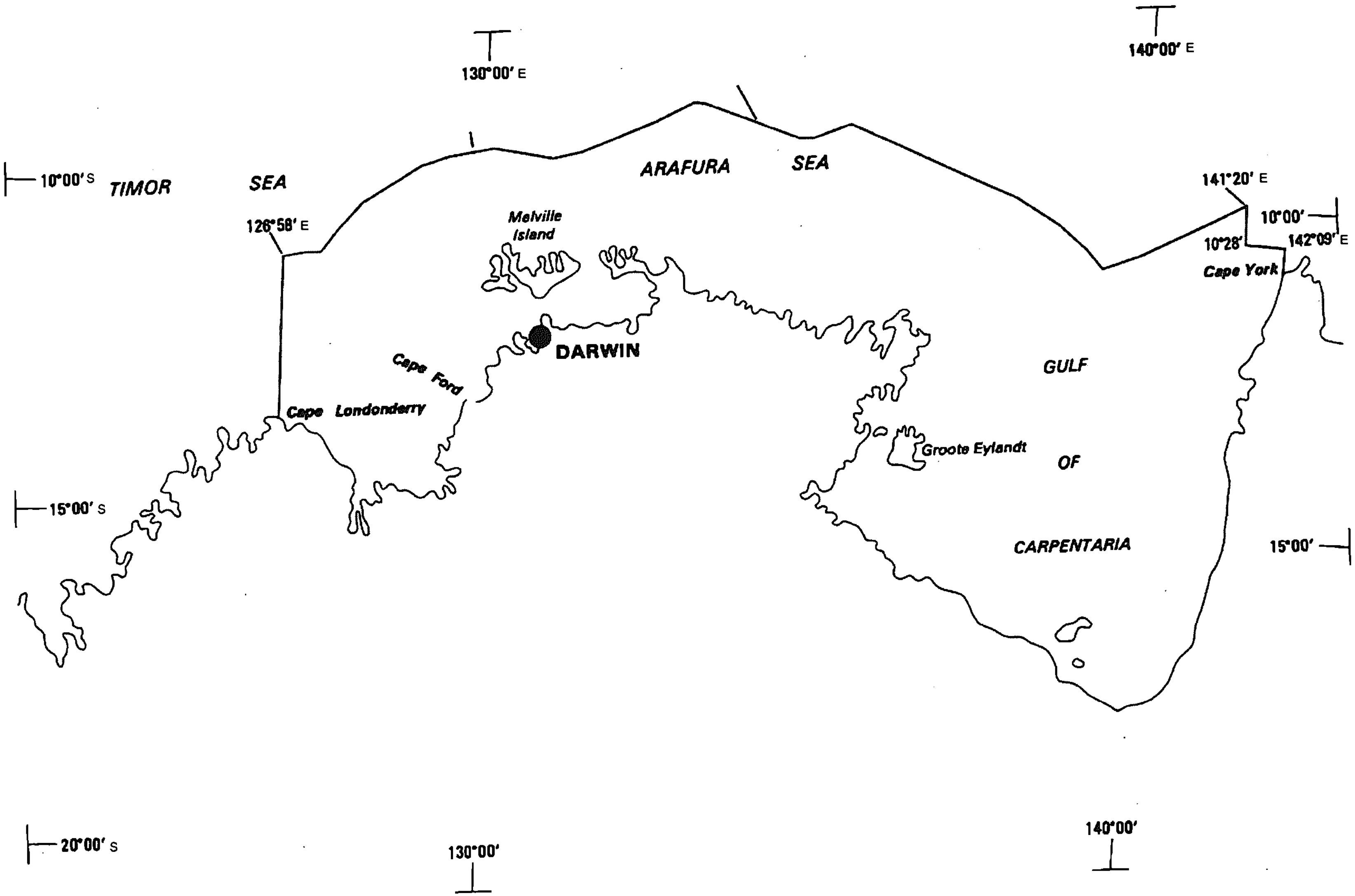
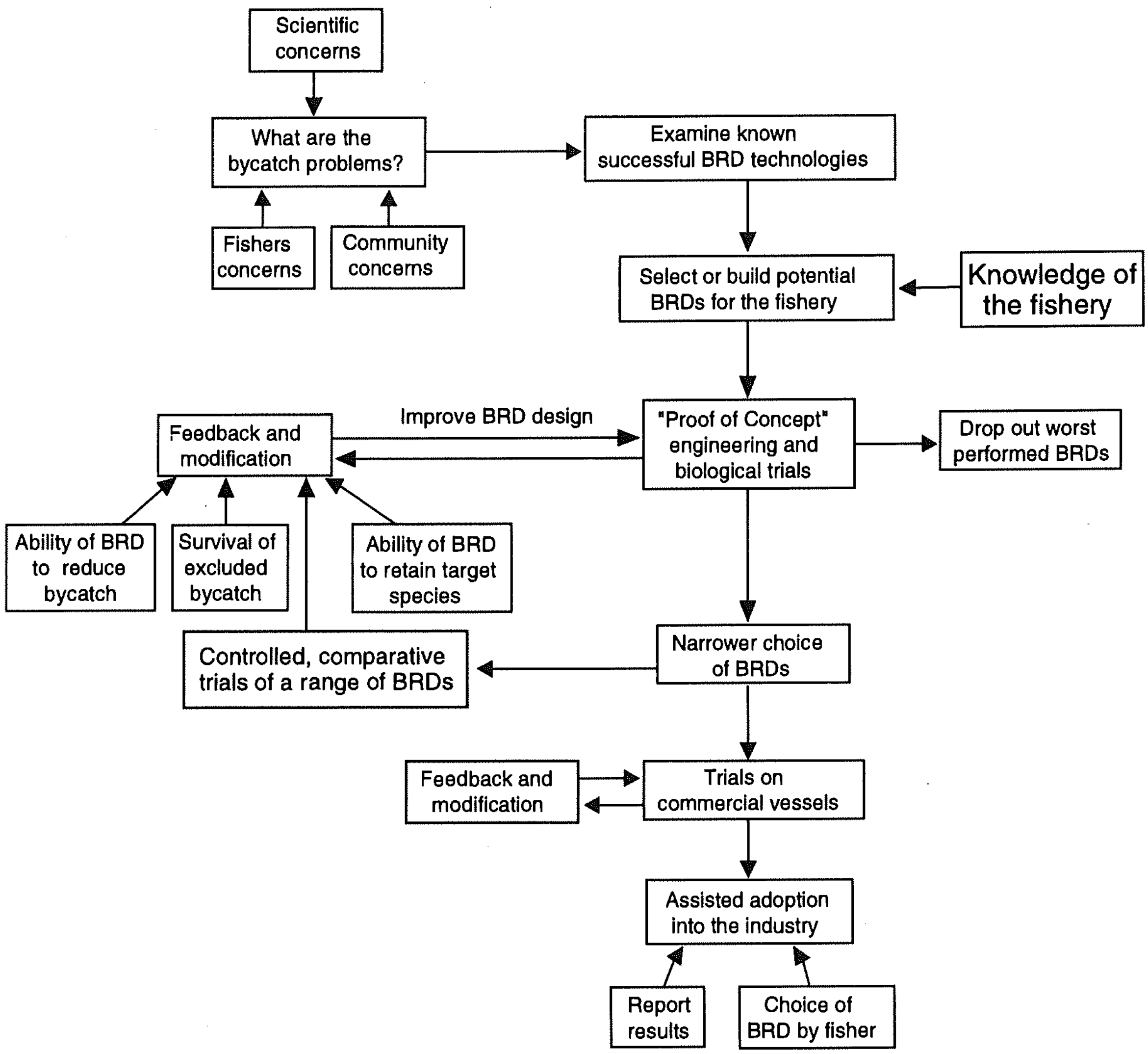


Figure 6. A diagram of the general method used to study bycatch reduction devices and facilitate their adoption into the NPF



B1. Comparison between diamond and square-mesh codend catches in the Northern Prawn Fishery of Australia

INTRODUCTION

Australian fisheries management authorities are bound by law to manage fisheries under the principles of ecologically sustainable development. Under these principles, the reduction of bycatch non-target species caught incidentally to the species at which effort is directed - has become a priority.

The NPF is one of the most valuable fisheries in Australia. Its production of prawns ranges between 8000 and 10000 tonnes (Pownall, 1994). However, it is estimated that over 30000 tonnes of bycatch is discarded from the NPF each year (Pender *et al.*, 1992; Ramm *et al.*, 1990). The bycatch consists mainly of small fish of many species. In order to meet the criteria for environmentally sustainable development of the NPF, managers have had to address the issue of bycatch reduction.

Management bodies in conjunction with researchers and fishers in the NPF have tested modified fishing gear to reduce bycatch while maintaining the prawn catches. Fishing gears are inherently selective and can be modified to change both the species and sizes they retain while maintaining the flexibility of fishing operations, (Suuronen, 1995). For example, it has long been known by fishers, and has been confirmed experimentally, that fewer smaller fish are retained in trawls if the mesh size in the codends is increased (Armstrong *et al.*, 1990). It has also been shown that 'square-mesh' can enhance the selectivity of a trawl codend (Robertson and Stewart, 1988).

In square-mesh construction, the twines run along and across the net, rather than diagonally as in the more traditional diamond-mesh. The two sets of twines in square-mesh netting are always at right angles to one another, maintaining the open square shape of the meshes (MacLennan, 1992).

Square-mesh codends are more selective for most roundish species than are diamond-meshes (Robertson, 1983; Isaksen and Valdemarsen, 1986; Robertson and Stewart, 1988; Cooper and Hickey, 1989; Suuronen and Millar, 1992); however, they are less effective at releasing smaller (Cooper and Hickey, 1989; Millar and Walsh, 1992; Walsh, *et al.*, 1992) or show little difference (Fonteyne and M'Rabet, 1992). In a shrimp fishery in Iceland, square-mesh codends reduced the bycatch of small fish dramatically and the catch of under-sized shrimp to a great extent (Thorsteinsson, 1992).

The objectives of this part of the study were : (i) to compare the proportions of the commercial prawn species and the bycatch species retained in two different-sized (38 mm and 45 mm) square-mesh codends, with the proportions retained in the traditional diamond-mesh (45 mm) codend, and (ii) to assess the overall potential of square-mesh codends to reduce bycatch in the NPF while maintaining the catches of prawns.

MATERIALS AND METHODS

Two identical fourteen-fathom (25.6 m) headline length Florida Flyer prawn trawls were towed in a dual rig arrangement (Figure 7) by a 65 m research vessel (FRV *Southern Surveyor*). Each trawl was constructed from 57 mm polyethylene netting. Trawl opening was achieved by No. 9 Bison otter boards (1990 mm x 1435 mm) each weighing 490 kg. A sled weighing 500 kg provided an attachment point for the inner wingends of both trawls. The main warp wire were attached to the otter boards and sled with 100 m of 16 mm diameter wire bridles.

The diamond-mesh codend, measuring 150 x 150 meshes, was constructed from 44.5 mm knotted polyethylene mesh. This construction duplicated the standard codend used in the fishery. The square-mesh codends were constructed from 38 mm or 45 mm mesh knotless braided polyamide (Figure 8). Codend covers of 16 mm polyamide diamond-mesh netting were used to fully enclose each codend so we could quantify the small animals that escaped through the codends. To support the shape of the codend-cover and hold it off the square-mesh codend, the cover was fitted with two hoops of 12 mm diameter steel. They provided ample clearance for fish to escape through the codend into the codend cover. The larger hoop (1.5 m in diameter) was 3.36 m in front of the other (1.2 m in diameter). Thirty-six floats of 45 mm diameter and 90 mm length (flotation = 0.1 kg) and one 10 mm diameter float (flotation = 0.75 kg) were used to counter the negative buoyancy of the polyamide netting and steel hoops.

Figure 7 . Plan view of the dual-rigged 14 fathom Florida Flyer prawn trawl used in trials to test bycatch reduction devices.

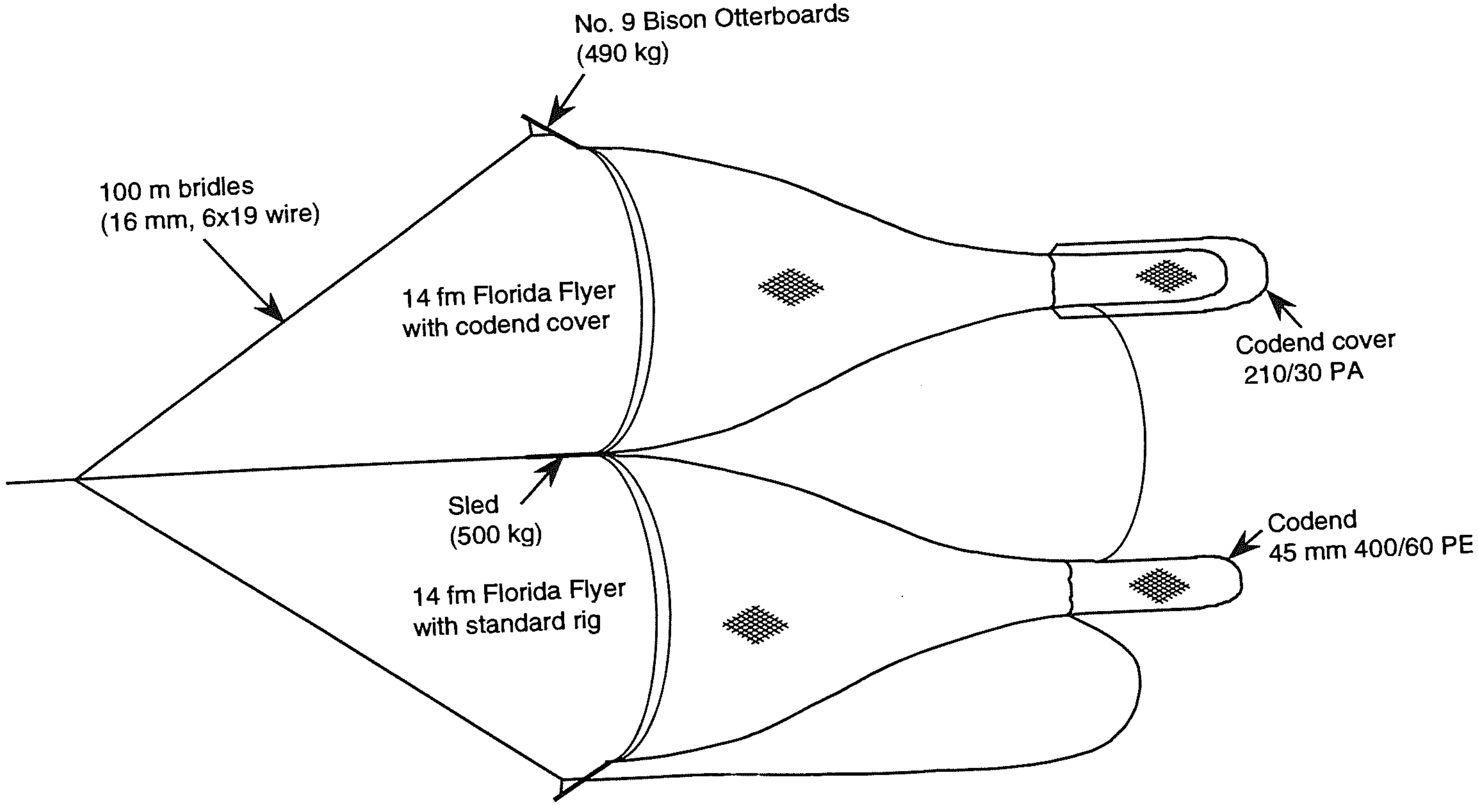
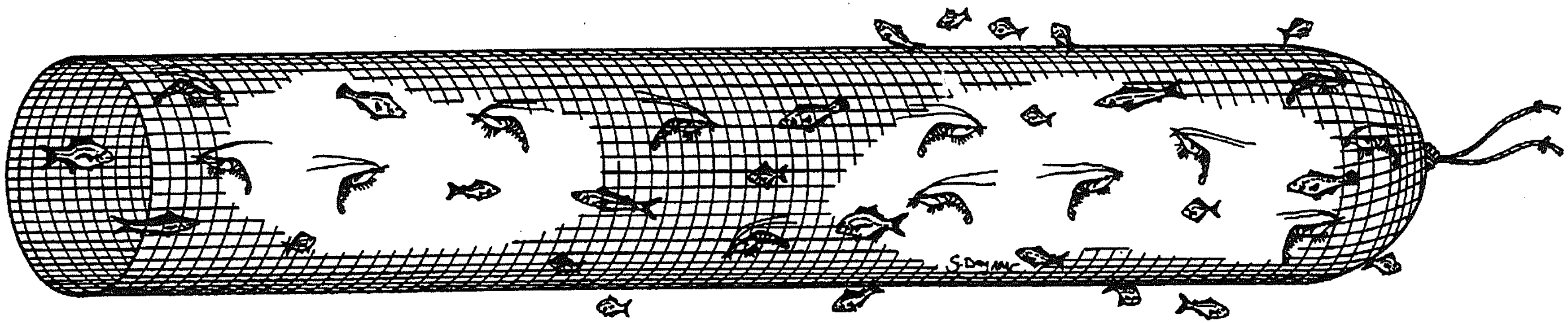


Figure 8. Diagram of a square-mesh codend trialed as a bycatch reduction device in the NPF

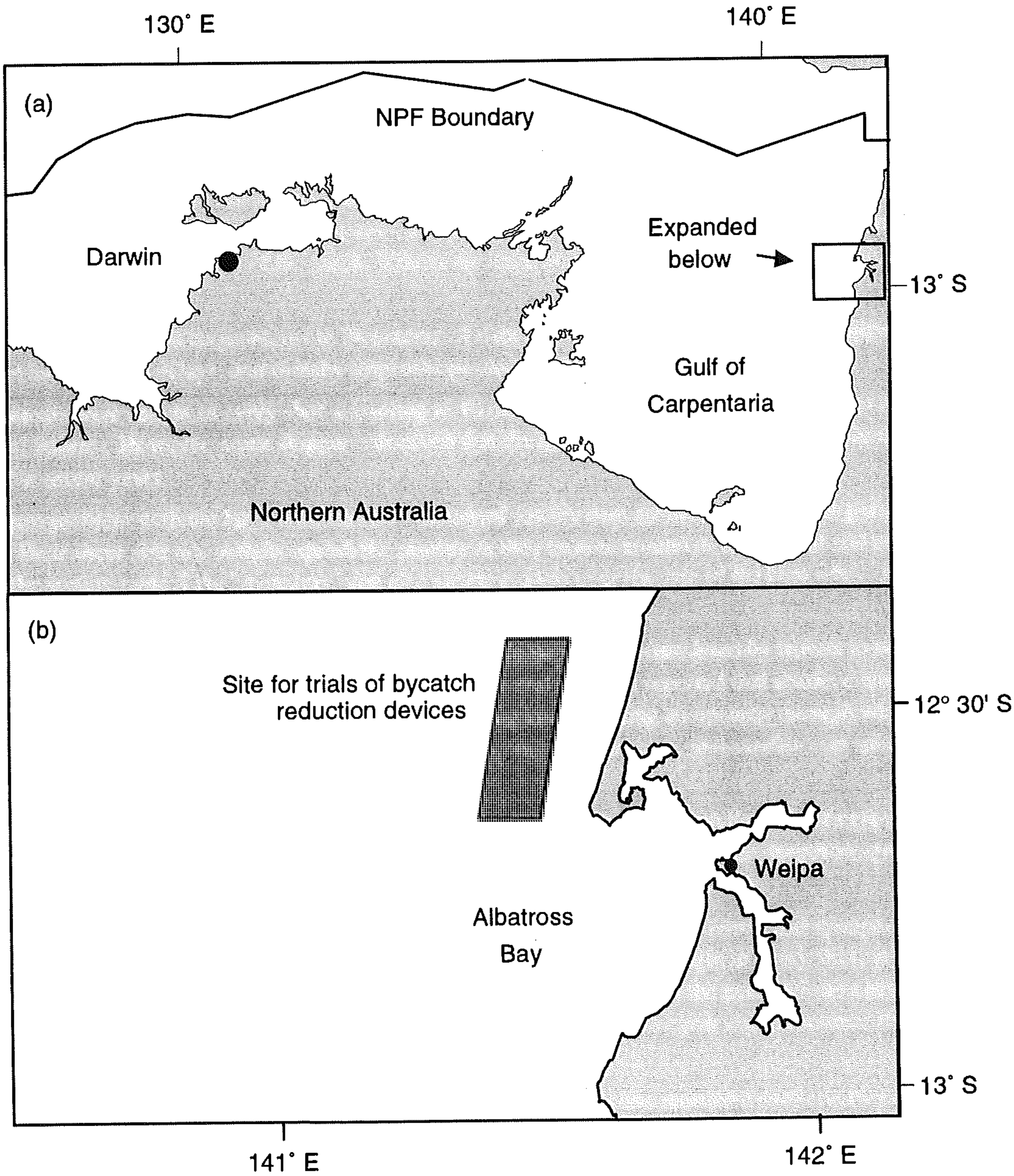


The trawl was rigged with the diamond mesh in one codend, and one of the two square meshes in the other. All tows were made at 1.5 m s-1, using a warp-to-depth ratio of 5:1. Tow duration was 30 minutes and all tows were made at night. The diamond and square-mesh codends were exchanged at the beginning of each night's trawls.

Study area

Fish were collected in the north-east Gulf of Carpentaria about five nautical miles west of Duyfken Point in Albatross Bay (Figure 9). This is a commercial fishing area. Trawls were made at depths between 18 and 25 m.

Figure 9 . North-east Gulf of Carpentaria showing the study area used during trials of bycatch reduction devices.



DATA COLLECTION AND ANALYSES

Thirty-three paired tows of the 38 mm square-mesh codend and forty-one paired tows of the 45 mm square-mesh codend were made against the diamond-mesh. The catches from the diamond and square-mesh codends and their covers were processed separately. The weight of the entire catch from each sample was recorded and all fish greater than about 1 kg were sorted, identified to species and weighed on board. All commercial prawns (*Penaeus semisulcatus*, *P. esculentus*, *Metapenaeus ensis* and *M. endeavouri*,) in each sample were identified to species, counted and weighed. Their carapace lengths were measured with callipers to the nearest millimetre. The remainder of the catch in each sample was sorted and the total number and weight of each species recorded. Or, if the remainder (mainly small fish and invertebrates) was large, it was sub-sampled (usually between 10 percent and 50 percent of the catch), and the total numbers and weights of each taxon from each tow was calculated. Catch samples from tows in which the net was damaged or not operating correctly were discarded.

DATA ANALYSIS

By adding together the catches in the codend and the codend cover we knew how many animals entered each trawl, and what percentage of the total catch went through each of the codends.

We examined the retention characteristics of each codend in terms of numbers and weight of both prawns and of bycatch (using only taxa that appeared in ten or more tows). A linear model in SAS with two factors — codend mesh and haul — was fitted. Each haul was considered as a 'block' (Snedecor and Cochran, 1980) to minimise the residual variation and improve our ability to detect a difference between the two types of mesh. Before analysis, the data were arc-sine transformed to stabilise the variance. For convenience, the data were transformed to a 100-point scale (rather than degrees or radians), so that they could be treated as pseudo-percentages.

RESULTS

A total of 11595 commercial prawns weighing 332.15 kg, and about 64 8955 (274 taxa) bycatch items weighing 13189 kg, were caught in the paired tows. The numbers and weight of both prawns and bycatch from the diamond-mesh codend and its cover, and from the square-mesh codends and their covers are detailed in Table 4.

Catch rates of commercial prawns during the 38 mm mesh trials were 75.6±8.6 individuals per tow (by numbers), and 2.07±0.21 kg per tow (by weight) in the net with the diamond-mesh codend; and 73.2±7.3 individuals per tow (by numbers), 2.03±0.16 per tow (by weight) in the net with the square-mesh codend. Catch rates of bycatch were 4530.4±454.4 individuals per tow (by numbers), 86.77±6.15 kg per tow by weight) in the diamond-mesh codend; and 3962.7±455.4 individuals per tow (by number), 86.55±7.91 kg per tow (by weight) in the square-mesh codend.

Catch rates of commercial prawns during the 45 mm mesh trials were 85.7±7.9 individuals per tow (by number), 2.44±0.20 kg per tow (by weight) in the diamond-mesh codend; and 77.3±7.7 individuals per tow (by number), 2.3±0.2 kg per tow (by weight) in the square-mesh codend. Bycatch catch rates were 5230.6±553.2 individuals per tow (by number), 102.28±9.72 kg per tow (by weight) in the diamond-mesh codend; and 4419.3±509.8 individuals per tow (by number), 93.27±10.78 kg per tow (by weight) in the square-mesh codend.

In the 38 mm square-mesh codend trials, the overall retention of commercial prawns was 95.7 percent by numbers and 98.5 percent by weight in the diamond-mesh codend and 92.1 percent by numbers and 97.0 percent by weight in the square-mesh codend; a difference of 3.6 percent by number and 1.5 percent by weight. The overall loss of bycatch was 33.8 percent by numbers and 10.4 percent by weight from the diamond-mesh codend, and 34.5 percent by numbers and 14.4 percent by weight from the 38 mm square-mesh codend; a difference of 0.7 percent by numbers and 4.0 percent by weight of bycatch.

In the 45 mm square-mesh codend trials, the overall retention of commercial prawns was 90.0 percent by numbers and 98.4 percent by weight in the diamond-mesh codend, and 78.1 percent by numbers and 92.1 percent by weight in the square-mesh codend; a difference of 11.9 percent by number and 6.3 percent by weight. However, the loss consisted mainly of non-market-sized prawns (see below). The overall loss of bycatch was 26.2 percent by numbers and 7.9 percent by weight from the diamond-mesh codend, and 56.3 percent by

Table 4. Total number and weight of commercially important prawns and bycatch items caught in

(a) 38 mm square-mesh codend vs 45 mm diamond-mesh codend

		Prawn catches (n = 33)			**Bycatch catches** (n = 32)		
		Number	**Weight (kg)**	**Mean wt (g)**	**Number**	**Weight (kg)**	**Mean wt (g)**
Codend mesh	Diamond	2387	67.18	27.37 ± 1.38	96 055	2491.38	86.87 ± 29.16
	Square	2225	64.97	29.40 ± 0.97	83 130	2373.73	140.96 ± 54.78
Codend Cover	Diamond	108	1.01	10.63 ± 1.30	49 071	287.84	11.68 ± 1.42
	Square	190	2.03	11.32 ± 0.78	43 768	397.94	13.19 ± 0.33
Totals		4910	135.19		272 024	5 550.89	

(b) 45 mm square-mesh codend vs 45 mm diamond-mesh codend

		Prawn catches (n = 41)			**Bycatch catches** (n = 39)		
		Number	**Weight (kg)**	**Mean wt (g)**	**Number**	**Weight (kg)**	**Mean wt (g)**
Codend	Diamond	3126	99.26	26.93 ± 0.92	150 754	3678.58	122.50 ±37.05
	Square	2475	88.47	33.48 ± 0.78	75 507	2320.54	177.51 ± 49.73
Codend Cover	Diamond	388	1.64	8.22 ± 1.08	53 563	317.48	13.55 ± 2.04
	Square	696	7.59	14.41 ± 1.09	97 107	1321.70	35.39 ± 14.61
Totals		6685	196.96		376 931	7638.30	

numbers and 36.3 percent by weight from the 45 mm square-mesh codend; a difference of 30.1 percent by numbers and 28.4 percent by weight.

The commercial prawn catch from the 38 mm square-mesh trials consisted of the grooved tiger prawn *P. semisulcatus* (61.1 percent by numbers), the red endeavour prawn *M. ensis* (28.9 percent), the brown tiger prawn *P. esculentus* (8.0 percent) and the blue endeavour prawn *M. endeavouri* (2.0 percent).

The commercial prawn catch from the 45 mm square-mesh trials consisted of *P. semisulcatus* (50.4 percent), *M. ensis* (29.5 percent), *M. endeavouri* (12.1 percent) and *P. esculentus* (8.0 percent).

Retention of *P. semisulcatus*, *P. esculentus* and *M. ensis* in the diamond-mesh codend was greater than 95 percent; for *M. endeavouri* it was as low as 22.7 percent. Retention of prawn species in the square-mesh codends was lower for all species in both sizes of square-mesh codend except for a slight increase in the percentage of *M. endeavouri* retained in the 38 mm square-mesh (25.8 percent compared to 22.7 percent in the diamond-mesh). Differences between the 45 mm square-mesh and the diamond-mesh codends were as high as 21.9 percent for *P. esculentus* and 21.6 percent for *M. endeavouri*. For all species the 38 mm square-mesh codend retained a greater percentage of prawns than the 45 mm square-mesh codend.

The overall percentage of commercial prawns lost through the codends includes individuals that are less than the preferred market size. Market-sized prawns in the NPF are known as "under 30s" (fewer than 30 individual prawns per pound by weight). The carapace lengths that equate to this preferred market-size are 26 mm for *P. semisulcatus*, 25 mm for *P. esculentus*, 26 mm for *M. endeavouri* and 29 mm for *M. ensis*.

The retention of market-sized prawns in the diamond-mesh codend was almost 100 percent. Only 0.3 percent (19) of market-sized prawns out of a total of 6 009 prawns passed through the diamond-mesh codend. The number of market-sized prawns retained in the 38 mm square-mesh codend was 99.2 percent and in the 45 mm square-mesh codend was 96.6 percent. The diamond-mesh retained 0.4 percent more market-sized prawns than the 38 mm square-mesh codend and 3.1 percent more than the 45 mm square-mesh codend (Table 5).

For all prawn species and both sizes of square-mesh the retention of market-sized prawns in the codend was greater than 95 percent, except for *M. endeavouri* in the 38 mm square-mesh codend where it was 88.9 percent (due to a small catch from which one market-sized prawn escaped through the codend).

The percentage differences between the numbers and weights of each bycatch taxon caught in the square-mesh codend compared to the diamond-mesh codend are given in Table 6.

The 55 bycatch taxa caught in ten or more paired trawls during the 38 mm square-mesh codend comparisons were used to compare catch rates between the diamond-mesh codend and the 38 mm square-mesh codend. Twelve fish species were significantly less numerous in the square-mesh codend and thirteen fish species weighed significantly less. Reduction of the fish bycatch in the 38 mm codend ranged from 56.4 percent (by numbers), 57.2 percent (by weight) for *Upeneus sundaicus* to 8.2 percent (by numbers), 7.1 percent (by weight) for *Pomadasys maculatum*. Two species — *Carangoides malabaricus* and *C. talamparoides* — showed a significant increase in numbers retained (26.6 percent and 11.7 percent respectively) but only *C. malabaricus* showed a significant weight increase (25.9 percent).

Fifty-nine bycatch taxa were caught in ten or more paired trawls during the 45 mm square-mesh comparisons. Of these 29 fish species and two invertebrate taxa were significantly less numerous in the square-mesh, and 28 fish species and three invertebrate taxa weighed significantly less. Significant reduction ranged from 69.1 percent (by numbers), 68.6 percent (by weight) for *Sillago sihama* to 9.5 percent (by numbers), 9.7 percent (by weight) for *Pomadasys kaakan*. One species of fish — *Caranx bucculentus* — showed a significant increase in numbers (13.1 percent), but not in weight, in the square-mesh.

All the commercial prawn species, M. endeavouri (24.4 percent by numbers, 26.6 percent by weight), *M. ensis* (11.6 percent by numbers, 9.2 percent by weight), *P. esculentus* (23.7 percent by numbers, 19.7 percent by weight) and *P. semisulcatus* (16.5 percent by numbers, 11.9 percent by weight) showed a significant reduction in overall numbers and weight retained in the 45 square-mesh.

Table 5. Number of prawns retained in the codend and codend cover during trials of square-mesh codends; C. sized in Cover = percentage of commercial-sized prawns in cover; Retain cover = percentage of prawns caught in the cover; C. Retain codend = percentage number of commercial-sized prawns retained in the codend.

		Diamond-mesh codend					Square-mesh codend					Difference	
Species	**Mesh size (mm)**	**Codend (*n*)**	**Codend Cover (n)**	**C. Sized in Cover**	**Retain cover (%)**	**C. Retain codend (%)**	**Codend**	**Codend Cover**	**C. Sized in Cover**	**Retain cover (%)**	**C. Retain codend (%)**	**Retain cover (%)**	**C. Retain codend (%)**
M. endeavouri	38	15	51	0	22.7	100.0	8	23	1	25.8	88.9	-3.1	11.1
M. endeavouri	45	126	334	0	27.4	100.0	20	328	1	5.7	95.2	21.6	4.8
M. ensis	38	684	18	2	97.4	99.7	675	41	5	94.3	99.3	3.2	0.4
M. ensis	45	998	26	1	97.5	99.9	857	90	29	90.5	96.7	7.0	3.2
P. esculentus	38	175	9	0	95.1	100.0	180	31	2	85.3	98.9	9.8	1.1
P. esculentus	45	266	12	0	95.7	100.0	189	67	7	73.8	96.4	21.9	3.6
P. semisulcatus	38	1513	30	7	98.1	99.5	1362	95	10	93.5	99.3	4.6	0.3
P. semisulcatus	45	1736	16	9	99.1	99.5	1409	211	50	87.0	96.6	12.1	2.9
All prawns	38	2387	108	9	95.5	99.6	2225	190	18	91.5	99.2	4.0	0.4
All prawns	45	3126	388	10	87.6	99.7	2475	696	87	71.2	96.6	16.4	3.1

Table 6. Percentage catch difference and standard error (Diff±SE) in numbers and weights between two sizes of square-mesh codends (38 mm and 45 mm) and the standard diamond-mesh codend (45 mm). The data here are of bycatch taxa occurring in more than 10 tows. – = more in diamond, + = more in square. *** = P<0.001, ** = P<0.01, * = P<0.05 and ns = no significant difference.

	38 mm square-mesh					**45 mm square-mesh**				
	Numbers			**Weights**		**Numbers**			**Weights**	
Species	**Tow**	**Diff ± SE**	**P**	**Diff ±S E**	**P**	**Tow**	**Diff ± SE**	**P**	**Diff ± SE**	**P**
Absalom radiatus	13	-7.1 ± 7.1	ns	-7.1 ± 7.1	ns	-	- -	-	- -	-
Amussiidae	22	-3.8 ± 4.6	ns	-3.7 ± 4.5	ns	31	3.4 ± 6.5	ns	4.0 ± 6.4	ns
Anodontostoma chacunda	31	1.4 ± 1.9	ns	1.4 ± 1.9	ns	38	-9.9 ± 4.0	*	-10.2 ± 4.1	*
Apistus carinatus	-	- -	-	- -	-	22	-50.9 ± 8.8	***	-53.1 ± 9.1	***
Apogon ellioti	30	-14.1 ± 3.8	***	-23.3 ± 4.4	***	38	-28.4 ± 5.4	***	-34.7 ± 5.9	***
Apogon poecilopterus	31	-20.4 ± 4.0	***	-24.3 ± 4.1	***	38	-35.0 ± 4.5	***	-41.4 ± 4.7	***
Arius thalassinus	11	5.3 ± 8.6	ns	-1.1 ± 8.7	ns	31	-7.4 ± 6.0	ns	-6.6 ± 6.4	ns
Bregmaceros sp	26	-3.6 ± 3.5	ns	-4.5 ± 4.1	ns	27	2.3 ± 4.1	ns	1.4 ± 4.8	ns
Carangoides caeruleopinnatus	16	10.7 ± 13.3	ns	10.4 ± 13.3	ns	-	- -	-	- -	-
Carangoides humerosus	28	4.9 ± 3.7	ns	4.0 ± 3.3	ns	31	-19.3 ± 4.8	***	-14.8 ± 4.5	**
Carangoides malabaricus	17	26.6 ± 11.9	*	25.9 ± 12.0	*	16	-3.8 ± 14.7	ns	3.2 ± 14.8	ns
Carangoides talamparoides	15	11.7 ± 5.4	*	8.4 ± 4.8	ns	13	-29.9 ± 12.1	*	-31.3 ± 13.2	*
Caranx bucculentus	30	8.8 ± 5.2	ns	10.1 ± 5.1	ns	32	13.1 ± 6.1	*	13.1 ± 6.9	ns
Centriscus scutatus	11	0.9 ± 11.1	ns	1.0 ± 11.2	ns	-	- -	-	- -	-
Chelonodon patoca	16	-4.3 ±7 .6	ns	-2.3 ± 7.6	ns	11	-1.0 ± 11.2	ns	0.6 ± 10.4	ns
Drepane punctata	-	- -	-	- -	-	17	-3.9 ± 5.9	ns	-3.9 ± 5.9	ns
Elates ransonetti	31	-4.0 ± 5.3	ns	-4.8 ± 5.6	ns	37	2.5 ± 5.0	ns	3.0 ± 5.1	ns
Fistularia petimba	19	-4.9 ± 5.4	ns	-4.9 ± 6.4	ns	22	8.2 ± 10.0	ns	8.3 ± 10.5	ns

Gazza minuta	18	5.3 ± 5.3	ns	5.3 ± 5.3	ns	22	-16.7 ± 6.3	*	-15.0 ± 6.1	*
Gerres filamentosus	20	-2.5 ± 5.4	ns	-2.3 ± 5.4	ns	34	-11.9 ± 4.3	**	-10.8 ± 4.3	*
Johnius volgleri	18	-5.8 ± 3.6	ns	-5.5 ± 3.5	ns	32	-27.5 ± 5.8	***	-25.7 ± 5.6	***
Johnius amblycephalus	-	- -	-	- -	-	31	-14.2 ± 5.2	*	-13.9 ± 5.2	*
Lagocephalus lunaris	-	- -	-	- -	-	11	1.9 ± 12.6	ns	0.5 ± 13.1	ns
Lagocephalus sceleratus	19	-51.3 ± 9.9	***	-52.7 ± 10.2	***	28	-50.3 ± 6.8	***	-51.8 ± 6.8	***
Leiognathus bindus	25	4.3 ± 6.4	ns	-1.3 ± 5.4	ns	32	1.7 ± 5.4	ns	-2.5 ± 7.1	ns
Leiognathus equulus	27	-0.2 ± 1.3	ns	-0.1 ± 1.1	ns	30	-3.4 ± 1.7	ns	-2.6 ± 1.4	ns
Leiognathus leuciscus	11	7.3 ± 9.7	ns	7.7 ± 9.0	ns	15	-10.1 ± 7.3	ns	-10.0 ± 7.0	ns
Leiognathus moretoniensis	31	-3.1 ± 4.6	ns	-3.4 ± 5.8	ns	38	-27.7 ± 4.9	***	-34.6 ± 4.9	***
Leiognathus splendens	31	-0.9 ± 1.2	ns	-0.8 ± 1.2	ns	37	-38.0 ± 3.8	***	-36.9 ± 3.6	***
Lutjanus malibaricus	-	- -	-	- -	-	13	-6.2 ± 10.0	ns	-3.3 ± 11.8	ns
Mene maculata	11	8.3 ± 13.9	ns	9.6 ± 15.0	ns	-	- -	-	- -	-
Mixed Crabs	18	-7.8 ± 8.5	ns	-9.0 ± 9.0	ns	16	5.6 ± 10.4	ns	5.6 ± 10.9	ns
Nemipterus hexodon	26	9.7 ± 10.3	ns	5.3 ± 11.9	ns	35	-1.8 ± 7.2	ns	-6.0 ± 7.6	ns
Paramonacanthus japonicus	-	- -	-	- -	-	11	5.1 ± 11.8	ns	7.3 ± 11.7	ns
Pellona ditchela	19	-15.8 ± 9.2	ns	-13.9 ± 9.0	ns	30	-67.0 ± 5.8	***	-66.5 ± 5.9	***
Pentaprion longimanus	31	6.4 ± 5.2	ns	9.4 ± 5.9	ns	36	-14.9 ± 5.0	**	-18.2 ± 6.0	**
Polynemus multiradiatus	13	3.4 ± 2.3	ns	2.3 ± 1.7	ns	13	-15.5 ± 10.1	ns	-16.0 ± 9.8	ns
Pomadasys kaakan	22	0.5 ± 1.7	ns	0.5 ± 1.7	ns	31	-9.5 ± 3.8	*	-9.7 ± 3.9	*
Pomadasys maculatum	31	-8.2 ± 1.8	***	-7.1 ± 1.7	***	38	-49.8 ± 3.1	***	-47.0 ± 3.2	***
Pomadasys trifasciata	31	-16.9 ± 3.2	***	-15.4 ± 3.2	***	38	-52.8 ± 4.1	***	-50.0 ± 4.1	***
Priacanthus tayenus	31	-34.0 ± 3.6	***	-33.0 ± 3.6	***	37	-54.3 ± 4.0	***	-55.2 ± 3.9	***
Psettodes erumei	23	-10.9 ± 8.8	ns	-13.8 ± 8.8	ns	19	21.2 ± 12.0	ns	16.6 ± 12.6	ns

Pseudorhombus arsius	11	18.1 ± 11.1	ns	18.0 ± 11.1	ns	20	-0.1 ± 7.1	ns	0.0 ± 6.9	ns
Rastrelliger kanagurta	10	-39.3 ± 7.9	***	-41.4 ± 8.3	***	-	- -	-	- -	-
Sardinella albella	28	-24.1 ± 6.4	***	-24.5 ± 6.8	**	35	-47.4 ± 5.3	***	-46.3 ± 5.5	***
Saurida micropectoralis	30	-13.3 ± 5.4	*	-19.2 ± 6.3	**	38	-45.9 ± 5.9	***	-55.3 ± 5.6	***
Saurida sp.2	29	-13.1 ± 6.4	ns	-18.8 ± 7.3	*	33	-32.3 ± 6.1	***	-43.1 ± 6.4	***
Secutor insidiator	19	-7.5 ± 8.6	ns	-9.7 ± 9.3	ns	17	8.4 ± 11.5	ns	8.5 ± 11.4	ns
Selaroides leptolepis	26	3.8 ± 7.7	ns	3.0 ± 8.9	ns	21	12.8 ± 12.4	ns	10.8 ± 13.0	ns
Sepioidae	11	6.5 ± 9.3	ns	7.0 ± 8.7	ns	14	-3.9 ± 11.6	ns	-3.2 ± 10.3	ns
Sillago sihama	22	-55.5 ± 7.6	***	-53.6 ± 7.8	***	33	-69.1 ± 5.5	***	-68.6 ± 5.7	***
Stolephorus sp.	28	1.7 ± 5.0	ns	3.0 ± 6.2	ns	23	5.7 ± 5.2	ns	3.0 ± 5.2	ns
Suggrundus isacanthus	13	-22.3 ± 11.4	ns	-21.8 ± 11.4	ns	23	-31.3 ± 6.9	***	-33.7 ± 7.2	***
Suggrundus macracanthus	14	-15.0 ± 10.0	ns	-20.5 ± 11.3	ns	23	-13.0 ± 8.7	ns	-15.1 ± 9.1	ns
Terapon puta	19	-43.9 ± 9.9	***	-44.3 ± 9.8	***	-	- -	-	- -	-
Terapon theraps	28	-8.6 ± 5.1	ns	-6.5 ± 5.1	ns	16	-26.0 ± 9.7	*	-22.3 ± 9.5	*
Teuthoidea	27	-13.1 ± 8.0	ns	-15.8 ± 8.3	ns	16	-35.5 ± 11.7	**	-37.4 ± 11.4	**
Torquigener whitleyi	26	-8.2 ± 4.1	ns	-7.5 ± 4.0	ns	33	-37.9 ± 6.2	***	-36.2 ± 6.2	***
Trash	-	- -	-	- -	-	22	- -	-	-20.0 ± 7.7	*
Trichiurus lepturus	-	- -	-	- -	-	10	3.4 ± 16.5	ns	6.8 ± 16.2	ns
Trixiphichthys weberi	-	- -	-	- -	-	10	9.4 ± 17.7	ns	13.0 ± 17.7	ns
Upeneus sp.	-	- -	-	- -	-	17	-35.1 ± 10.1	**	-41.5 ± 11.5	**
Upeneus sulphureus	31	1.1 ± 4.8	ns	-2.0 ± 5.0	ns	37	-26.8 ± 5.1	***	-33.1 ± 5.5	***
Upeneus sundaicus	17	-56.4 ± 9.8	***	-57.2 ± 9.8	***	22	-45.6 ± 8.5	***	-46.3 ± 8.4	***
Zoantharia sp.	17	-5.7 ± 3.9	ns	-7.9 ± 5.4	ns	24	-15.9 ± 5.8	*	-20.3 ± 6.6	**

DISCUSSION

The effectiveness of fishing gear for reducing bycatch in the NPF, was assessed by several criteria. Firstly, the modified gear should catch about the same number of commercial prawns (of market size) as the present standard gear. Secondly, it should catch significantly less bycatch. Thirdly, the bycatch that escapes should survive its encounter with the fishing gear. Lastly, the modified gear should have little effect on routine fishing activities.

In trials, both sizes of square-mesh codends met the first criterion. Although the 38 mm and 45 mm square-mesh codends retained fewer commercial prawns (4.0 percent and 16.4 percent less, respectively) than the standard diamond-mesh. Most of these were below market size. The loss of market-sized prawns was only 0.4 percent for the 38 mm and 3.1 percent for the 45 mm square-mesh codends. The 45 mm square-mesh codend was not only able to retain the equivalent number of prawns as the diamond-mesh codend, but it allowed 98 percent of smaller-than-market-sized prawns to escape and enhance the future fishable stock.

We are optimistic that Australian prawn fishers will accept the reduction in catches of the smaller prawn as Icelandic shrimp fishers have done: the loss of some 10-20 percent of their catch through was accepted because most of the shrimps were too small to use (Thorsteinsson, 1992).

Our trials have also shown that the square-mesh codends satisfy the second criteria: a significant reduction in the catch of a number of bycatch taxa. Although 45 mm square-mesh codend excluded more bycatch (30.1 percent by numbers and 28.4 percent by weight) than the 38 mm square-mesh (0.7 percent by numbers and 4.0 percent by weight), some taxa in the smaller mesh were reduced by more than 50 percent. However, some taxa were caught in larger numbers in the square-mesh than in the diamond-mesh codend.

The third criterion of effectiveness in a Bycatch Reduction Device is a high survival rate of individuals escaping from the trawl. This was generally true of escapees from the 45 mm square-mesh codends in the NPF, but varied between species (see Objective 3A). Although relevant to this criterion, work has not been done to assess the survival of prawns that escape through square-mesh codends.

The fourth criterion for assessing a Bycatch Reduction Device was that it should be easy to use without changing routine fishing activities (as Armstrong *et al.* (1990) pointed out there is little point in specifying gear designs that are unattractive to fishermen). Replacing the standard diamond-mesh codend with square-mesh codend would make very little difference to the actual operation of the trawl gear.

Possibly 'gilling' of fish would be greater in a square-mesh than in a diamond-mesh codend. As is takes extra time to remove these fish from the codend between each shot, it slows down the fishing. 'Gilling' depends on which sizes and species of fish are captured. If these individuals can be excluded from the codend by other Bycatch Reduction Devices, then 'gilling' could be reduced. However, the amount of gilling by the various codends has not been assessed for fishing operations in the NPF.

Fish 'gilling' in the codend during a tow can also block or 'blind' the meshes, which changes the net's selectivity and affects the amount of bycatch excluded. Casey *et al.* (1992) found that high catch rates of Atlantic mackerel caused 'blinding' of the meshes, but they could not detect any difference between the selectivity of the 60 mm square-mesh and 40 mm diamond-mesh codends. They concluded that square-mesh codends may conserve juveniles of certain species of groundfish, but were not likely to be effective for mackerel at normal commercial fishing densities .

All our tows during this study were of 30 minutes' duration, whereas commercial tows are more commonly for three hours. To fully assess the performance of square-mesh codends under commercial conditions it would be necessary to record the catches made during tows of between two and three hours.

BENEFITS

These results suggest that introducing square-mesh codends into the NPF would benefit most species, although a few of the bycatch species might have higher mortality rates. In relation to the Canadian groundfish fishery, Walsh *et al.* (1992) cautioned that in a mixed fishery of gadoids and flatfish, square-mesh codends may reduce the catches of small gadoids but the discards of small flatfish would be higher.

The use of a single mesh size for a fishery is a compromise, for some species will have very little chance of escape through the codend, while others will have little chance of being retained (Liu *et al.*, 1990). However, this should not be a reason to stay with the diamond-mesh codends in the NPF. The best solution may be a combination of different devices, with one device, the square-mesh codends, allowing the escape of species that cannot be excluded from the catch by other devices, and the other devices excluding species that would otherwise be caught.

Elimination of bycatch from prawn trawls in the NPF will not be achieved by any one device. A change to the square-mesh codend could be an effective and simple way of excluding of small fish from catches; it should be considered as a component of any bycatch reduction strategy. However, the optimum gear design will only be achieved through rigorous testing of each gear modification, with scientists working in conjunction with the fishers who operate in the fishery.

B2. Comparison of Bycatch Reduction Devices fitted into a standard prawn trawl codend

From the information we gathered, modified trawl-gear designs were chosen for study on the basis of their (i) applicability to Australian demersal trawl fisheries; (ii) record of success in bycatch reduction and efficiency in terms of commercial species' CPUE and (iii) potential for acceptance by the industry. These gears, their development and test procedures, and results obtained during the trials are described below.

METHODS

Gear trials

At the Australian Maritime College's flume tank, Bycatch Reduction Devices (BRDs) were fitted to full-scale prawn trawl codends and tested to ensure they functioned correctly before being tested in the NPF. Apart from giving us confidence that the BRDs would perform correctly in field trials, the tank tests enabled us to keep 'shake-down' trawls at the start of each cruise to a minimum (usually 5 paired trawls).

Gear trials were made during two month-long cruises of the MRV *Southern Surveyor* near Albatross Bay, Gulf of Carpentaria (Figure 9), in 1995. During the first cruise in February, preliminary 30 min trials were made, while during the second cruise in October, commercial length (2 h) trials were made. The second cruise used a selection of the BRDs tested in February, but with position adjustments to improve their performance and with a different combination of devices (Figure 10 a-n and Table 7).

The following BRDs were tested in February 1995: a Super Shooter, a Nordmøre grid, a fisheye, a radial escape section/large mesh funnel excluder, and four versions of square-mesh windows (Figure 10 a-n and described in detail below) — one basic square-mesh window, one with a black cylinder behind it, one made of glow netting and one with a hummer stimulator device behind it. The BRDs tested in October 1995 (described in detail below) were: an AusTED (described in Mounsey *et al.* 1995), two versions of a Super Shooter - fisheye combination, two versions of a Nordmøre grid - fisheye combination, two versions of a Nordmøre grid - square-mesh window combination (Figure 10 d, l, m & n). The differences between these devices are described below.

Gear descriptions

Trawl description: Catches from trawls with different BRDs could be compared directly with those from the standard trawl as the trawls were paired in the same tow (see sample design below). Two prawns trawls were used in a dual rig arrangement — two identical 14 fathom Florida Flyers spread by No. 9 bison boards and a sled for inner wing-end attachment. The mesh size of the trawls was 57, mm with 45 mm mesh used in the 150 x 150 mesh codend. All codends were divided into three sections 50 meshes deep, and all BRDs except the Super Shooter and Nordmøre grids were placed in the middle section, which left the lifting strops in their customary position. The Super Shooter and Nordmøre grid were placed in the first 50 mesh section.

Figure 10 (a). Side and end-on views of the Super Shooter inclined grid (reproduced from Watson *et al.* (1993))

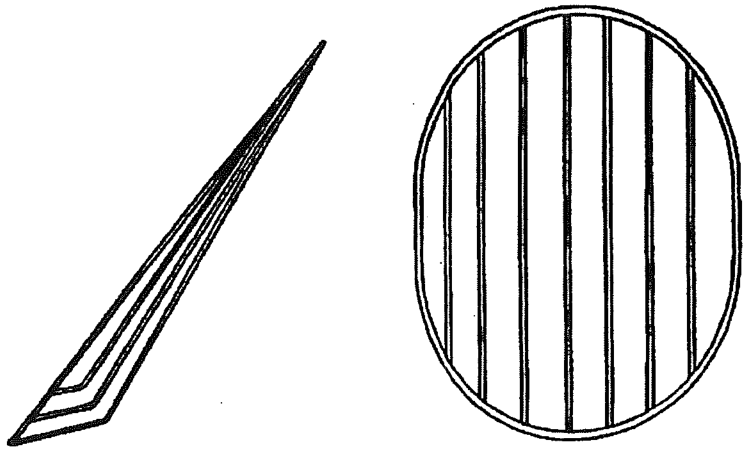


Figure 10 (b). Diagram of the Super Shooter rig used during the October 1995 cruise

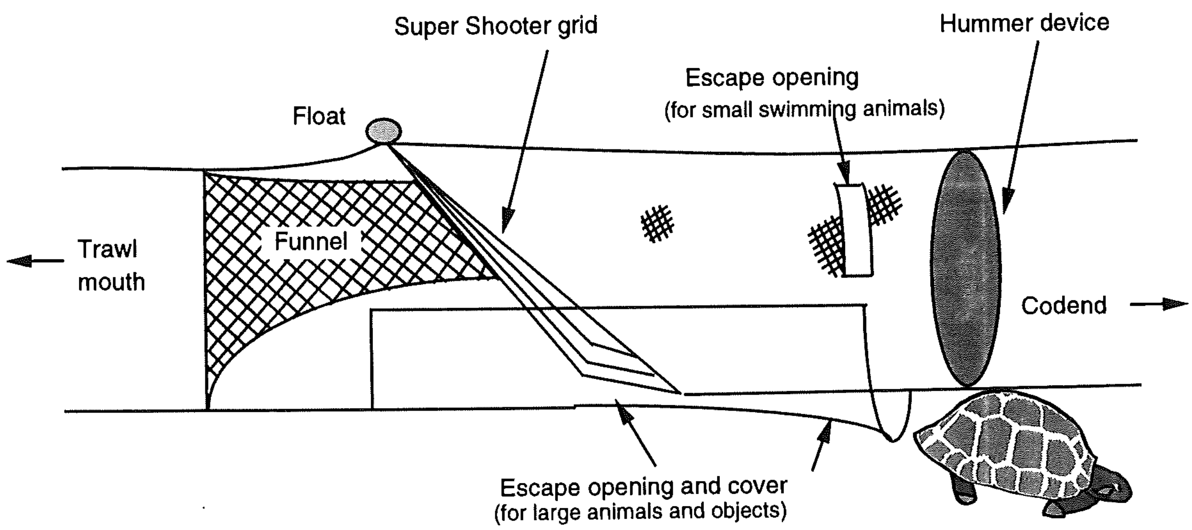


Figure 10 (c). Side and end-on views of the Nordmøre grid

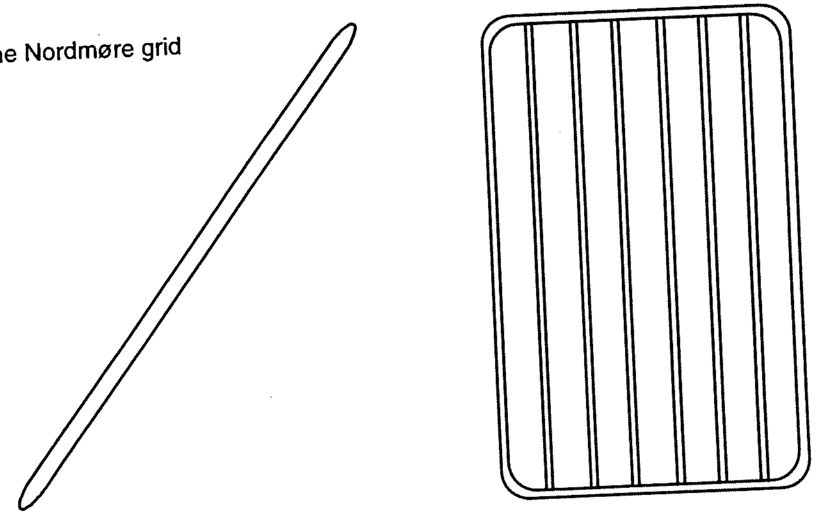


Figure 10 (d). The Nordmøre grid in a prawn-trawl codend (shown here with a fisheye)

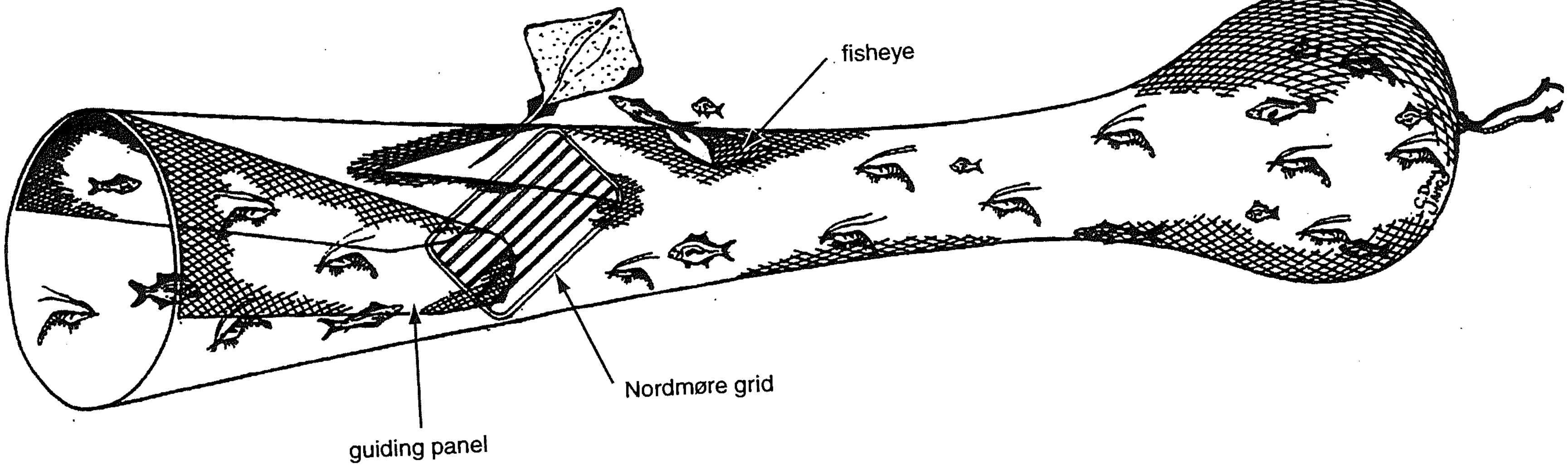


Figure 10 (e). Square-mesh window in a prawn-trawl codend

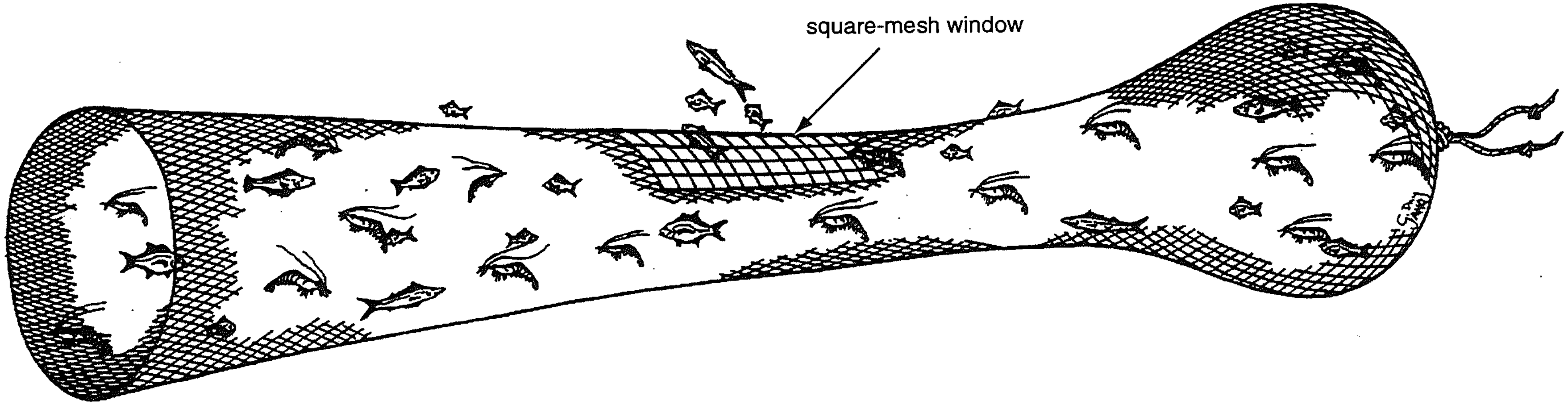


Figure 10 (f). Plain square-mesh window

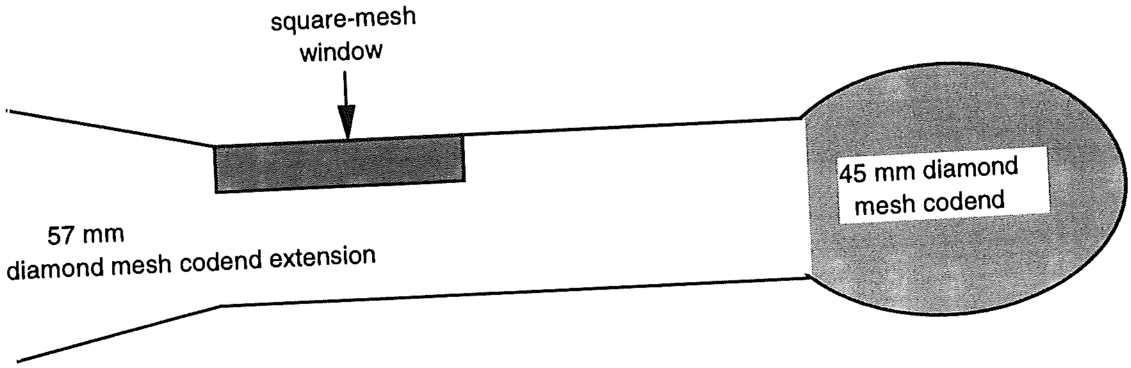


Figure 10 (g). Square-mesh window with a black cylinder fish-stimulator device

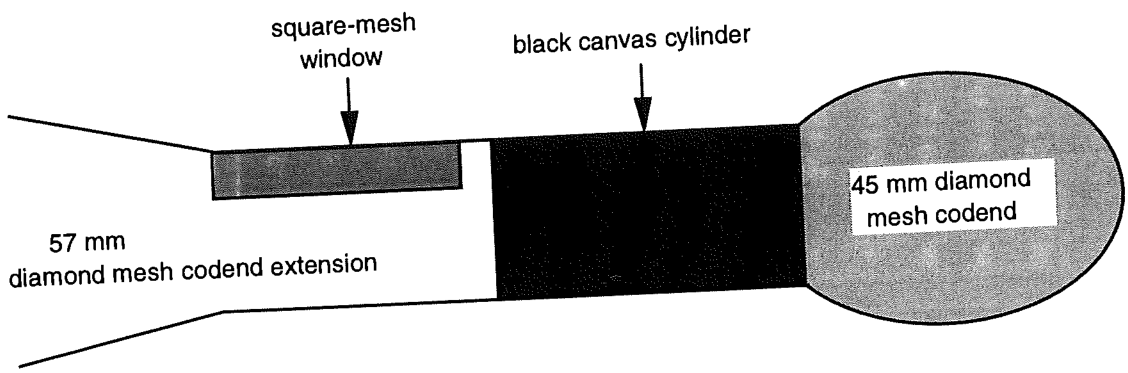


Figure 10 (h). Square-mesh window with a hummer fish-stimulator device

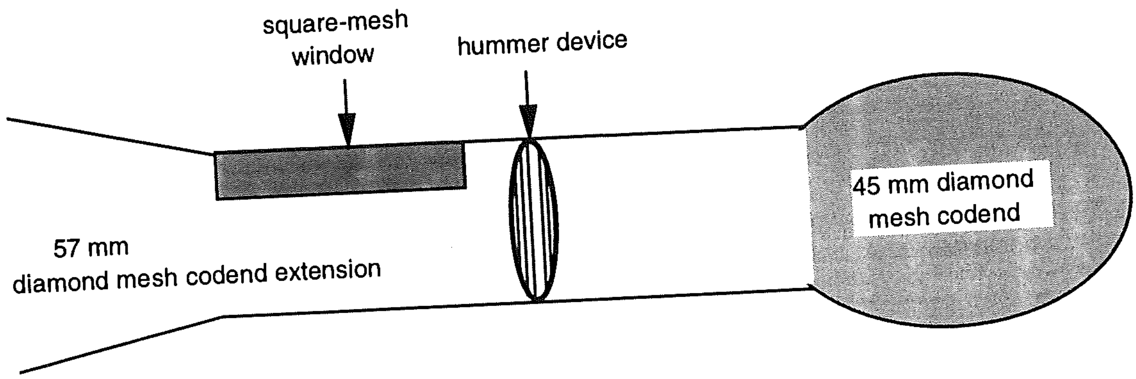


Figure 10 (i). Hummer fish-stimulatorused in the Super Shooter and one version of the square-mesh window
(reproduced from Watson *et al.* (1993))

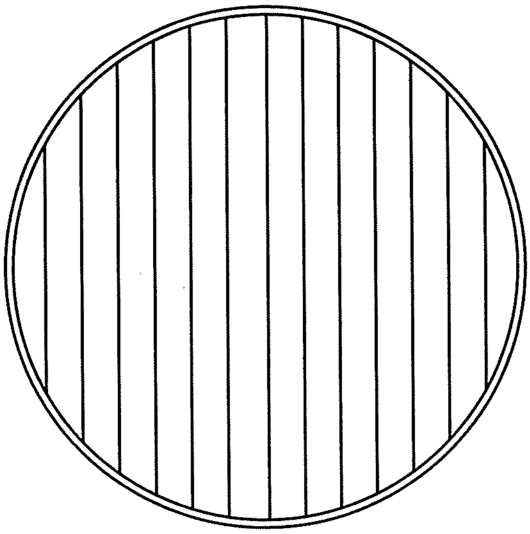


Figure 10 (j). Fisheye
(reproduced from Watson *et al.* (1993))

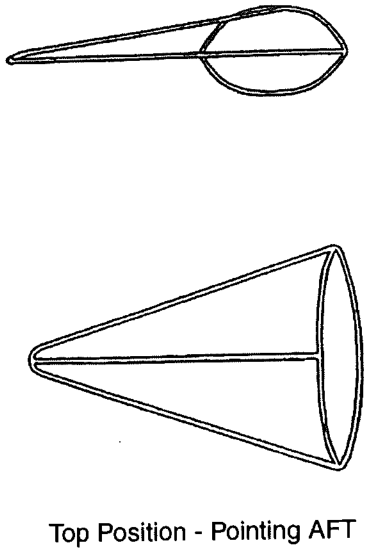


Figure 10 (k). Radial Escape Section or Large Mesh Funnel
(reproduced from Watson *et al.* (1993))

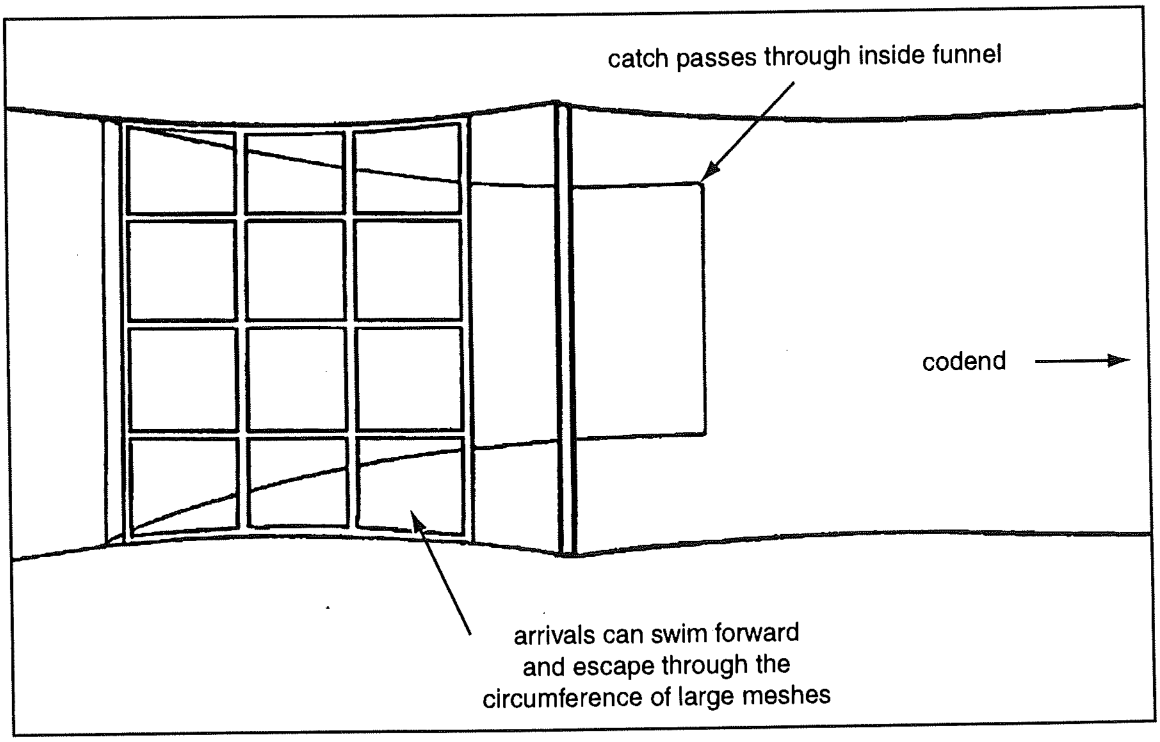


Figure 10 (I). The AusTED in a prawn-trawl codend

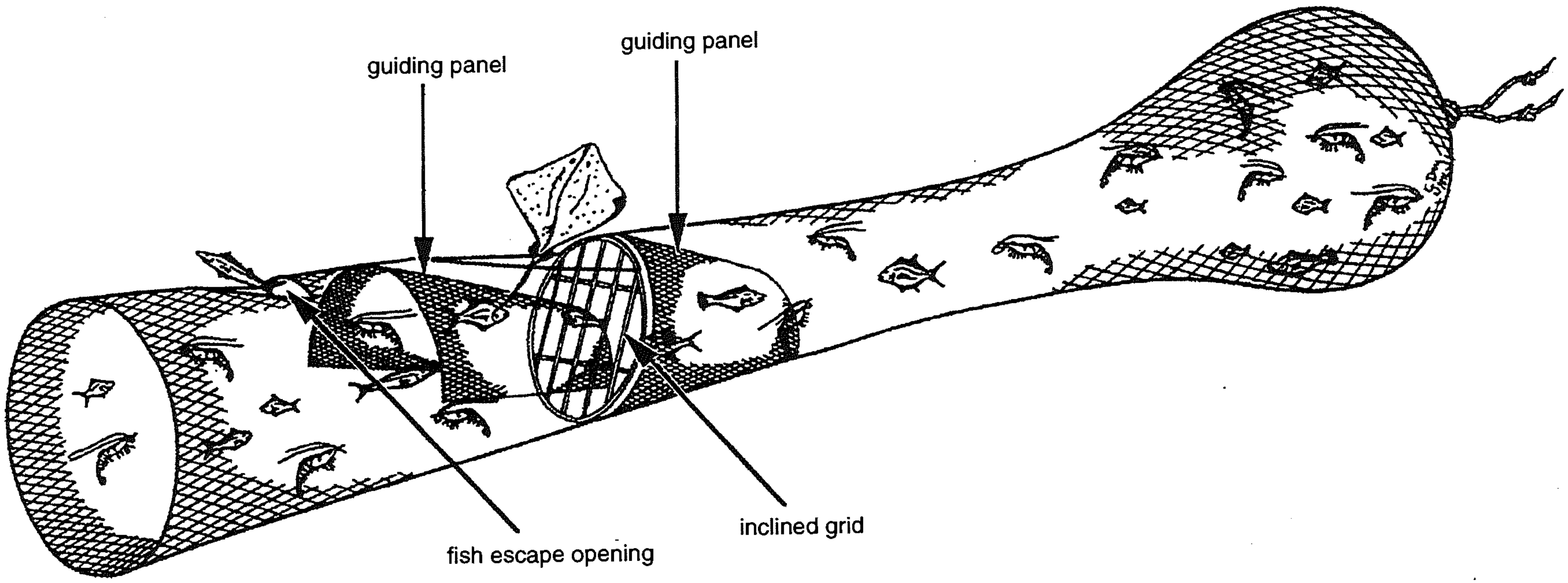


Figure 10 (m). The Super Shooter in combination with the fisheye 2 in a prawn-trawl codend

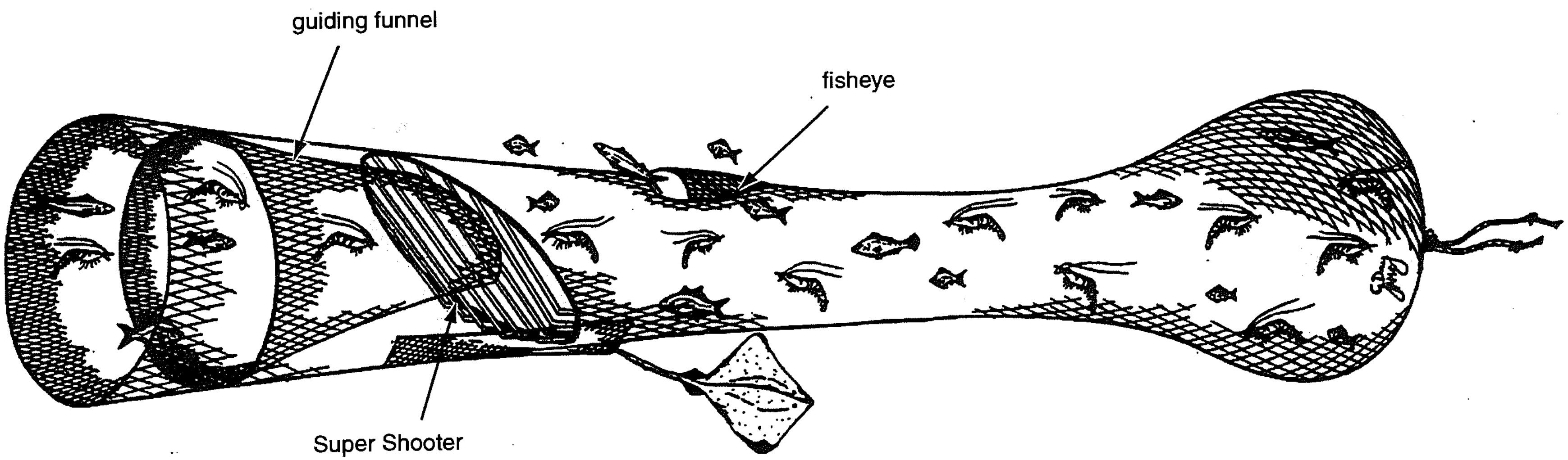


Figure 10 (n). Nordmøre grid in combination with the square-mesh window 2 in a prawn-trawl codend

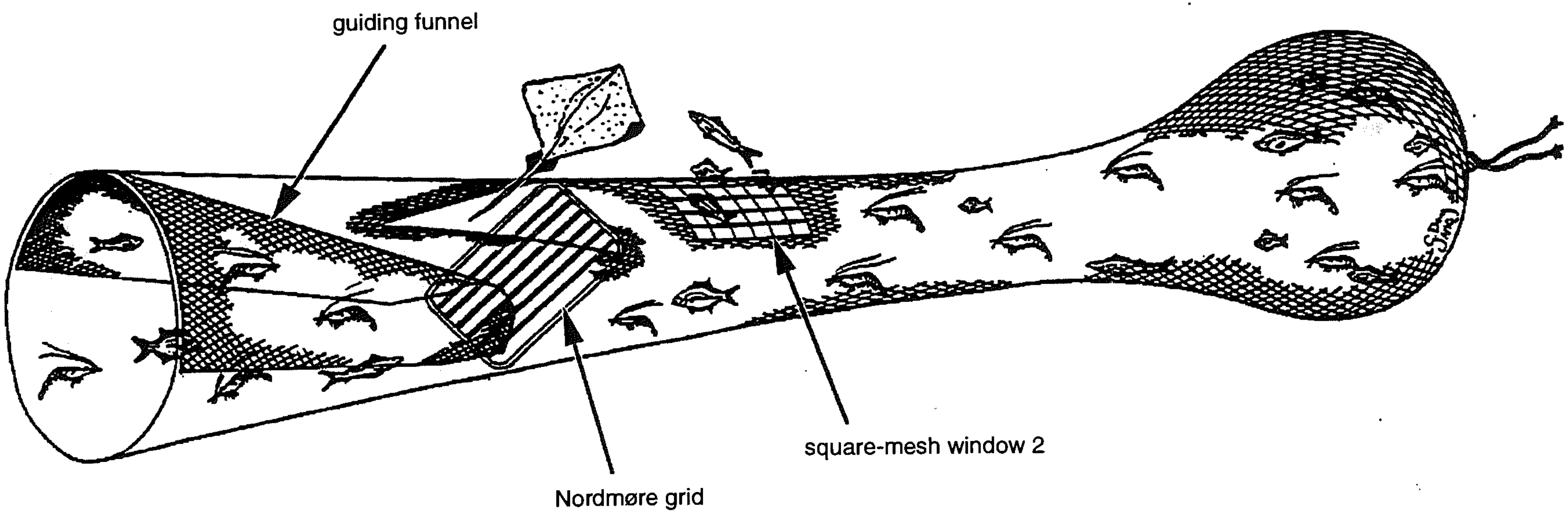


Table 7. Bycatch exclusion and prawn-catching performance of bycatch reduction devices during two cruises. The Feb '95 trials of the first cruise are separated into 2 legs: 1 = first leg in good weather; 2 = 2nd leg in rough weather. Catches that are statistically significant from the catches of the standard prawn trawl are shown thus: * = <0.05; ** = <0.01; *** =<0.001. nr = not recorded; % = percentage of catch of standard net

Bycatch reduction device	Cruise leg	No. trawls	No. large elasmobranchs (>5 kg)	No. turtles caught	Small fish excluded (% weight)	No. sea snakes caught	No. prawns caught (%)	Weight prawns caught (%)
February 1995 cruise								
Super Shooter	1	19	1	1#	0	nr	95.6	89.9
Super Shooter	2	4	0	0	1.0	nr	90.9	87.9
Nordmøre grid	1	17	0	0	3.7^{*}	nr	92.5	87.6
Nordmøre grid	2	12	0	0	8.8^{***}	nr	55.4^{***}	46.4^{***}
Fisheye	1	3	1	0	0	nr	129.8	122.4
Fisheye	2	10	0	2	4.4	nr	92.5	70.4^{*}
Radial escape section	1	20	1	2	4.7^{**}	nr	104.6	105.4
Radial escape section	2	9	1	0	7.7^{**}	nr	74.3^{*}	56.7^{***}
Square-mesh window	1	20	7	2	5.3^{**}	nr	91.5	91.6
Square-mesh window	2	10	1	0	6.6^{*}	nr	64.1^{**}	51.4^{***}
Square-mesh window + black cylinder	1	18	4	1	3.2	nr	87.4	86.7
Square-mesh window + black cylinder	2	14	2	2	6.1^{*}	nr	64.1^{***}	55.4^{***}
Square-mesh window + glow netting	1	16	2	1	3.1	nr	90.9	92.3
Square-mesh window + hummer	1	17	0	3	5.3^{**}	nr	91.4	90.4
Standard trawl	1	20	1	2		nr		
Standard trawl	2	15	2	0		nr		

turtle caught in front of excluder grid

Bycatch reduction device	Cruise leg	No. trawls	No. large elasmobranchs (>5 kg)	No. turtles caught	Small fish excluded (% weight)	No. sea snakes caught	No. prawns caught (%)	Weight prawns caught (%)
October 1995 cruise								
AusTED	–	15	3	0	26.6^{***}	3	78.0^{**}	75.2^{***}
Super Shooter + fisheye 1	–	15	3	0	16.3^{*}	8	95.4	98.2
Super Shooter + fisheye 2	–	21	0	0	13.5^{**}	12	89.5	89.4^{*}
Nordmøre + fisheye 1	–	15	1	0	30.9^{***}	8	81.0^{*}	83.3^{**}
Nordmøre + fisheye 2	–	22	1	0	27.5^{***}	6	85.3^{**}	86.1^{**}
Nordmøre grid+ square-mesh window 1	–	15	1	0	38.9^{***}	4	66.0^{***}	62.3^{***}
Nordmøre grid+ square-mesh window 2	–	22	1	0	28.4^{***}	4	83.7^{**}	84.4^{***}
Fisheye	–	15	11	4	10.7	7	89.7	92.0
Standard trawl	–	36	24	7		15		

Super Shooter

The Super Shooter was originally designed in the United States to exclude turtles from the Gulf of Mexico shrimp fishery. A funnel of netting guides the catch towards an inclined grid – at about 45° from the vertical with 100 mm bar spacing – down which large animals are guided to an escape opening in the floor of the codend (Figure 10 a & b). A flap of buoyant polyethylene netting covers this escape opening to minimise prawn loss. Behind the grid is a hummer stimulator device and side openings to allow fish escapement. The hummer is an aluminium hoop crossed with several tightly strung, parallel, thin steel wires and tied vertically into the codend. It is designed to vibrate and stimulate fish to swim forward and out through the escape openings on either side. The device was used during the February 1995 cruise but removed for the October 1995 cruise. In the February 1995 cruise the Super Shooter was used without any other secondary BRD, whereas in the October 1995 cruise the gear combinations discussed below were used with the Super Shooter.

The two Super Shooter - fisheye combinations used in the October 1995 cruise differed in the orientation of the fisheye. On both legs of the cruise it was placed 38 meshes behind the Super Shooter. On both legs of the cruise, the fisheye's elliptical opening facing forward, but on the first leg it was sewn in above the forward codend meshes, while on the second leg it was sewn in below the forward codend meshes.

Nordmøre grid

This design originated in Norway (Valdemarsen *et al.* 1993). Our version had a 1100 mm x 900 mm inclined aluminium grid angled at about 40° from the horizontal with a bar spacing of 100 mm (Figure 10 c & d). We chose this low grid angle to improve sponge and debris exclusion. A panel of netting guided the catch towards the bottom of the grid. Large animals (most commonly turtles, sharks and rays) and some small animals contact the grid and escape through a triangular opening in the codend at the top of the grid. Smaller species such as prawns can pass through the grid into the codend. In the February 1995, cruise the Nordmøre grid was used without any other secondary BRD, whereas in the October 1995 cruise the gear combinations described below were used with the Nordmøre grid.

The two Nordmøre grid - fisheye combinations used in the October 1995 cruise differed in the orientation of the fisheye. In both designs the fisheye was placed 38 meshes behind the grid, but the elliptical opening of the fisheye was either below the level of the codend extension (1st leg of the cruise) or above the level of the codend extension as in Figure 2a (2nd leg of the cruise).

The two Nordmøre grid - square-mesh window combinations used in the October 1995 cruise differed in the positioning of the square-mesh window. It was either inserted directly behind the inclined grid (1st leg of the cruise) or inserted 10 meshes of standard diamond-mesh codend material behind the inclined grid.

Square-mesh window

Square-mesh windows have been investigated as a means reducing the bycatch of small fish since the early 1980s (e.g. Robertson 1983, 1984), and were first studied in penaeid fisheries in 1992 (Broadhurst and Kennelly 1994). The device we used was a 150 mm (6") polyethylene square-mesh netting panel (8 bar lengths wide by 13 bar lengths long), in the middle 50 mesh section of the codend (Figure 10 e). Small animals that can swim strongly can escape upwards out of this window, while most of the poorer swimmers (e.g. prawns) pass into the codend.

Three other variations of the square-mesh window were also tested. One had a window of square-mesh netting that glows green in the dark (developed by Japanese net manufacturers Nichimo), highlighting the window at night. Another had a 1.5 m long canvas black cylinder just behind the window (Figure 10 g) (see Glass and Wardle 1995 and Glass *et al.* 1995). And another had a hummer stimulator device placed 5 meshes behind the window (Figure 10 h, i) (as used for the Super Shooter). The black cylinder and hummer stimulator devices were designed to stimulate fish to turn and swim forward, and so improve their chances of escape through the nearby square-mesh window.

Square-mesh windows on their own were used only during the February 1995 cruise, although they were used as secondary BRDs (in combination with another BRD) during the October 1995 cruise.

Fisheye

The fisheye (named from its shape) was developed for the Gulf of Mexico shrimp fishery (Watson *et al.* 1993). It is a steel frame, which is sewn into the top of the codend to provide a small elliptical opening for fish to escape (Figure 10 j). Animals pass into the codend and must turn to swim forward and upwards to escape through this device.

Fisheyes were used on their own during both cruises and were used in combination with the Super Shooter and the Nordmøre grid during the October 1995 cruise (Figure 10 d & m).

Radial escape section (RES)

The RES (also known as the 'Large mesh/funnel excluder') was developed by Watson and Taylor (1988). The version we used consisted of a small mesh webbing funnel surrounded by a radial section of large mesh (9'' square-meshes 3 bars wide) (Figure 10 k). The funnel was designed to guide the catch past the square-mesh section of codend. Stronger-swimming animals can then turn around, swim forward between the funnel and codend, and out through the large square-meshes. The RES has a wire hoop encased in plastic to support the codend at the aft end of the funnel. This ensures that the meshes stay open during the tow, but it is flexible enough to withstand the rigours of trawling.

The RES was used only during the February 1995 cruise.

Data collection

The catch-sampling procedure involved weighing the entire catch, removing all large animals (greater than about 1 kg) and, removing all commercially important prawns, if the catch was greater than about 50 kg, a subsample of the remaining catch was taken and processed. Each large animal was identified to species, weighed and measured (standard length [SL] for fish, total length [TL] for sharks and sea snakes, disc width for rays and carapace length for sea turtles). The remaining catch (or the subsample) was sorted and identified into species groups, each species group was counted and weighed, and individual animals measured (as described above). Commercially important prawns were sorted and identified into species groups, and each species group was counted and weighed.

The species composition of the catch was determined by adjusting the weights and numbers of the subsample's species composition by the appropriate factor to match the total weight of the catch.

Differences in the catching performance of the codend designs were measured by comparing catches of animals retained by each codend with those from the standard prawn trawl. Separate comparisons were made for commercially important prawns, small fish bycatch, large animals (>5 kg), sea turtles, and sea snakes (reliable data from the October cruise only). Animals greater than 5 kg (usually rays and sharks) warranted a separate category because these animals – known as monsters – are large enough to cause considerable damage to prawns, decreasing their value.

SAMPLE DESIGN AND DATA ANALYSES

We needed to compare the performances of the Bycatch Reduction Devices within the time constraints of the month-long cruises. The performance criterion to assess each device was that it retained as many prawns as possible, while substantially reducing the quantities of bycatch caught in the trawl.

Using a twin-gear arrangement, we were able to test two devices during each trawl. This is useful, as the difference in catch between two simultaneous shots with the same gear is likely to be much smaller than the difference in catch between shots at different times and in different places.

A traditional approach would have been to compare each device against the control, possibly switching sides at random to reduce bias due to any systematic differences in the efficiency of the two nets. This limits the number of shots for each device to the total number of trawls that can be achieved in the time available divided by the number of devices to be tested. It also means that the experimental devices are never compared directly, so the standard error of the difference between any two experimental devices is much larger that it need be.

Balanced semi-systematic incomplete blocks for comparing Bycatch Reduction Devices:

We decided to treat each trawl as a 'block' with 2 'units' (Cochran and Cox, 1957; Snedecor and Cochran, 1980) and allocate pairs of devices in such a way that all possible combinations were tested. For example, device A was paired up with B, C, D,... etc and the control, an equal number of times. With 4 devices, there are 6 possible combinations: AB, AC, AD, BC, BD, CD. To test 10 devices in the preliminary trials, 45 trawls were required to complete all the combinations.

To allow for any systematic difference in catch between the port and starboard nets, we attempted to balance the number of times that any particular device was attached to a given (port or starboard) net. Furthermore, we needed to minimise the time required to change devices on the trawls, and therefore the time between trawls. We therefore designed a sequence of trawls that required only one change of device between trawls, alternating between nets for consecutive trawls. This meant that a given device would be present on one particular net for two consecutive trawls. An example of the sequence is given below:

Port	A	A	C	C	E	E
Stbd	B	F	F	D	D	G

To test all combinations it was not always possible to limit the change to one net, and some trawls required the devices on both nets to be changed, but this was kept to a minimum.

For repeat sequences, randomisation was necessary. This was achieved by re-allocating the devices to different treatment codes. For example, the Square-Mesh Window was assigned the code A in the first round of trials, but in subsequent rounds it may have been assigned as code F and the code C. All devices were re-allocated codes in the same way and this set up a completely different order of combinations for each round of trials.

Statistical models

Analysis of variance was used to analyse the catch data. The following model was used to describe the catch:-

CATCH = NIGHT NET NET(NIGHT) TRAWL(NIGHT) GEAR

where NIGHT is the mean catch for each the device tested, NET is the mean catch from each side of the paired trawl (either port or starboard), NET(NIGHT) is the mean catch from each side of the paired trawl for each night, TRAWL(NIGHT) corresponds to the mean catch of each trawl (an estimate of what the catches would have been if all gears could have been tested in every trawl) and GEAR is the mean catch associated with each Bycatch Reduction Device.

The catch from one side of the paired trawls was sometimes lost or the net did not perform properly; for example, sharks bite holes in the codend. In such cases, the combination was repeated, ensuring the integrity of the design. This formed the basis of the first analysis.

The data were analysed by fitting a linear model PROC MIXED (SAS, 1989), including all the factors to describe the catch (as detailed above).

Percentage differences in performance between the devices and the standard codend were obtained by using the least-square means catches for each device in the following formula:

$$\text{Percent Reduction by Device} = \frac{\text{Mean Catch by Control} - \text{Mean Catch by Device}}{\text{Mean Catch by Control}} \times 100\,\%$$

The weather during the first cruise was dramatically different between the first two weeks (calm seas, Beaufort Wind Force 0 to 3) and the second two weeks (very rough seas, Beaufort Wind Force 7 or 8). Preliminary analysis of the data showed much higher variability in catch data in the 2nd leg – weeks 3 and 4 of the cruise – so BRD performances were analysed separately for each of the two legs. The October cruise data were analysed for the whole month.

RESULTS

General results

From the February 1995 cruise, the data from 120 paired, 30 min trawls (240 samples) were analysed: 83 paired trawls during leg 1 of the cruise and 37 paired trawls during leg 2. From the October 1995 cruise, data from 87 paired commercial-length (2 h) trawls (176 samples) were analysed. A total of 1150 kg of commercially important prawns and 18900 kg of fish bycatch were caught from all trawls during the February cruise, and 900 kg of commercially important prawns and 14100 kg of fish bycatch were caught in the October cruise. The ratio of fish bycatch weight to commercially important prawn weight, measured from the standard prawn net only, was 19.4:1 in February and 15.7:1 in October.

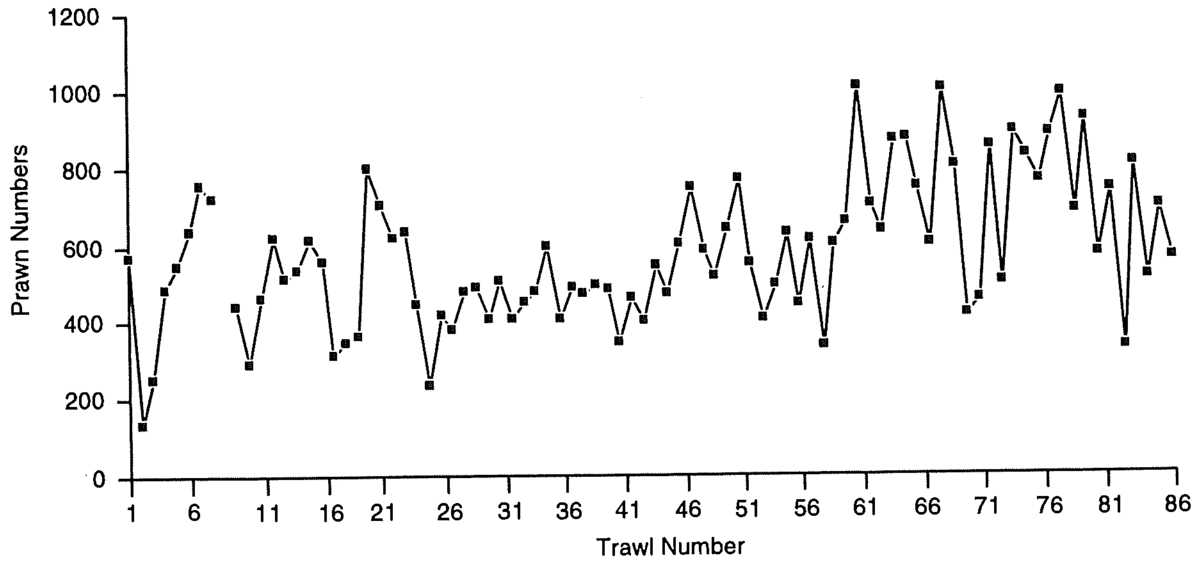
The terms NIGHT and TRAWL(NIGHT) provide information on the variability of the catch in time and space (environmental factors). These were highly significant for the numbers of prawns ($P<0.001$), the weight of prawns ($P<0.001$) and the weight of bycatch ($P<0.001$). These results correspond to large differences in catch between nights and also within nights (see Figure 11).

The terms NET and NET(NIGHT) provide information on the performance of the net (either port or starboard) to which the BRD was attached: the first term is the overall difference between port and starboard nets over the whole series of trawls, and the second term is the extent to which the difference between the nets fluctuated from night to night. The term NET was highly significant for the numbers of prawns ($P<0.001$), the weight of prawns ($P<0.001$) and the weight of bycatch ($P<0.001$), whereas the term NET(NIGHT) was completely non-significant. This combination of results corresponds to a substantial difference in catch between the nets, which remained more or less constant over time. Differences between the por' and starboard net during the October cruise were 55.7 ± 12.8 for numbers of prawns, 2.3 ± 0.4 kg for weight of prawns and 33.6 ± 6.8 kg for weight of bycatch. Catches in the port net were greater.

Given the size of the variation for the environmental factors and the difference between nets, these trials would have had a low power to discriminate between test codends in terms of their catch performance had not this statistical design been used.

The term GEAR provides information about the performance of each of the different Bycatch Reduction Devices. This was highly significant for the numbers of prawns ($P<0.001$), the weight of prawns ($P<0.001$) and the weight of bycatch ($P<0.001$), indicating that there as a considerable range in the performance of all the devices (though some were more or le^s identical).

Figure 11. Mean number of prawns caught in each paired trawl during October 1995 cruise, excluding the effects of each device.



Prawn catches

During the February 1995 trials, prawn catches were dominated by the banana prawn – *Penaeus merguiensis* – (46 percent by weight) and the grooved tiger prawn – *Penaeus semisulcatus* – (44 percent by weight). The other commercially important prawns caught were *Metapenaeus endeavouri* (2.9 percent), *P. monodon* (2.2 percent), *M. ensis* (1.1 percent), *P. esculentus* (0.8 percent), *P. latisulcatus* (<0.1 percent) and *P. longistylus* (<0.1 percent). Commercially unimportant species, mainly *Trachypenaeus* spp. and *Metapenaeopsis* spp., made up less than 3 percent of prawn catches by weight.

In the commercial-length trials of October 1995, prawn catches were dominated by the grooved tiger prawn – *Penaeus semisulcatus* – (58 percent by weight) and the red endeavour prawn – *Metapenaeus ensis* – (34 percent by weight). The other commercially important prawns caught were *P. esculentus* (2.2 percent), *M. endeavouri* (1.2 percent), *P. merguiensis* (0.2 percent), *P. latisulcatus* (0.1 percent) and *P. monodon* (0.1 percent). Commercially unimportant species made up less than 4 percent of prawn catches by weight.

During the 30 min trials (February 1995) prawn retention varied with weather conditions. On leg 1, during good weather, the prawn catches of the BRDs and the standard net were not significantly different (Table 7). The fisheye and radial escape section both caught more prawns, while the other BRDs retained between 86.7 percent and 95.6 percent of the standard net's prawn catches. Four devices – Nordmøre grid, radial escape section, square-mesh window and square-mesh window with hummer – had statistically the same prawn catches and a significant, although small, reduction in small-fish bycatch. However, during rough weather in leg 2, the retained catch from 4 of 6 devices – Nordmøre grid, radial escape section, square-mesh window and square-mesh window with black cylinder – dropped to below 75 percent of the catch caught by the standard net (a significant difference). Although comparative data were collected from only 4 trawls of the Super Shooter, it was the only BRD to have statistically the same catch as the standard net in rough weather; the fisheye did not catch significantly fewer prawns, but did catch significantly less. However, these data were also based on relatively few trawls for each device on both legs.

During the commercial-length trials (October 1995), there was no significant prawn loss from codends with the Super Shooter + fisheye 1 or the fisheye on its own (Table 7). The Super Shooter + fisheye 1 lost less than 5 percent of the standard trawl's prawn catches. The Super Shooter + fisheye 2 produced significant losses of prawn weights, but not prawn numbers. The AusTED, Nordmøre grid + fisheye and Nordmøre grid + square-mesh windows had significantly lower catches of prawns . However, fewer prawns were lost from the Nordmøre + fisheye and the Nordmøre + square-mesh window after modification.

Fish catches

The fish bycatch from each cruise was made up of over 250 species, most weighing less than 300 g. The species composition, which is not described here, consisted of a wide variety of species similar to that described by Blaber *et al.* (1990), Ramm *et al.* (1990) and Martin *et al.* (1995). Details of the bycatch species composition can be obtained from the authors.

In the 30 min trials (February 1995), small, though statistically significant reductions in small-fish catches were made when the net was fitted with the Nordmøre grid, radial escape section, square-mesh window, square-mesh window with hummer device and, in poor weather, the square-mesh window with a black cylinder (Table 7). However, during these trials, no BRD reduced the catch of small fish by more than 9 percent.

During commercial-length trials (October 1995), small-fish exclusion by most devices was greatly improved. The highest exclusion was achieved by the Nordmøre grid + square-mesh window, but the Nordmøre grid + fisheye and the AusTED also excluded more than 26 percent of small fish bycatch. The Super Shooter + fisheye excluded about half of this amount (13.5 percent – 16.3 percent) of small fish bycatch. There was no significant reduction in the amount of small fish in catches using the fisheye alone.

Large–animal catches

In the 30 min trials (February 1995), the catch of large animals heavier than 5 kg, or 'monsters', consisted of 16 sea turtles (all flatback turtles, *Natattor depressa*), and 23 elasmobranchs — 17 stingrays (including 12 *Himantura toshi*), 3 sharks, and 3 sharkfin guitarfishes.

In the commercial length trials (October 1995), the catch of 'monsters', consisted of 11 sea turtles (8 flatbacks, *N. depressa*; 2 loggerheads, *Caretta caretta*; and 1 Olive Ridley, *Lepidochelys oliva*), 2 sciaenid fishes and 43 elasmobranchs. The elasmobranchs consisted of 27 stingrays (including 18 *H. toshi*, and 4 *Pastinachus sephen*), 14 sharkfin guitarfishes (12 *R. djiddensis* and 2 *R. ancylostoma*), 1 shovelnose ray (*Rhinobatus typus*), and 1 sawfish (*Anoxypristis cuspidata*).

In the 30 min trials (February 1995), the 52 trawls with inclined excluder grids (Super Shooter or Nordmøre grid) caught 1 sea turtle (caught forward of the excluder grid) and only 1 large elasmobranch (a ray caught in a trawl using a Super Shooter). The 172 trawls from the 7 codends without inclined excluder grids caught 15 turtles (1 every 11 trawls), and 22 large elasmobranchs (1 every 8 trawls).

During the commercial-length trials (October 1995), no sea turtles were caught when inclined excluder grids were used (125 trawls), whereas without these grids (51 trawls) 11 sea turtles were caught (1 every 4.6 trawls). Nets with inclined excluder grids caught 10 large elasmobranchs (1 every 12.5 trawls), while nets without inclined excluder grids (fisheye and standard trawl) caught 35 (1 every 1.5 trawls).

Seasnake exclusion

A total of 67 sea snakes were caught in codends during the 2 h trials; they were caught in all 9 of the BRDs being compared. The lowest catch rates were in codends containing the AusTED (1 every 5 trawls) and the 2 Nordmøre grids with a square-mesh windows (1 every 4 or 5 trawls). The other 5 devices performed the same or slightly worse than the standard trawl, catching about 1 sea snake every 2 trawls.

Video evidence

During both cruises, video data was collected to increase our knowledge of the reactions of prawn and bycatch species to trawl nets and to BRDs. Most of the footage was collected during the day, but still provided valuable information on how they react to BRDs and how changing a BRD can improve its performance. These data have not been quantitatively assessed, but our observations are reported here to aid the discussion of BRD performances.

Animal survival

A detailed report of the survival of small-fish escapees from square-mesh devices is presented in Section 3A. This is the only study of survival of trawl escapees made in tropical waters.

The only other observations on survival of animals from prawn trawls were made of sea turtles and sea snakes during the 2 h trawls on the October 1995 cruise. These animals were removed from the catch, and if they were alive were held on deck to recover before being returned to the water. During this cruise, six out of eight sea turtles (75 percent) and 31 of 52 sea snakes (60 percent) were released alive. The two turtle deaths were both loggerhead sea turtles (*Caretta caretta*) and the six survivors were all flatback turtles (*Natattor depressa*). The sea snakes released alive were 15 of 31 *Hydrophis elegans*, 9 of 10 *H. ornatus*, 6 of 10 *Lapemis hardwickii* and 1 unidentified species.

DISCUSSION

Preliminary trials

In the 30 min trials, most BRDs showed marked differences in prawn retention between legs 1 and 2. The prawn losses in leg 2 occurred in weather that is unworkable for most of the NPF trawler fleet, but not for the 77 m CSIRO research vessel, Southern Surveyor. We would not expect such prawn losses to occur when the trawls are working along the sea bed. Rather, catch loss is more likely, and often observed, when the trawls are on the surface after retrieval. In our study, prawns and some bycatch may have gone out the BRD openings during heavy surging of the sea before the net was hauled on deck. Furthermore, one net was surface-towed in heavy seas while the other was being hauled and emptied, thus increasing the catch loss at this stage of the operation. Loss of prawns during haulback delay has been recorded in NSW prawn trawling (Broadhurst and Kennelly 1996a). It appears, therefore, that the prawn losses on leg 2 of the February cruise were probably a result of weather and of operational conditions that are not normal in this fishery; these data should not be used to assess BRD performance. This problem was addressed in the 2 h trials in October by retrieving the two codends onto the deck at the same time and by not trawling if the weather was worse than 'Force 7'.

Leg 1 of the short trials produced promising prawn retention results for most BRDs but only low rates of exclusion for small-fish bycatch. The two devices with inclined grids in leg 1 had no significant loss of prawns and excluded all turtles and nearly all other 'monsters' from their catches. These results, along with video evidence of how animals reacted to BRDs, enabled us to change the configuration of selected devices to give better performance in the 2 h trials in October.

Commercial-length trials

The results of the commercial-length trials are more strongly emphasised than the preliminary trials for the following reasons:

- commercial-length trials are more representative of BRD performance under commercial conditions
- the problems arising from haulback delay during the short trials had been resolved for the commercial-length trials
- BRDs were adjusted before the commercial-length trials, which eliminated some of the inefficiencies encountered in the first trials in the NPF

The commercial-length trials enabled us to select the most promising devices that warranted further study, thereby reducing the number to be tested.

In short, the commercial-length trials are more representative than the short trials of how the BRDs might perform in the NPF on commercial boats, and so the remaining discussion will focus on these results.

The bycatch during these two cruises was typical of the NPF in being mainly of small fish. This bycatch is made up of more than 200 species (typically more than 50 species in each trawl) and, as in other areas of the Indo-west Pacific, most of these fish are of the same size ranges as the commercially important prawns. This makes excluding fish bycatch based on size selectivity more challenging than if the fish and prawns were different sizes. Several of the BRDs are designed to work by allowing escapement based on the differences in behaviour of bycatch species and prawns, such as the superior swimming ability of most fish.

The bycatch to prawn ratio varies throughout the NPF between 8:1 and 21:1 depending on the fishing ground (Pender *et al.* 1992). During our study, this ratio was toward the higher end of this range (19.4:1 and 15.7:1), due to high fish abundances that are characteristic of the Albatross Bay region (Blaber *et al.* 1994). This area is also known to have relatively high numbers of monsters, so the catch rates for sea turtles (1 every 4.6 trawls) and large elasmobranchs (1 every 1.5 trawls) are also likely to be higher than in most areas of the NPF.

Exclusion of small fish

A number of BRDs were able to reduce the weight of unwanted small-fish bycatch by between 15 and 40 percent, and one of these devices — the Super Shooter — also showed no significant loss of prawns. In a previous study, we showed that 45 mm square-mesh codends can reduce the catch of unwanted fish bycatch by 22 percent without significant loss of commercial-sized prawns (see Objective 2, Section B1). Further development of BRDs to reduce the small-fish bycatch is likely to increase these exclusion rates for the NPF.

Scientists at the NSW Fisheries Research Institute who have been studying the reduction of fish bycatch from prawn trawl fisheries since 1991, have achieved exclusion rates of between 23.5 percent and 41 percent in the NSW oceanic prawn trawl fishery (Broadhurst and Kennelly 1996). This level of exclusion should be achievable in the NPF, but even a 20 percent reduction through adoption of BRDs would translate to an annual reduction of 14,000 t of fish bycatch from prawn trawl catches.

The most promising devices for improving small-fish bycatch reduction in the NPF appear to be square-mesh panels or windows, fisheyes and square-mesh codends. However, some of the inclined grids, such as the Nordmøre grid or AusTED, also have shown their ability to reduce unwanted fish catches and have the potential to be highly effective BRDs if their prawn loss could be reduced without diminishing their fish-exclusion ability.

Exclusion of monsters

This study has shown that several varieties of inclined grids are capable of virtually eliminating catches of sea turtles and greatly reducing catches of large elasmobranchs. This study has also shown that the Super Shooter can maintain catches of the target species of prawns. There is unpublished evidence that modified versions of the Nordmøre grid and AusTED are also capable of maintaining prawn catches while excluding monsters from trawl catches.

The catching and killing of sea turtles in prawn trawls has become a sensitive issue. The evidence from this study shows that full adoption of BRDs could reduce the annual capture of sea turtles from about 5000/y (estimated by Poiner and Harris 1996) to virtually zero. Poiner and Harris (1996) also estimated that a proportion of the turtles drown in trawls (less than 1000/y); these deaths would also be eliminated with the full adoption of BRDs. Although it is possible that turtles may still be damaged from the encounter with the trawl or BRD, the introduction of BRDs would greatly improve the current situation.

Catches of other monsters would also be greatly reduced with the full adoption of BRDs by the NPF fishery. That in turn should reduce the number of prawns crushed by these animals, but this is still yet to be quantified. Other advantages include fewer problems sorting the catch, less damage to trawl gear and less impact on the demersal community.

A potential problem with using inclined grid BRDs is that the grid can be temporarily blocked by animals or plants allowing prawns to escape through the BRD. This problem can usually be avoided by setting up the BRD correctly or by using a BRD better suited to the fishing conditions.

Sea snake exclusion

Sea snakes are common in NPF trawl catches. Wassenberg *et al.* (1994) estimated that about 120,000 sea snakes (of 14 species) were captured in the 1991 prawning season in the Gulf of Carpentaria alone. We have shown that certain BRDs (e.g. Nordmøre grid – square-mesh panel combination or AusTED) can reduce catch rates of sea snakes by more than half. Qualitative video evidence also shows that sea snakes are capable of using square-mesh panels to escape from prawn trawls once captured. This study and Wassenberg *et al*'s. (1994) both recorded a 60 percent survival rate of sea snakes captured in prawn trawls in the NPF. If these BRDs are fully adopted into the NPF, the number of sea snakes caught would drop to about 60,000/y and the number of sea snake deaths would be halved from 48,000/y to less than 24,000/y in the Gulf of Carpentaria.

Prawn retention

In the commercial-length trials, only the Super Shooter + fisheye combination and the fisheye on its own caught the same amount of prawns as the standard codend with no BRD. The square-mesh codends study reported in Objective 2, Section B1, also did not lose commercially important prawns, while all the other BRDs tested, did.

Modifications of these devices should improve their prawn retention, judging by the Nordmøre grid + fisheye and the Nordmøre grid + square-mesh window combinations. In both cases, a few minor changes in their setup resulted in greatly improved performances in the second versions (Table 7). This style of incremental improvement will continue in future trials, and would also continue as part of the routine fine-tuning of trawl gear by fishers in the NPF.

BENEFITS

This study has shown that there are BRDs that can be of major benefit to prawn trawl fishers in the NPF, by effectively excluding unwanted bycatch while maintaining catches of commercially valuable prawns. Some of these devices could be used successfully in their present form — such as the Super Shooter — while others need some fine-tuning to improve prawn retention or decrease bycatch.

There are other benefits of using these BRDs:

- no or fewer sea turtles in catches
- fewer small fish to be sorted from catches
- fewer monsters and therefore fewer damaged prawns in catches, thereby increasing the value of the catch
- fewer under-commercial-sized prawns in catches, thereby enhancing future stocks
- decreased fishing impacts on bycatch species, which helps to maintain ecological biodiversity and resilience of these demersal communities.

Furthermore, voluntary adoption of BRDs by the Northern Prawn Fishery may avoid involuntary adoption which could happen, given the current pressures from community, conservation and trade bodies; such pressures can influence fisheries management decisions.

OBJECTIVE 3.

- **Investigate the survival of and damage to animals that escape through Bycatch Reduction Devices**

A. Survival of selected tropical prawn trawl bycatch species after escaping through square-mesh codends

INTRODUCTION

Ecologically sustainable development is becoming a goal for fisheries managers throughout the world. To achieve it, the bycatch must be reduced to avoid killing commercially or recreationally important species; to avoid removing organisms from the food chain that are beneficial to the target species; to avoid killing rare and protected animals such as turtles; to avoid criticism of the stranding of large numbers of dead fish; to reduce the sorting time between trawls to improve product quality; to reduce fuel costs by lessening the drag from the bycatch in the trawl; to increase the efficiency of the trawl, which might enable tows to be longer and the catch to be cleaner with fewer crushed prawns or shrimps (Andrew and Pepperell, 1992; High *et al.* 1969).

The Northern Prawn Fishery (NPF hereafter) is one of the most valuable fisheries in Australia, with an annual production between 8 000 and 10 000 tonnes (Pownall, 1994). It also catches large quantities of bycatch, which is the part of the catch that is captured incidentally to the species at which effort is directed. The bycatch of the NPF consists mainly of small fish of many species. It is estimated that over 30 000 tonnes are discarded each year (Pender *et al.*, 1992; Ramm *et al.*, 1990).

Attempts to reduce the bycatch in the NPF have included testing codends through which fish can escape. Square-mesh codends reduced the bycatch of trawls by at least 22 percent (described in Objective 2, B1). However, it is not known whether the fish that escape through these codends survive. The meshes might damage the fish, possibly fatally, so survival rates need to be investigated (Sangster, 1992) in order to assess the effectiveness of square-mesh codends as a Bycatch Reduction Device.

Many studies have investigated the survival of discarded catch, in both temperate (Beek *et al.* 1989; Neilson *et al.*, 1989; Berghahn *et al.*, 1992; Millner *et al.*, 1993; Kaiser and Spencer, 1995) and tropical waters (Wassenberg and Hill, 1989, 1990; Harris and Poiner, 1990; Hill and Wassenberg, 1990; Poiner *et al.*, 1990, 1996). Discarded catch is defined as that portion of the catch returned to the sea for economic, legal or personal reasons (Alverson *et al.*, 1994). Discards differ from escapees, as they are retained in the net until the end of the trawl and are sorted on deck before being dumped, whereas escapees leave the net before it is hauled on board the vessel. Studies of the survival of trawl escapees have been made in temperate waters (Efanov and Istomin, 1988; Main and Sangster, 1990, 1991; Boris and Efanov, 1991; Isaksen, 1991, Soldal *et al.*, 1991 and 1993; Jacobsen *et al.*, 1992; DeAlteris and Reifstech, 1993; Kaiser and Spencer, 1995). The amount and variety of bycatch are small in these waters compared to tropical trawl fisheries, so their findings cannot be simply transferred to tropical fisheries. The aim of the current study is to assess the survival of prawn-trawl escapees through square-mesh codends. This study is the first of its kind in tropical waters.

METHODS

Survival Experiments

Survival was assessed by recapturing fish that had passed through a square-mesh codend, holding them for 8-10 days and comparing their survival rates with fish that had not passed through a square-mesh codend, but were held in the same conditions.

Two separate survival experiments were performed, one in May 1994 and another in August 1994. Both experiments used a covered codend to retain fish that had passed through either a square-mesh codend (treatment) or a trawl with an open codend (control). Another group of fish caught with hook-and-lines was used as an additional control.

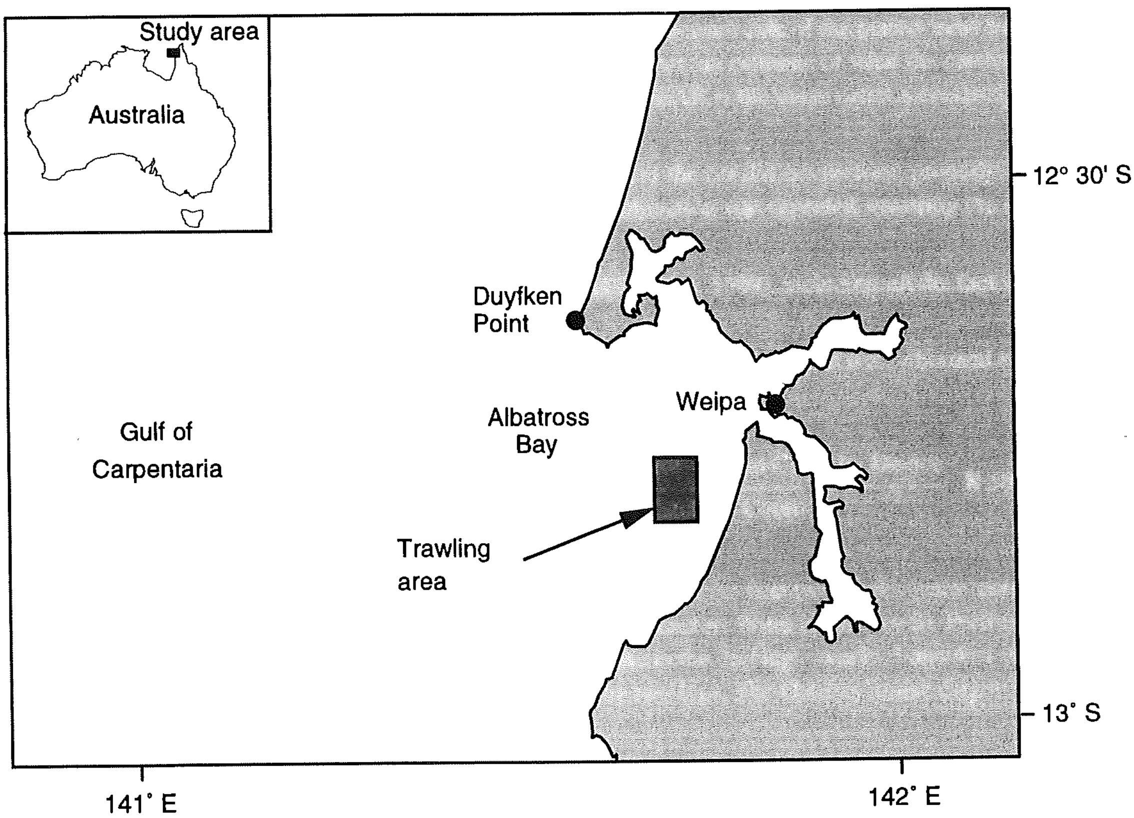
Fishing Gear

In the first experiment (May 1994), a Florida Flyer commercial prawn trawl with a nine-fathom (16.4 m) headline was towed at 1.3 m s-1 by a 17 m prawn trawler (FV *Milana J*). The net was fitted with a 45 mm square-mesh codend, with a codend cover of 16 mm diamond-mesh netting. To support the shape of the cover and hold it off the square-mesh codend, the cover was fitted with two hoops of 12 mm diameter steel. The larger hoop (1.5 m in diameter) was 3.36 m in front of the other (1.2 m in diameter).

Due to difficulties in controlling the rate at which the codend came to the surface, some species suffered swim bladder damage, which would not normally be associated with escaping through a square-mesh codend. We therefore carried out a second experiment, using a four-fathom prawn (7.3 m) trawl fitted with smaller versions of the codend and codend cover. The net was towed in shallow water (5-7 m) with rope warps from a 12 m fishing vessel (FV *Island Girl*).

Fish were collected about 2 nautical miles south of the mouth of the Embley estuary in Albatross Bay in the north east Gulf of Carpentaria (Figure 12). Trawls were made in 8 to 10 m of water during the first experiment and 5 to 7 m during the second.

Figure 12. North-east Gulf of Carpentaria, showing the trawling area for collection of fish for survival experiments



Fish-holding Facilities

Cages (2 m x 1 m x 1 m) of 25 mm aluminium pipe were covered with 38 mm square-mesh netting and surrounded by 2 cm galvanised wire mesh to protect the fish from sharks. Three-metre long rope bridles were attached to the bottom corners of each cage and connected to one of two anchor lines by 5 m of rope and 1.5 m of chain.

A 5 m cylinder of netting was attached to an opening (0.5 m long) in the top of the cage to provide access to the cage. After the fish were put in the cage, the cylinder was closed securely and connected to one of the two large floats. The floats, which marked the position of the cages, were attached to the anchors by 10 m lengths of rope. The cages were moored about 500 m from the shore in 3-6 m of water.

Pools were also used for holding fish at the CSIRO Marine Laboratories field station at Weipa. The pools, which were above-ground, measured 3.7 m in diameter, with a capacity of 7000 litres. A double layer of 95 percent 'shade-cloth' overhead filtered sunlight and kept temperatures within a narrow range. Sea water was fully exchanged every two days, with incoming sea water pumped from the Embley estuary and filtered through a 15 600 L h^{-1} sand filter (Sandpiper 600).

The fish in the pools were fed daily with grated prawn and fish. The fish in the cages were fed only twice during the experiment because of bad weather and to minimise the disturbance created by raising the cages to the surface.

Collection of Fish

During the first experiment, tows of 10 minutes were made and the net was then hauled to the surface. We retrieved the codend cover and carefully transferred the fish to containers of seawater and then to the cages.

During the second experiment, the trawl was towed for 5 minutes and then hauled to the surface. The fish retained in the codend cover were carefully transferred to a small floating plastic cage, ensuring they remained in water. If there were more than about 100 fish, the catch was discarded to avoid possible damage from overcrowding. Fish from this experiment were transferred either to the anchored sea cages or to the pools onshore.

For collecting the control fish, the trawl was modified by rolling back and securing the square-mesh codend. Fish entering these trawls passed through the main body of the net directly into the codend cover. Tows to collect controls were made in the same area, and in between, tows to collect the treatment fish. The tows were five minutes in duration. The fish were handled in the same way as the treatment fish. All the trawls were made during the day.

At the beginning of the second experiment, a second set of control fish was collected by fishing line and barbless hooks from the area where the cages were anchored in about 3-6 m depth. The fish were pulled to the surface slowly (about 0.5 m s^{-1}) and placed in a bucket of water. The hooks were quickly removed from their mouths and they were then put in a separate cage of the type described above.

DATA ANALYSES

The numbers of fish in each taxon were counted as they were transferred to the cages. At the end of the experiment (after 8-10 days), the cages were raised and each fish that was alive was identified and counted. The fish held in the pools were monitored twice a day and any dead ones were removed and identified. The percentage survival rate was calculated for each taxon and separately for each experiment.

Taxa with 10 or more treatment fish and at least one control fish were treated separately. Taxa with fewer than 10 individuals were grouped together as 'Others' and analysed together.

The Fisher Exact test (SAS, 1989) was used to test the null hypothesis that there was no significant difference between the number of fish surviving after passing through the square-mesh (treatment) and the number of fish surviving that had not passed through the square-mesh (control).

RESULTS

Experiment 1:

Fish kept in Cages

A total of 163 individual fish from 3 taxa were transferred to the cages. Of these, 124 from 3 taxa had passed through the square-mesh (treatment fish) and 39 from the same 3 taxa had passed through an open codend (control fish), (Table 8).

After 10 days, 26 percent of the treatment fish and 56 percent of the control fish were still alive. In both groups survival varied with taxon: for example all *Saurida* spp. died before the end of the experiment, whereas all *Terapon puta* control fish survived.

Valid comparisons between treatment and control fish could be made for two taxa. Only 21 percent of *Leiognathus splendens* survived after passing through the square-mesh, which was significantly less ($p < 0.05$) than the control (80 percent). There was also a significant difference ($p < 0.01$) between the survival of *Terapon puta* controls (100 percent) and the treatment fish (50 percent).

Experiment 2:

Fish kept in Cages

(i) Trawl-caught fish

A total of 368 fish from 14 taxa were transferred to the cages. Of these, 250 from 14 taxa had passed through the square-mesh (treatment fish) and 118 from 11 taxa had passed through an open codend (control fish). For six taxa, more than 10 individuals were retained; the remaining fish (55) were grouped as 'Others' (Table 9 (a)).

After 8 days, 21 percent of the treatment fish were still alive. However, survival varied between taxa, ranging from 100 percent for *Terapon puta* to 0 percent for *Cynoglossus* spp., *Sardinella* spp. and *Secutor* spp.

After 8 days, 15 percent of the control fish were still alive. Survival, again, varied between taxa, ranging from 100 percent for *Sillago* spp. and *Terapon puta* to 0 percent survival for *Cynoglossus* spp., *Sardinella* spp. and *Secutor* spp.

Valid comparisons between the treatment and control fish could be made for only 3 taxa and the 'Others' group, as all experimental and control *Cynoglossus* spp., *Sardinella* spp. and *Secutor* spp. died. For all four comparisons — *Leiognathus* spp., *Sillago* spp., *Terapon puta* and 'Others' — there was no significant difference between the rate of survival of the individuals that had passed through the square-mesh and those that had not.

(ii) Line-caught fish

Thirty-five fish were caught by hook-and-line, and were transferred to one of the cages. After eleven days, 34 were still alive: 12 Absalom radiatus, 20 Terapon puta and 2 Sillago spp.; the one Polynemus spp. did not survive.

Fish kept in Pools

A total of 209 fish from 11 taxa were transferred to the pools. Of these, 123 fish from 11 taxa had passed through the square-mesh (treatment fish) and 86 fish from 11 taxa had passed through an open codend (control fish). More than 10 individuals in 3 taxa survived; the remaining fish (96) were grouped as 'Others' (Table 9 (b)).

After seven days, 83 percent of the treatment fish were still alive. These included 97 percent of *Leiognathus splendens*, 83 percent of 'Others', and 80 percent of *Cynoglossus* spp., while all *Secutor ruconius* had died.

Of the control fish, 92 percent survived for eight days. Both *Cynoglossus* spp. and *Leiognathus splendens* had 100 percent survival; 'Others' had 98 percent , and *Secutor ruconius* had 64 percent.

The survival of *Secutor ruconius* that had passed through the square-mesh was significantly less ($p < 0.01$) than those that had not. There was no significant difference between the survival of *Cynoglossus* spp., *Leiognathus splendens* and the 'Others' that had passed through the square-mesh and those that had not.

Table 8 . Survival of fish that passed through a square-mesh (Treatment) or open (Control) codend and were then kept in cages for 10 days during Experiment 1.

	Treatment			Control		
	In cages (*n*)	Survived (*n*)	Survival (%)	Into cages (*n*)	Survived (*n*)	Survival (%)
Leiognathus splendens	71	15	21	5	4	80
Saurida spp.	19	0	0	16	0	0
Terapon puta	34	17	50	18	18	100
Total	124	32	26	39	22	56

Table 9 (a) Survival of fish that passed through a square-mesh (Treatment) or open (Control) codend and were then kept in cages for 8 days during Experiment 2.

	Treatment			Control		
	Into cages (n)	Survived (n)	Survival (%)	Into cages (n)	Survived (n)	Survival (%)
Cynoglossus spp.	17	0	0	1	0	0
Leiognathus spp.	114	7	6	49	1	2
Sardinella spp.	37	0	0	15	0	0
Sillago spp.	28	17	61	6	6	100
Secutor spp.	10	0	0	19	0	0
Terapon puta	16	16	100	1	1	100
Other spp.	28	13	46	27	19	70
Total	250	53	21	118	27	15

Table 9 (b) Survival of fish that passed through a square-mesh (Treatment) or open (Control) codend and were then kept in pools for 7 - 8 days during Experiment 2.

	Treatment			Control		
	Into tanks (n)	Survived (n)	Survival (%)	Into tanks (n)	Survived (n)	Survival (%)
Cynoglossus spp.	10	8	80	5	5	100
Leiognathus splendens	62	60	97	15	15	100
Secutor ruconius	10	0	0	11	7	64
Other spp.	41	34	83	55	52	95
Total	123	102	83	86	79	92

Figure 13 The percentage of fish surviving (all species) per day from the pool experiments

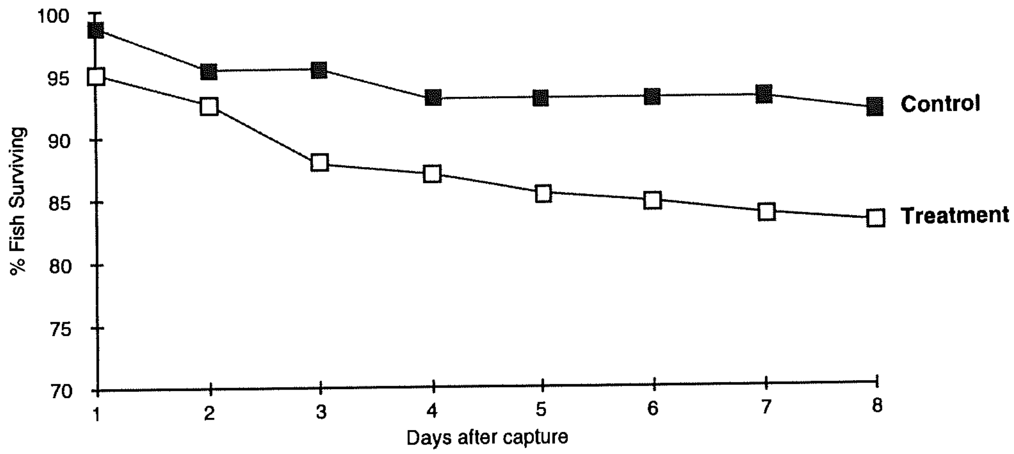


Figure 13 shows the percentage of fish surviving in the pools during the eight days of experiment 2. Most of these deaths occurred within the first three days after their capture: 19 of the 21 deaths of treatment fish and 6 of the 7 deaths of control fish were within that time span.

DISCUSSION

Although we did not examine the causes of death, Soldal *et al.*, (1993) stated that accurate mortality rates of fish that die of injuries caused by escapement from the codend are difficult to assess, as there is no single reason for fish dying. Fish are not only injured while passing through the codend meshes, but also by contact with the net wall or other fish and crustaceans in the trawl.

Markedly fewer fish survived in cages than in pools. However, Main and Sangster (1991) stated that it is unwise to lay too much emphasis on the survival rates of fish held in cages, as they may die of causes other than scale damage from contact with codend meshes. They qualified this by saying that if a fish survives (in a cage), then it has obviously recovered from its traumatic experience in the trawl, but if it dies there is always some uncertainty about the cause of death. We recommend that, in future experiments, all fish are held in pools.

The mortality of bycatch is highly variable between species (Kaiser and Spencer 1995). Our results suggest that bycatch species can be divided into three broad categories with respect to survival after passing through a square-mesh codend. Firstly, species that are hardy and able to survive encountering and escaping from a trawl (e.g. *Terapon puta*); secondly, species that are susceptible to the stress of passing through the square-mesh, some of which may die (e.g. *Leiognathus splendens*, *Sillago* spp. and *Secutor ruconius*); and thirdly, species that are extremely fragile and have a low probability of surviving an encounter with the codend of a trawl (e.g. *Sardinella spp.*). The poor survival of this last group may be a result of the trauma of being caught in the trawl rather than the effects of passing through the square-mesh itself, or by having a delicate body that sustains fatal damage easily. The survival rates of all these categories will be affected by such factors as the individual size of fish (*Soldal et al.*, 1991), the catch composition (Main and Sangster, 1991) and the length of time in the trawl (Von Kelle, 1976).

In our experiment in tropical waters, most deaths in the pools occurred during the first three days of captivity. In subtropical waters, fish discarded from prawn trawls also died in greatest numbers within the first three days (Wassenberg and Hill, 1993). In temperate fisheries, the same period was critical for cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) that escaped through the meshes of a Danish seine codend (Soldal *et al*, 1993). Secondary infections associated with scale loss resulted in haddock deteriorating quickly and dying within 24 hours (Main and Sangster, 1991). We did not observe any deaths from secondary infections amongst fish that were held for eight days. Our experiments suggest that, even in the tropics, survival experiments should last at least four days.

BENEFITS

These experiments provide the first evidence of the proportion of the fish that survive after escaping from square-mesh codends in tropical waters. The results from these experiments are essential for assessing the effectiveness of square-mesh codends as Bycatch Reduction Devices. We show that, for most species, most fish are likely to survive. These results can also be applied to other Bycatch Reduction Devices that use square-mesh, such as square-mesh panels.

B. Damage to selected species escaping from prawn trawl codends: a comparison between square-mesh and diamond-mesh

INTRODUCTION

Prawn trawling in tropical Australian waters results in large amounts of unused bycatch. The ratio of bycatch to target catch in the Northern Prawn Fishery may range from 5:1 to 10:1 by weight (Harris and Poiner,1990; Pender *et al.*, 1992). The main components of this bycatch are small fish, sharks and rays.

A joint study by CSIRO Division of Fisheries, the Australian Maritime College and the Northern Territory Fisheries Division is looking at ways of reducing unused bycatch in this fishery. Reduction of bycatch would be expected to result in: less damage to prawns, resulting in a higher proportion of export quality product; reduced sorting time; less criticism of the industry from environmental and recreational fishing lobbies; and maintenance of the ecosystem that supported the original fishery.

One of the fishing gears being trialed during this study is the square-mesh codend. The meshes remain open during tows, unlike the widely used diamond-mesh codend currently used in prawn fisheries (Main and Sangster, 1990). Therefore escapement of unused bycatch is expected to be greater from square-mesh codends than the same-sized diamond-mesh.

There has been very little research into damage to fish escaping through prawn-trawl codends. Studies of damage to fish escaping through codend meshes have been carried out in the cooler waters of the North Sea (Main and Sangster, 1990) where, unlike tropical waters, the diversity of species is relatively low. The survival of tropical species escaping through codend meshes has not been researched.

The objectives of this study were to measure the damage to a range of species that had escaped through codend meshes. Such an assessment will: (i) help predict survival of fish species escaping through square-mesh codends and (ii) help explain survival rates of different species measured in any future studies.

MATERIALS AND METHODS

(i) Study Area

The study was carried out in the Gulf of Carpentaria in commercial prawn trawling grounds five nautical miles west off Duyfken Point, Qld (Figure 9). The water depth ranged from 15 to 20 m.

(ii) Trawl regime

Fish for damage assessment were collected over 10 nights from 15 November to 24 November 1993. Trawls were carried out from the CSIRO Fisheries Division research vessel MRV *Southern Surveyor*. Each trawl was of 30 minutes duration and was conducted at night in a North-South direction.

(iii) Sampling gear

Gear trials comparing two sizes of square-mesh (45 mm and 38 mm) with a diamond-mesh codend (45 mm mesh) were carried out. The latter is the standard codend mesh used by commercial trawlers in the Northern Prawn Fishery. Comparisons were made using dual-rigged 14 fathom Florida Flyer prawn trawls (Figure 7). One net was rigged with the standard diamond-mesh codend and the other with one of the square-mesh codends. Small mesh (16 mm) codend-covers, with rings to help prevent masking of the inner codend, were used to retain individuals that escaped through the codend meshes.

To minimise further damage to the escapees while in the fine mesh cover, the codend and cover were brought on deck in a heavy duty plastic scoop (a cone of 1.5 m diameter and 1.2 m depth) filled with seawater. Once on deck the catch in the cover was released into the water-filled scoop (also used to bring the catch on board). Selected fish were removed individually from the scoop by hand and placed in MS222 (Tricaine methane sulphonate) at a toxic concentration of 100 parts per million of seawater.

(iv) Selection of species for damage assessment

The main target species of the fishery in this area are *Penaeus semisulcatus* (grooved tiger prawn), *Penaeus esculentus* (brown tiger prawn), *Metapenaeus endeavouri* (blue endeavour prawn) and *Metapenaeus ensis* (red endeavour prawn).

The sampling area had been sampled earlier in the same cruise with a beam trawl. The 10 species of fish and 5 species of crustacean selected for damage assessment were the species most frequently caught during this earlier sampling and that are also common as bycatch in other areas of the Northern Prawn Fishery. Species were chosen from different fish families with different body forms. Commercially important species were also kept for damage assessment. (Table 10).

(v) Laboratory work

Individuals of species selected for damage assessment were identified, counted, measured (standard length) and weighed. Standard length, greatest body depth, and greatest body width were measured by vernier callipers to the nearest millimetre. The weight of catch in the codend and cover was recorded for every station.

Each fish was examined visually for damage to the head, scale loss, fin damage, and body wounds. Scale loss was estimated as a percent area loss; damage to fins and head was ranked from 1 to 4, as follows: 1= no damage; 2 = damaged but not expected to affect survival; 3 = badly damaged and 4 = loss of the body part being examined. The areas examined for damage were; left dorsal scales, right dorsal scales, left median scales, right median scales, left ventral scales, right ventral scales, pelvic scales, jaws, left preoperculum, right preoperculum, left operculum, right operculum, left eye, right eye, dorsal fin spines, dorsal fin rays, adipose fin, anal fin spines, anal fin rays, caudal fin, left pectoral fin, right pectoral fin, left pelvic fin, right pelvic fin, body wounds.

DATA ANALYSIS

Damage

The highest score for each structure examined, regardless of whether it was measured on the left or right side of the fish, and an overall percentage scale loss for each fish were used in the analyses. These variables refer to damage to the following body parts: jaw, preoperculum, operculum, eye, dorsal fin, anal fin, caudal fin, pectoral fin, pelvic fin. Wounds and scale loss were also examined.

The variance of each variable as examined for heteroscedacity and transformed accordingly.

A multivariate analysis of variance (MANOVA) was carried out with PROC GLM (SAS Institute 1989). The model used to examine the effect of Codend-type on the eleven dependent variables was as follows.

$$Y_{ij} = m + C_i + e_{ij}$$

where Y_i is the vector of eleven dependant variables measured

m = overall mean

C_i = effect of the codend type where i = 1 to 3 and e_{ij} is the error of the jth observation for codend i.

The eleven dependant damage variables were:

mean rank of

1. jaw damage
2. preoperculum damage
3. operculum damage
4. eye damage
5. percentage scale loss
6. dorsal fin damage
7. anal fin damage
8. anal fin damage
9. caudal fin damage
10. pelvic fin damage
11. wounds

Table 10. Species selected for damage assessment studies and the reasons for their selection. Reasons for selection are marked with a tick (√), except for *Caranx bucculentus,* which was examined because of previous CSIRO work. Abundance = because it is abundant in the NPF bycatch; Shape = because it is part of a suite of different fish body shapes examined; Commercial = because it is of commercial significance.

Scientific name	**Common name**	**Reason for choice as a species to be examined for damage**			
		Fisheries target species	**Abundance**	**Shape**	**Commercial**
Sardinella albella	Perforated-scale sardine		√	√	
Saurida micropectoralis	Short-finned lizardfish		√	√	
Arius thalassinus	Giant Salmon catfish			√	
Apogon poecilopterus	Pearly-finned cardinal-fish		√	√	
Caranx bucculentus	Blue-spotted trevally	Of interest to CSIRO			
Leiognathus splendens	Black-tipped ponyfish		√	√	
Lutjanus malabaricus	Saddle-tailed sea-perch				√
Pomadasys maculatum	Blotched javelinfish		√	√	
Upeneus sulphureus	Sundise goatfish		√	√	
Pseudorhombus arsius	Large-toothed flounder		√	√	
Penaeus latisulcatus	Western king prawn				√
Penaeus semisulcatus	Green tiger prawn	√			
Penaeus esculentus	Brown tiger prawn	√			
Metapenaeus endeavouri	Endeavour prawn	√			√
Metapenaeus ensis	Endeavour prawn	√			√
Portunus pelagicus	Sand crab			√	√

The following variables were included in the model as co-variates: aspect ratio 1 (depth/length), aspect ratio 2 (width/length), fish depth, and total weight of the catch (in kg). Aspect ratio 2 was omitted for species where it was significantly correlated with aspect ratio 1 ($P<0.05$). The significance of each variable was assessed with Pillai's trace statisic.

Regression analysis was used to find the direction of any significant relationship between damage variables and the codend type and covariates.

RESULTS

General

During the net comparison trials 82 stations were trawled; of these 43 were comparisons of 45 mm diamond versus 45 mm square-mesh codend, and 39 were of 45 mm diamond versus 38 mm square-mesh codends. There were 81 species of escapees. Damage to escapees was examined at nine stations. Thirteen species of escapees were examined: nine species of fish and four species of prawn (Table 11). Of the species selected, only 6 species of fish were collected in sufficient numbers for statistical analyses (i.e. $N> 10$ in one treatment).

At three of the stations, escapees were taken from the cover of the 45 mm square-mesh codend, at 4 of the stations escapees were taken from the cover of the 45 mm diamond-mesh codend and at 2 of the stations escapees were taken from the cover of the 38 mm square-mesh codend.

Overall Damage to escapees

There was a significant effect of codend ($p<0.05$) for all five species that were compared for 45 mm square and diamond-mesh codends (Table 12). Aspect ratio one and total weight of catch were related to overall fish damage for two species.

Only two species had differences in damage in the 38 mm square-mesh codend versus 45 mm diamond-mesh codend comparisons, according to the model (Table 12). These variables were codend type and the covariates aspect ratio and total weight of catch for *Sardinella albella* and depth of fish for *Upeneus sulphureus*.

Table 11. Species studied for damage after escaping from codends.

Scientific name	Codend mesh type		
	45 mm diamond	38 mm square	45 mm square
Fish			
Sardinella albella	52	15	60
Saurida micropectoralis	11	25	22
Arius thalassinus	2	0	0
Apogon poecilopterus	61	63	37
Caranx bucculentus	11	13	1
Leiognathus splendens	40	30	54
Lutjanus malabaricus	7	0	1
Pomadasys maculatum	5	10	55
Upeneus sulphureus	68	56	55
Prawns			
Penaeus semisulcatus	1	1	1
Penaeus esculentus	1	1	1
Metapenaeus endeavouri	1	1	1
Metapenaeus ensis	2	1	1

Damage to particular parts of the fish

Eight of the measures of fish damage were significant in the overall MANOVA model for 45 mm diamond-mesh codend versus 45 mm square-mesh codend comparison and 6 in the 45 mm diamond versus 38 mm square-mesh codend comparison (Table 13).

(i) 45 mm diamond versus 45 mm square-mesh comparison

Damage to the jaws was significant in *Leiognathus splendens*; we attributed it to the codend type. The regression analysis showed that damage to fish escaping from the 45 mm square-mesh codend was worse than for those escaping the 45 mm diamond-mesh codend (Table 14).

Damage to the preoperculum was significant in *Upeneus sulphureus*; we attributed it to codend type and depth of fish. The escapees from the 45 mm diamond-mesh codend had worse damage those of the 45 mm square-mesh codend, and it was worse for those with deeper bodies regardless of the codend type (Table 14).

Scale loss was significant in all species. Differences were attributed to codend type and three covariates: aspect ratio 1, maximum depth of fish and total weight of catch. The combination of variables that explain scale loss differs for each species (Table 14).

Dorsal fin damage was significant in *Sardinella albella* and *Upeneus sulphureus*. This was attributed to codend differences and was worse in 45 mm diamond-mesh codend escapees than 45 mm square-mesh codend escapees.

Anal fin damage for *Sardinella albella* was attributed to total weight of catch, with damage being worse with a heavier catch. Anal fin damage was attributed to codend type for *Apogon poecilopterus* and *Leiognathus splendens*, damage being worse in 45 mm square-mesh codend escapees than 45 mm diamond-mesh codend escapees.

Caudal fin damage was significant in *Saurida micropectoralis* only. Damage was related to aspect ratio, being greater with an increase in aspect ratio 1.

Pelvic fin damage in *Apogon poecilopterus* and *Upeneus sulphureus* was greater in the 45 mm square-mesh codend escapees than 45 mm diamond-mesh codend escapees. Pelvic fin damage was less for *Upeneus sulphureus* with increase in depth of fish.

Wounds on *Saurida micropectoralis* were associated with total weight of catch and codend type, being less with higher total weight of catch and greater in 45 mm square-mesh codend escapees than 45 mm diamond-mesh codend escapees. *Upeneus sulphureus* had more wounds in 45 mm square-mesh codend escapees than 45 mm diamond-mesh codend escapees, but less with increase in maximum depth of fish.

(ii) 45 mm diamond-mesh versus 38 mm square-mesh comparison

Damage to the eyes was significant for *Sardinella albella*. It was less with greater aspect ratio 1 of fish; greater in 45 mm diamond-mesh codend escapees than 38 mm square-mesh codend escapees and less with higher total weight of catch (Table 15).

All three species examined from the 38 mm square-mesh codend comparison had significant scale loss. This relates to different variables depending on the species. *Sardinella albella* had more damage with increase in aspect ratio 1 and less damage with an increase in total weight of catch. *Apogon poecilopterus* and *Upeneus sulphureus* had less damage with increase in maximum depth of fish (Table 15).

Dorsal fin damage was significant for *Apogon poecilopterus* and *Upeneus sulphureus*. This was greater with increase in maximum depth of fish for *Apogon poecilopterus* and less with increase in maximum depth of fish for *Upeneus sulphureus*.

Caudal fin damage in *Sardinella albella* was greater in the 45 mm diamond-mesh codend escapees than the 38 mm square-mesh codend escapees and less with increase in total weight of catch.

DISCUSSION

The species that escape from the 45 mm square-mesh codend could be expected to escape from open diamond-mesh of the same size. This is not, however, the case for all species examined; *Sardinella albella*, *Saurida*

Table 12. Variables that explained a significant amount of the variation in damage for the two codend comparisons.

Codend comparison	Species	Codend	Covariates		
			Aspect ratio 1	Maximum fish depth (mm)	Total weight of catch
45 mm square vs. 45 mm diamond					
	Sardinella albella	p = 0.0001	p = 0.0003	-	p = 0.0001
	Saurida micropectoralis	p = 0.0018	p = 0.0001	-	p = 0.0033
	Apogon poecilopterus	p = 0.0001	ns	p = 0.0002	ns
	Leiognathus splendens	p = 0.0001	ns	ns	ns
	Upeneus sulphureus	p = 0.0001	ns	p = 0.0001	ns
38 mm square vs. 45 mm diamond					
	Sardinella albella	p = 0.0142	p = 0.0001	-	p = 0.0003
	Saurida micropectoralis	ns	ns	-	ns
	Apogon poecilopterus	ns	ns	-	ns
	Caranx bucculentus	ns	ns	-	ns
	Leiognathus splendens	ns	ns	-	ns
	Upeneus sulphureus	ns	ns	p = 0.0007	ns

Table 13. The body parts of each species that showed significant differences between the observed damage from square and diamond codend comparisons. (+ = P < 0.05) (- = ns). (1 = jaw ; 2 = preoperculum; 3 = operculum; 4 = eye; 5 = scale loss; 6 = dorsal fin; 7 = anal fin; 8 = caudal fin; 9 = pectoral fin; 10 = pelvic fin damage; 11 = wounds)

	45 mm diamond versus 45 mm square-mesh codend										
	Damage variables										
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
S. albella	-	-	-	-	+	+	+	-	+	-	-
S. micropectoralis	-	-	-	-	+	-	+	-	-	+	-
A. poecilopterus	-	-	-	-	+	-	+	-	-	+	-
L. splendens	+	-	-	-	+	-	+	-	-	-	-
U. sulphureus	-	+	-	-	+	+	-	-	-	+	+
	45 mm diamond versus 38 mm square-mesh codend										
S. albella	-	-	-	+	+	-	-	+	-	-	-
A. poecilopterus	-	-	-	-	+	+	-	-	-	-	-
U. sulphureus	-	+	+	-	+	+	-	-	-	-	-

Table 14. Results from the model of sources of significant damage for five fish bycatch species from the 45 mm square versus 45 mm diamond mesh codend comparisons. The probability statistics of the explanatory variables and the direction of the significant relationships ($p < 0.05$) are presented. di>sq = diamond mesh codend escapees with greater damage than square-mesh codend escapees, sq>di = square-mesh codend escapees with greater damage than diamond-mesh codend escapees; +ve = increase in damage with increase in explanatory variable; -ve = decrease in damage with increase in explanatory variable.

Species	Damage variable	Codend	Covariates		
			Aspect ratio 1 (depth/length)	**Maximum depth of fish (mm)**	**Total weight of catch (kg)**
Sardinella albella	scale loss	0.3213	0.0001 (+ve)	-	0.0001 (-ve)
	dorsal fin damage	0.0267 (di > sq)	0.0745	-	0.1187
	anal fin damage	0.8183	0.1351	-	0.0251 (+ve)
	pectoral fin damage	0.0001 (di > sq)	0.2901	-	0.0299 (-ve)
Saurida micropectoralis	scale loss	0.0035 (di > sq)	0.0016 (+ve)	-	0.0351 (+ve)
	caudal fin damage	0.3349	0.0001 (+ve)	-	0.0938
	wounds	0.0033 (sq > di)	0.6351	-	0.0062 (-ve)
Apogon poecilopterus	scale loss	0.0007 (di > sq)	-	0.0001 (-ve)	-
	anal fin damage	0.0001 (sq > di)	-	0.1427	-
	pelvic fin damage	0.0056 (sq > di)	-	0.3868	-
Leiognathus splendens	jaw damage	0.0001 (sq > di)	-	-	-
	scale loss	0.0001 (di > sq)	-	-	-
	anal fin damage	0.0001 (sq > di)	-	-	-
Upeneus sulphureus	preoperculum damage	0.0001 (di > sq)	-	0.0001 (+ve)	-
	scale loss	0.0001 (sq > di)	-	0.0001 (-ve)	-

	dorsal fin damage	0.0064 (di > sq)	-	0.8658	-
	pelvic fin damage	0.0052 (sq > di)	-	0.0184 (-ve)	-
	wounds	0.0212 (sq > di)	-	0.0002 (-ve)	-

Table 15. Results from the model explaining sources of significant damage for three fish bycatch species from the 38 mm square versus 45 mm diamond-mesh codend comparisons. The probability statistics of the explanatory variables and the direction of the significant relationships ($p < 0.05$) are presented. di>sq = diamond mesh codend escapees with greater damage than square-mesh codend escapees, sq>di = square-mesh codend escapees with greater damage than diamond mesh codend escapees; +ve = increase in damage with increase in explanatory variable; -ve = decrease in damage with increase in explanatory variable.

			Covariates		
Species	**Damage variable**	**Codend**	**Aspect ratio 1 (depth/length)**	**Maximum depth of fish (mm)**	**Total weight of catch (kg)**
Sardinella albella	eye damage	0.0059 (di > sq)	0.0493 (-ve)	-	0.0194 (-ve)
	scale loss	0.8097	0.0001 (+ve)	-	0.0013 (-ve)
	caudal fin damage	0.0052 (di > sq)	0.8127	-	0.0026 (-ve)
Apogon poecilopterus	scale loss	-	-	0.0330 (-ve)	-
	dorsal fin damage	-	-	0.0014 (+ve)	-
Upeneus sulphureus	preoperculum damage	-	-	0.1184	-
	operculum damage	-	-	0.1780	-
	scale loss	-	-	0.0041 (-ve)	-
	dorsal fin damage	-	-	0.0025 (-ve)	-

micropectoralis, *Apogon poecilopterus*, *Leiognathus splendens*, *Pomadasys maculatum* and *Upeneus sulphureus* all have a greater proportion escaping from the 45 mm square-mesh codend than the diamond-mesh codend of the same size.

All species either have a significantly larger proportion escaping from the 45 mm square-mesh codend than from the diamond or no significant difference. The lack of differences in the number of some species escaping from the diamond and square-mesh codends may be related to the low numbers of these species caught (e.g. *Lutjanus malabaricus*, *Pseudorhombus arsius*, *Metapenaeus endeavouri*, *Metapenaeus ensis* and *Portunus pelagicus*).

The shape and size of the species are relevant. For example, the spines of *Arius thalassinus* prevent even small individuals from escaping. This was the only species where a significantly smaller proportion escaped from the 38 mm square-mesh codend than the 45 mm diamond-mesh codend. This may be attributed to the size of the mesh; even when open, 38 mm mesh is too small for the spines of *Arius thalassinus* to fit through.

Sardinella albella, *Saurida micropectoralis*, *Apogon poecilopterus*, *Lutjanus malabaricus*, *Pomadasys maculatum*, *Penaeus semisulcatus* and *Penaeus esculentus* all had significantly higher proportions escaping through the 38 mm square-mesh codend than the 45 mm diamond-mesh codend. This, again, would be attributed to the square-mesh remaining open and the diamond-mesh closing during trawling.

The *Lutjanus malabaricus* and *Caranx bucculentus* that escaped from any of the codends were all juveniles. These fish were not visually damaged. Their body depth and width were considerably smaller than any of the mesh sizes used. Trials at a different time of year or another site might involve different sizes of these species and give different results. Further study may be required to look at damage through codend meshes for subadults and adults of these species.

Few flat-fish *Pseudorhombus arsius* and crab *Portunus pelagicus* escaped from any of the codends, possibly because of the shape of these species: broad and flat.

The release of commercially valuable prawns by a bycatch exclusion device is not very appealing to commercial fishermen. However, the prawns escaping in these trials were mainly subadult pre-spawners and the release of this class of prawn may benefit the industry by allowing the prawns to grow to a more valuable size, reach maturity and spawn before capture.

The species with large loss of scales, such as *Sardinella albella*, *Apogon poecilopterus* and *Upeneus sulphureus*, have relatively deciduous scales. Fish that escaped from the 38 mm square-mesh codend had the most extreme loss of scales, and included the only individuals to lose lateral line scales. One third of *S. albella* lost their scutes as well as other scales.

The majority of the fish that escaped from the 45 mm mesh codends were not damaged seriously. (The mean damage rank of less than three for any of the damage variables). However, further research is needed to explore the survival rates of escapees from different codends.

This study suggests that, overall, escapees from 45 mm mesh codend are less damaged and therefore have a better chance of survival than escapees from the 38 mm square-mesh codend or 45 mm diamond-mesh codend (Table 12). Additionally, the 45 mm square-mesh codend is more likely to allow fish to escape than either the 45 mm diamond or 38 mm square-mesh codends.

Fish escaping from the 38 mm square-mesh codend are more severely damaged than those escaping from the diamond-mesh codend: the mean damage rank of the former reached *three* in several cases. The survival rate of these fish is likely to be lower than if the codend had been of 45 mm diamond-mesh.

The damage to prawns that escaped into the codend cover was slight: the worst damage seemed to be broken tips to their antennae.

BENEFITS

Both the 45 mm and 38 mm square-mesh codends reduce the catch of small bycatch species. It appears that many of the escapees suffer only slight damage and so their subsequent survival may be high. The use of square-mesh codends may be a useful way of reducing certain size classes of bycatch in the Australian Northern Prawn Fishery. However, information on the survival rates of codend escapees will be an important part of the assessment of these devices.

OBJECTIVE 4.

- **Describe the reaction of fish and prawns to trawls in order to enhance our ability to develop trawls that minimise catches of unwanted species.**

INTRODUCTION

The vertical distribution and behaviour of prawns and fish entering a trawl were examined with the aid of a multi-level beam trawl (MBT) in the Northern Prawn Fishery (NPF). Trials were conducted on the FRV *Southern Surveyor* in 1994, as part of a Fisheries Research and Development Corporation (FRDC) funded project on the effects of trawl design on bycatch in tropical prawn fisheries. This is a collaborative project between the Australian Maritime College, the CSIRO Division of Fisheries (Cleveland) and the Northern Territory Department of Primary Industry and Fisheries (Darwin).

A knowledge of the behaviour of fish and prawns is necessary for designing techniques to reduce bycatch while retaining valuable prawns. A variety of Bycatch Reduction Devices (BRDs) have been developed to reduce the capture of the small fish that usually dominate prawn trawl bycatch. Many of these BRDs, such as fisheyes and square-mesh windows, rely on fish being better swimmers than prawns. The BRDs are placed in the top of the codend; the more active fish swim through an escape opening while the prawns are swept passively into the codend.

Underwater video cameras are a popular way of observing how animals react to trawls. Prawn trawling, however, is mainly done at night and in turbid waters. Under these conditions, expensive low-light cameras struggle to film at effective ranges, and artificial lighting is of limited use due to backscattering and its influence on natural behaviour patterns. Daylight filming allows the use of relatively cheap video cameras; however, the species of interest may not be present in the trawl during the day and its behaviour in the day may differ from its behaviour at night. To overcome these shortcomings and gather evidence of how prawns and fish react to prawn trawls, the Australian Maritime College constructed a multi-level beam trawl.

Trials in the NPF

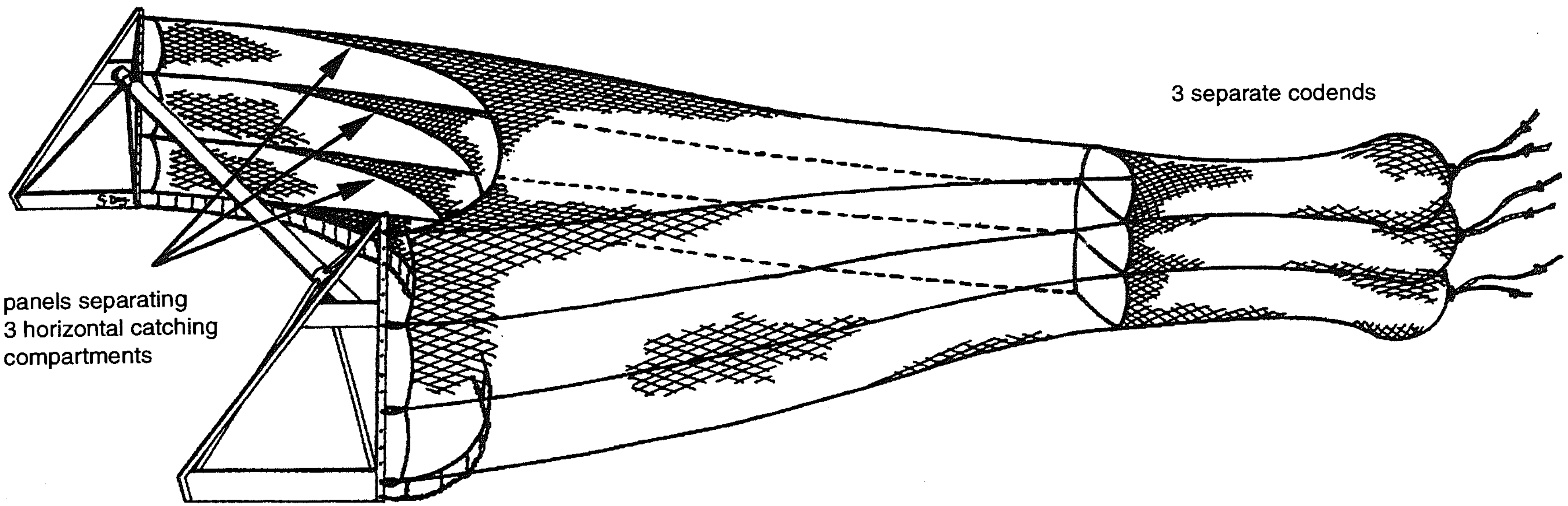
The MBT, 4 m wide and 1.8 m high, was made of aluminium (Figure 14). The height of the beam trawl is the maximum height of otter boards currently used in the NPF; the width was selected to provide adequate sample numbers. If required, these dimensions also allow the MBT to be towed as a try-net by NPF trawlers, collecting catch data without hampering the commercial operation. A four-seam trawl based on a Florida Flyer design was towed from the aluminium frame. It had three equally spaced vertical compartments (0 - 600 mm; 600 mm - 1200 mm; 1200 mm - 1800 mm). Each compartment was divided by identical horizontal panels so that prawns and fish reacting vertically to ground-chain contact could enter any one of the three compartments. A lead-ahead panel attached to the upper headline was extended between the wingends to prevent animals from escaping over the headline. A mesh size of 50 mm was used throughout the trawl.

Sea trials were conducted in Albatross Bay in the Gulf of Carpentaria over eight nights. A total of 49 half-hour tows were performed at an average tow speed of 2.7 knots.

The codend on the lower compartment caught the most fish (40 percent) and commercial prawns (81 percent). This suggests either that their usual habitat is close to the sea bed (already known for prawns), that the escape response of most fish and prawns is to move away close to the sea bed, or a combination of these behaviours. The top and middle compartments caught 39 and 20 per cent of the total fish catch respectively, and 14 and 5 per cent of the prawn catch. This suggests that the lead-ahead panel guided many animals into the trawl that otherwise would have escaped over the upper headline.

A more detailed analysis of the results revealed some interesting species-specific behaviour (Figures 15 (a)(b) & 16). For example, the dollar fish (*Leiognathus splendens*) and the 'sardine' (*Sardinella albella*) were caught mainly in the upper codend. A number of the sardines were also caught in the meshes of the lead-ahead panel. These results suggest that a BRD placed in the top of the codend, such as a square-mesh window or fisheye, may successfully exclude these species. A species of flatfish (*Pseudorhombus arsius*) was caught mainly in the lower codend, and a species of grinner (*Saurida micropectoralis*) was more evenly dispersed between the three codends, indicating a less directed response to the trawl (Figure 16).

Figure 14. The multi-level beam trawl used to study the reaction of fish and prawns to trawl gear (with lead-ahead panel removed)



Over 78 percent of grooved tiger prawns (*Penaeus semisulcatus*) and 86 percent of red endeavour prawns (*Metapenaeus ensis*) were caught in the lower codend (Figure 15 (a)). The bigger grooved tiger prawns were mainly caught by the upper codend (Figure 15(b)). This suggests that they are more active and either enter the upper codend after contact with the ground chain or are swimming at the time of capture. Too few blue endeavour prawns (*Metapenaeus endeavouri*) and brown tiger prawns (*Penaeus esculentus*) were caught for analysis.

BENEFITS

The headline height of a prawn trawl in the NPF may reach 1.8 m to maintain trawl geometry, as the headline of the trawl is attached to the aft trailing edge of the otterboard. Our trials indicate that the headline height could be reduced without significant loss of prawns but with a significant reduction in fish bycatch. Future trials with the MBT will test the effectiveness of the lead-ahead attachment to the lower compartments and will further test industry claims that the current headline height is required to catch large swimming prawns.

In future trials the headline height will be tested on a commercial prawn trawl. The Australian Maritime College is testing a 6 fathom prawn trawl with the headline at 50 percent of otterboard height. Trawl spread and warp tension data suggested that an increase in swept area may result from this modification, and no change in otterboard orientation was detected.

In summary, the multi-level beam trawl is providing us with valuable behavioural information that would be difficult, if not impossible to obtain by underwater video cameras. The net will help us to develop Bycatch Reduction Devices to exclude bycatch more effectively while retaining the valuable prawn catch. The study is also providing information on the viability of headline height modifications to improve trawl performance.

Figure 15 (a). The percentage of prawns that were caught in the multi-level beam trawl mouth at three different heights above the sea bed for four different species.

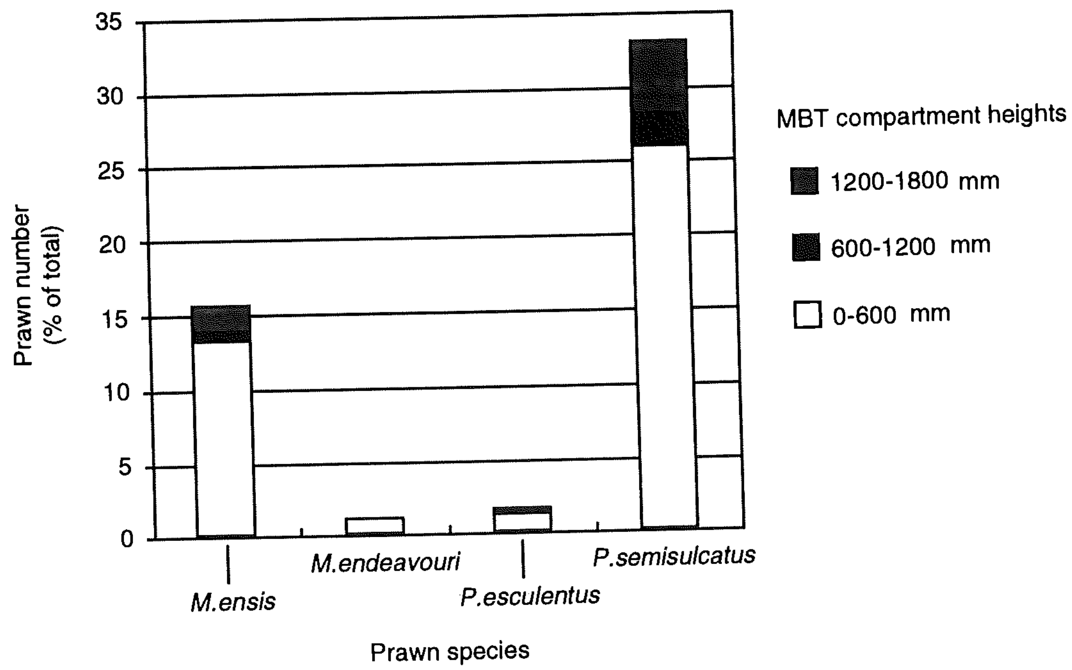


Figure 15 (b). The percentage of tiger prawns (*Penaeus semisulcatus* and *P.esculentus*) that entered the multi-level beam trawl at three different heights above the sea bed.

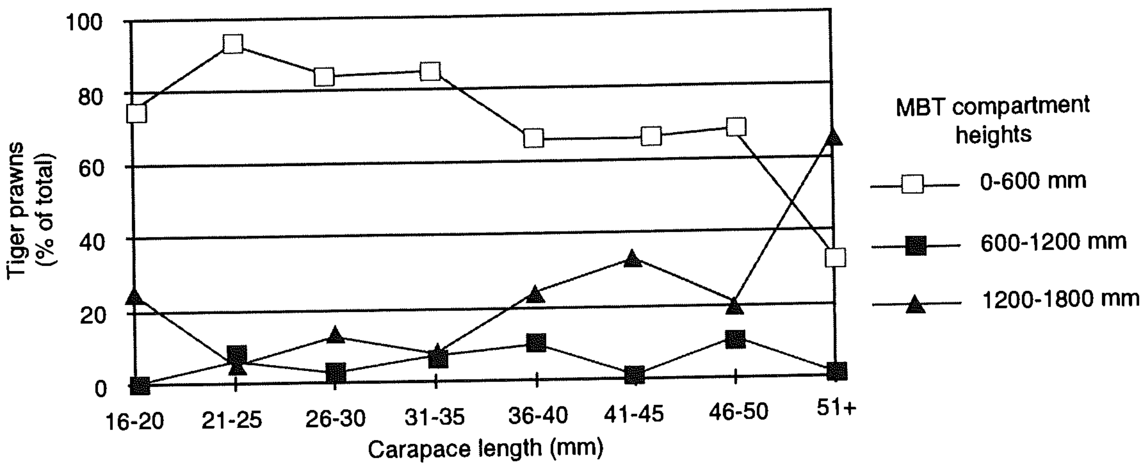
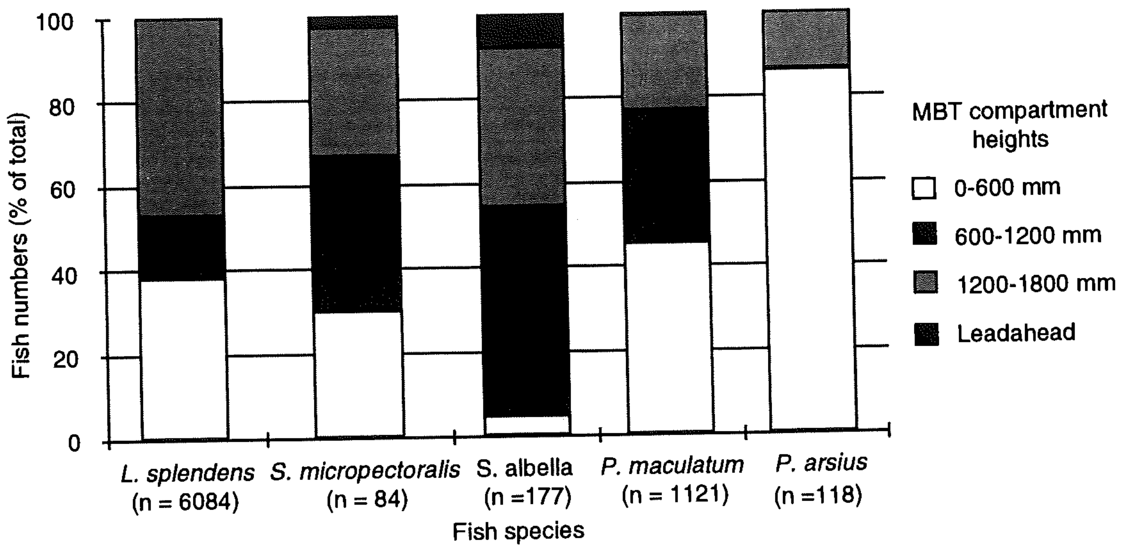


Figure 16. The numbers of different fish species that were caught in the multi-level beam trawl mouth at three different heights above the sea bed.



OBJECTIVE 5.

- **To develop an ongoing literature data base on environmentally friendly trawl gear research that can be accessed by other Australian research organisations.**

A literature database has been produced with the software package *Procite.* It includes scientific and 'grey' literature on the following topics: Bycatch Reduction Devices, trawl gear selectivity, behaviour of animals in trawls, fate of trawl discards, effects of trawling, survival of trawl escapees and trawl gear engineering performance.

Copies of the database are held at CSIRO Marine Laboratories in Cleveland, Australian Maritime College and Northern Territory Department of Primary Industry and Fisheries. The database, which is added to regularly, will be available to all fisheries research institutions in Australia. To date, more than 300 records have been entered.

Where possible, each record contains information on at least the following fields:

title	place of meeting (e.g. if from proceedings/workshop)
authors	date of the meeting
author affiliation	keywords
abstract	notes
journal name	ISBN number
volume number	ISSN number
issue number	publisher (for other than journals)
pages	place of publication (for other than journals)
date	availability (where hard copies are held)

OBJECTIVE 6.

- **To promote the results of the project to the fishing industry.**

The desired end point of any new trawl gear development is its voluntary acceptance and adoption by the industry. To this end, a substantial effort was directed to publicising the project's objectives and results, specially to the fishing industry. The primary focus of the communication plan was to report the results in fishing industry magazines, at fishing industry meetings and through newsletters. Other means of reporting were also used: publishing in scientific journals, oral and poster presentations at scientific conferences, press releases, articles in general community magazines, and radio and television interviews.

This output is listed below and some of the written articles are attached in the appendices. Copies of most of the television segments and posters can be obtained on request from project staff.

LIST OF THE COMMUNICATION ITEMS

1. **Papers in scientific journals (see Appendix A):**
   - Brewer, David T.; Eayrs, Steve; Mounsey Richard P.; and Wang, You-Gan. 1995. Assessment of an environmentally friendly, semi-pelagic fish trawl. *Fisheries Research.*
2. **Articles in fishing industry magazines (see Appendix C):**
   - Brewer, David and Eayrs, Steve. 1994. "New prawn and fish-trawl gear reduces non-target bycatch". *Australian Fisheries* 53(3): 9-11.
   - Eayrs, Steve, David Brewer, and Neville Gill. "NPF fishers inspect Bycatch Reduction Devices". *The Queensland Fisherman* January 1996.
   - Eayrs, Steve, David Brewer, and Neville Gill. "NPF fisherman view Bycatch Reduction Devices" *Professional Fisherman*, February 1996.

- David Brewer, Steve Eayrs and Nick Rawlinson. "Bycatch Reduction Devices show promise in the NPF". *Australian Fisheries*, May 1995.
- Nick Rawlinson and Dave Brewer. "Monsters, blubber and other bycatch - NPF operators' views on bycatch reduction" *Australian Fisheries*, May 1995.
- Steve Eayrs, David Brewer, Shekar Bose and Rik Buckworth. "Multi-level beam trawl reveals fish and prawn behaviour" *Professional Fisherman*, July 1996.
- David Brewer, Nick Rawlinson, Steve Eayrs and John Salini. "Bycatch Reduction Devices can benefit prawn fishers". *Fishing Boat World*, December 1996.
- David Brewer, Nick Rawlinson, Steve Eayrs and John Salini. "Bycatch Reduction Devices can benefit prawn fishers". *Professional Fisherman*, January 1997.

3. **Articles in science magazines (see Appendix C):**
   - David Brewer. "Escape Nets reduce fish bycatch" *Ecos* magazine. Spring 1994.
   - Anon. "Bycatch Reduction Devices in the Gulf of Carpentaria." *AMC News*, December 1995.

4. **Articles in local community newspapers (see Appendix C):**
   - "New net to cut trawl bycatch" - *The Cairns Post* June 23 1994
   - "One of a kind fish experiment" - *The Weipa Bulletin*, August 12 1994

5. **Articles in local and large newspapers (see Appendix C):**
   - "Fishermen aim to cut slaughter" - *The Sunday Mail* July 24 1994
   - "New net trials aim to cut loss of marine life" - *The Courier Mail* November 30 1994
   - "A better way to fish, by hook or crook" - *The Canberra Times* March 4 1995
   - "The Killing Beds" - *The Weekend Australian* June 10-11 1995
   - "Nets with a catch - fish escape" - *The Courier Mail* June 14 1995

6. **Television segments in a variety of programs including children's information, science and community programs:**
   - The ABC program, *"Landline"* covered a story on our bycatch survival research in 1994
   - A program called *"Cross Country"* covered a story on the project in general in 1995

7. **Oral presentation of project results at fishing industry workshops:**
   - Various members of the team have presented project results at several industry meetings including three annual workshops and two practical gear demonstration days on board MRV *Southern Surveyor*.

8. **Oral presentation and posters of project results at local, national and international scientific seminars and conferences:**
   - Seminar at CSIRO Fisheries, Cleveland in July 1995 - "Bycatch reduction in Australia's NPF" by David Brewer and Nick Rawlinson. This was to local scientists.
   - Seminar at the Second World Fisheries Congress in July 1996 - "Recent advancements in environmentally friendly trawl gear in Australia" by David Brewer. This was presented to a world-wide forum of scientists, managers, fishers and politicians.
   - Seminar at Kuwait Working Group on Demersal Fisheries, Kuwait, May 1996 - "Bycatch reduction research in Australia's Northern Prawn Fishery" by David Brewer

- **Posters at the Second World Fisheries Congress in July 1996 titled**
  1. Assessment of an environmentally friendly, semi-pelagic fish trawl. Brewer, Eayrs, Mounsey, Wang and Salini.
  2. A comparison between diamond and square-mesh codend selectivity in the Northern Prawn Fishery of Australia. Rawlinson, Brewer, Eayrs and Salini.
  3. Survival of selected fish species after escaping from square-mesh codends. Rawlinson, Brewer and Salini.

9. Radio interviews:

- There have been many (6-10) radio interviews made, mainly with Australian regional stations, but no record of them was kept.

10. Newsletters to industry and the general public (see Appendix C):

- These were prepared for general distribution to scientific or industry meetings or mailing lists to help inform these groups of the projects objectives and results

INTELLECTUAL PROPERTY

No commercial intellectual property arose from this work.

FURTHER DEVELOPMENT

Two new FRDC projects have arisen from this work. Their titles and objectives are as follows:

1. Ecological sustainability of bycatch and biodiversity in prawn trawl fisheries.

OBJECTIVES:

- To review the literature of prawn trawl bycatch, including methods of estimating and monitoring it, to add to the already substantial database on Bycatch Reduction Devices.
- To develop cost-effective, accurate and feasible methods of describing and monitoring prawn trawl bycatch that would be acceptable to all stakeholders.
- To compile a detailed description of the bycatch in the NPF, Torres Strait tiger prawn fisheries and Queensland East Coast banana prawn fisheries to provide a reference for future assessments.
- To measure the impact of prawn trawling on the sustainability of selected vertebrate bycatch species, particularly those that may be vulnerable or endangered, and of those bycatch species for which no significant reductions can be achieved.
- To assess the effects of prawn trawling on the biodiversity of key fish and other vertebrate communities.

2. Commercialisation of strategies and devices to reduce bycatch in northern Australian prawn trawl fisheries.

OBJECTIVES.

- Exchange information with commercial trawl fishers about ways of reducing the catch of non-target organisms in their trawl nets.
- Further develop promising Bycatch Reduction Devices and other bycatch reduction strategies under commercial conditions.
- Document, accumulate and publish performance data of turtle-excluder devices and bycatch reduction gears suitable for the commercial fishing industry of the Queensland East Coast, the Torres Strait, the Northern Prawn Fishery, and other interested parties.
- Encourage and promote the use of Bycatch Reduction Devices by commercial trawl operators.

We expect that the two new FRDC projects will be followed up with the following topics:

1. Study of the economic values of using BRDs

A study of the financial costs and benefits of using BRDs will clarify this debate. Such a study is likely to show that the cost of purchase and operation of BRDs is minute, the cost due to prawn loss can be zero or better, but improved product quality would have significant financial benefits. This study is especially important in the NPF which exports most of its prawns to countries that demand the highest quality (= high-priced) product (e.g. from individual finger-packed prawns). If using BRDs decreases the proportion of damaged prawn in the catch, they will directly increase annual profits.

2. Demonstration and training in fitting and using BRDs

For BRDs to perform effectively, they must be fitted and used correctly. Workshops should be given to demonstrate the correct fitting and use of BRDs. Australian and American experts could visit the main fishing ports in the NPF and Qld East Coast to demonstrate these techniques.

3. Investigate the possibility of manufacturing BRDs in Australia

The adoption of BRDs into Australian prawn trawl fisheries will be cheaper and more efficient if local industry is used to manufacture the most popular BRDs. The sooner local BRD production is 'on-line' the sooner the local industry will benefit.

4. Detailed behavioural studies of prawn and fish bycatch in trawls

Detailed studies of prawn and bycatch behaviour in trawls will have two main benefits. Firstly, they will enable us to adjust BRDs so that any prawn losses can be further minimised, as well as improve escapement of unwanted fish bycatch. Secondly, improved knowledge of escapement and survival of animals from trawls with and without BRDs will be critical to studying:

(a) whether under-commercial-sized prawns that escape from certain BRDs survive to enhance stocks.

(b) whether BRDs exclude some bycatch species more than others, thereby changing the species composition of the marine community.

(c) whether the amount of bycatch excluded by using BRDs is enough to provide for the sustainability of species that otherwise are not exploited.

STAFF

Name	Organisation	Position	Major roles
Dr S.J.M. Blaber	CSIRO*	Senior Principal Research Scientist	Joint Principal Investigator
D.T. Brewer	CSIRO*	Fisheries Ecologist	Biologist/ Project Co-ordinator/ Database
C.Y. Burridge	CSIRO*	Biometrician	Statistician/ Experimental Design
M.J. Farmer	CSIRO*	Fisheries Biologist	Biologist
N.J.F. Rawlinson	CSIRO*	Fisheries Ecologist	Biologist/ Gear Construction/ Experimental Design
J.P. Salini	CSIRO*	Fisheries Ecologist	Biologist/ Cruise Leader
Y. Wang	CSIRO*	Biometrician	Statistician/ Experimental Design
T.J. Wassenberg	CSIRO*	Fisheries Ecologist	Biologist
I. Cartwright	AMC#	Head: School of Fisheries	Joint Principal Investigator
S. Eayrs	AMC#	Fisheries Technologist	Gear Technology
D.C. Ramm	NTDPIFΔ	Senior Research Scientist	Joint Principal Investigator
R.C. Buckworth	NTDPIFΔ	Research Scientist	Biologist

* CSIRO = Commonwealth Scientific and Industrial Research Organisation, Division of Marine Research, Cleveland, Queensland

AMC = Australian Maritime College, Beauty Point, Tasmania

Δ NTDPIF = Northern Territory Department of Primary Industry and Fisheries, Darwin, Northern Territory

DISTRIBUTION

Distribution list for the final report:

- ten copies to FRDC (one unbound)
- one copy to NORMAC
- one copy to Queensland TrawlMAC
- three copies to CSIRO Division of Marine Research, library
- one copy to Australian Maritime College, library
- one copy to Northern Territory Department of Primary Industry and Fisheries, library

FINAL COST

The final acquittal report was forwarded to FRDC on 12 September. A copy of the report follows.

CSIRO - Division of Fisheries
GPO Box 1538
Hobart TAS 7001

Fisheries Research & Development Corporation Research Grant

Final Audited Statement of Receipts and Expenditure

As at 12 September 1996

Name of Grantee:	CSIRO Division of Fisheries.	**FRDC Funds:**	
Title of Project:	The effects of trawl design on bycatch and benthos in prawn and fin-fish Fisheries.	1993/94	$258,177
		1994/95	$266,701
		1995/96	$269,203
		AMC Funds	$6,000
CSIRO Project No:	DF24CMTFS - - AT		$800,081
FRDC Project No:	93/179	Received to date	$726,780

Receipts:	**1992/93**	**1993/94**	**1994/95**	**1995/96**	**1996/97**	**Total**
July–December		$64,544	$262,438	$133,976		$460,958
January–June		$64,544	$66,676	$1 34,602		$265,822
TOTALS	$0	$129,088	$329,114	$268,578	$0	$726,780

Less Expenditure:	**Overall Budget**	**1992/93**	**1993/94**	**1994/95**	**1995/96**	**1996/97**	**Total**
Salaries	$434,454		$149,912	$162,162	$165,718	($7,365)	$470,427
Travel	$126,420		$31,837	$24,66	$27,065		$83,567
Operating	$115,531		$77,152	$89,027	$73,908	$6,000	$246,087
Capital	$117,676						$0
TOTALS	$794,081	$0	$258,901	$275,854	$266,691	($1,365)	$800,081
Cash Balance:		$0	($129,813)	($76,553)	($74,666)	($73,301)	($73,301)

Comments: As pointed out on previous acquittal reports, the CSIRO financial system does not allow the transfer of funds to other collaborating bodies to be recorded against the expenditure category for which it is intended. It is for this reason that significant variations exist across all categories of expenditure. The overspend highlighted in the 30 June 1996 statement has now been transferred back to an internal CSIRO account an additional $6,000 is now due from FRDC due to request to pay $6,000 to AMC. Total outstanding is therefore $73,301.

Prepared by responsible officer:	*Certified by responsible officer:*
Greg Lyden	Peter Green
External Grants Officer	Finance Manager
12-Sep-96	12-Sep-96

REFERENCES

Alshuth, S. 1989. Variation in growth of adult North Sea sprat (*Sprattus sprattus* L.). International Council Exploration of the Sea. Council meeting, Copenhagen, Denmark.

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: 339. FAO, Rome. 233p.

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

Andrew, N.L., Kennelly, S.J. and Broadhurst, M.K. 1993. An application of the Morrison Soft TED to the offshore prawn fishery in NSW, *Australia. Fisheries Research.* 16: 101-111.

Armstrong, D.W., Ferro, R.S.T., MacLennan, D.N., and Reeves, S.A. 1990. Gear selectivity and conservation of fish. *Journal of Fish Biology*. 37: 261-262.

Beek, F.A., Leeuwen, P.I., and Rijnsdorp, A.D. 1989. On the survival of plaice and sole discards in the otter trawl and beam trawl fisheries in the North Sea. *ICES CM* 1989/G:46.

Berghahn, R., Waltemath, M. and Rjinsdorf, A.D. 1992. Mortality of fish from the bycatch of shrimp vessels in the North Sea. *Journal of Applied Ichthyology*. 8: 293-306.

Blaber, S.J.M., Brewer, D.T. and Harris, A.N. 1994. Distribution, biomass and community structure of demersal fishes in the Gulf of Carpentaria, Australia. *Australian Journal of Marine and Freshwater Research.* 45 (3): 375-396.

Boris, V.M. and Efanov, S.F. 1991. To the problem of natural and traumatical mortality of Baltic herring. *ICES CM* 1981/J:13.

Broadhurst, M.K. and Kennelly, S.J. 1994. Reducing the bycatch of juvenile fish (mulloway) in the Hawkesbury River prawn-trawl fishery using square-mesh panels in codends. *Fisheries Research* (Amsterdam). 19: 321-31.

Broadhurst, M.K. and Kennelly, S.J. 1995. A trouser-trawl experiment to assess codends that exclude juvenile mulloway (*Argyrosomus hololepidotus*) in the Hawkesbury River prawn-trawl fishery. *Marine and Freshwater Research.* 46 (6): 953-958.

Broadhurst, M.K. and Kennelly, S.J. 1996a. Effects os square-mesh panels in codends and of haulback delay on bycatch reduction in the oceanic prawn-trawl fishery of New South Wales, Australia. *Fishery Bulletin*. 94: 412-422.

Broadhurst, M.K. and Kennelly, S.J. 1996b. Reducing bycatch while increasing commercial prawn catches. Professional Fisherman Incorporating *Australian Fisheries*. July 1996. p 24.

Broadhurst, M.K. and Kennelly, S.J. 1996c. Solving by-catch problems in New South Wales estuarine prawn-trawl fisheries. Professional Fisherman Incorporating *Australian Fisheries.* June 1996. p 28.

Casey, J., Nicholson, M.D. and Warnes, S. 1992. Selectivity of square-mesh codends on pelagic trawls for Atlantic mackerel (*Scomber scombrus* L.). *Fisheries Research.* 13: 267-279.

Cassie, R.M. 1955. The escapement of small fish from trawl nets and its application to the management of the New Zealand snapper fisheries. *New Zealand Marine Department of Fisheries Bulletin.* 11, 99 pp.

Cochran, W.G. and Cox, G.M. 1957. *Experimental Designs*, Second edition. New York. Wiley.

Cooper, C. and Hickey, W. 1989. Selectivity experiments with square-mesh codends of 130, 140 and 155 mm. In: S.G. Fox and J. Huntington (Editors), Proceedings of the World Symposium on Fishing Gear and Fishing Vessel Design, The Newfoundland and Labrador Institute of Fisheries and Marine Technology, St. John's, Newfoundland, Canada, pp. 52-57.

Crocos, P.J. 1987. Reproductive dynamics of the Grooved Tiger prawn, *Penaeus semisulcatus*, in the North western Gulf of Carpentaria, Australia. *Australian Journal of Marine and Freshwater Research.* 38, 79-90

DeAlteris, J. T. and Reifsteck, D.M. 1993. Escapement and survival of fish from the codend of a demersal trawl. *ICES Marine Science Symposium.* 196: 128-131.

Edwards, R.R.C. 1983. The Taiwanese pair trawler fishery in tropical Australian waters. *Fisheries Research.* 2: 47-60.

Efanov, S.F. and Istomin, I.G. 1988. Survival of Alaska pollack and selective properties of trawl cod-ends. *ICES CM* 1988/B:20.

Engås, A. and Godø, O.R. 1986. Influence of trawl geometry and vertical distribution of fish on sampling with bottom trawl. *Journal of Northwestern Atlantic Fisheries Science.* 7: 35-42.

Fonteyne, R. and M'Rabet, R. 1992. Selectivity experiments on sole with diamond and square-mesh codends in the Belgian coastal beam trawl fishery. *Fisheries Research.* 13: 221-233.

Glass, C.W. and Wardle, C.S. 1995. Studies on the use of visual stimuli to control fish escape from codends. II. The effect of a black tunnel on the reaction behaviour of fish in otter trawl codends. *Fisheries Research.* 23: 165-174.

Glass, C.W., Wardle, C.S., Gosden, S.J. and Racey, D.N. 1995. Studies on the use of visual stimuli to control fish escape from codends. I. Laboratory studies on the effect of a black tunnel on mesh penetration. *Fisheries Research.* 23: 157-164.

Goudey, C.A. 1987. The development of a semi-pelagic trawl for squid and butterfish. In: The Ocean - An International Workplace, Proceedings of Oceans '87. Vol. 2. Marine Engineering; Policy, Education and Technology Transfer. pp. 645-648.

Harris, A.N. and Poiner, I.R. 1990. Bycatch of the prawn fishery of Torres Strait; composition and partitioning of the discards into components that float or sink. *Australian Journal of Marine and Freshwater Research.* 41: 37-52.

Harris, A.N. and Poiner, I.R. 1996. Incidental capture, direct mortality and delayed mortality of sea turtles in Australia's Northern Prawn Fishery. *Marine Biology.* 125: 813-825.

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 animals. *Commercial Fisheries Review.* 31: 20-33.

Hill, B.J. and Wassenberg, T.J. 1990. Fate of discards from prawn trawlers in Torres Strait. *Australian Journal of Marine and Freshwater Research.* 41: 53-64.

Isaksen, B. and Valdemarsen, J.W. 1986. Selectivity experiments with square-mesh codends in bottom trawl. International Council for the Exploration of the Sea. *CM* 1986/B:28, 18 pp.(mimeo).

Isaksen, B. 1991. Survival of fish from Danish seine and trawl cod-ends. European Commission Workshop on Cod-end selectivity. Marine Laboratory, Aberdeen, Scotland, June 1991.

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

Jacobsen, J.A., Thomsen, B., and Isaksen, B. 1992. Survival of saithe (*Pollachius virens* L) escaping through trawl meshes. *ICES CM* 1992/B:29.

Kailola, P.J., Williams, M.J., Stewart, P.C., Riechelt, R.E., McNee, A. and Grieve, C. 1993. Australian Fisheries Resources. Bureau of Resource Sciences, Department of Primary Industries and Energy, and the Fisheries Research and Development Corporation. Canberra, Australia. 422 pp.

Kaiser, M.J. and Spencer, B.E. 1995. Survival of bycatch from a beam trawl. *Marine Ecology Progress Series.* 126: 31 -38.

Liu, H-C., Sainsbury, K.J. and Chiu, T-S. 1985. Trawl cod-end mesh selectivity for some fishes of north-western Australia. *Fisheries Research.* 3: 105-129.

MacLennan, D.N. 1992. Fishing gear selectivity: an overview. *Fisheries Research.* 13: 201-204.

Main, J. and Sangster, G.I. 1984. Observations on the reaction of fish to fishing gear using a towed wet submersible and underwater television. Gamble, J.C. and Shand, J. eds. Progress in underwater science. Report of the Underwater Association (NS) 9: 99-114.

Main, J. and Sangster, G.I. 1990. An assessment of the scale damage to and survival rates of young gadoid fish escaping from the codend of a demersal trawl. Scottish Fisheries Research Report, 46, 28 pp.

Main, J. and Sangster, G.I. 1991. Do fish escaping from codends survive? Scottish Fisheries Working Paper No 18/91.

Martin, T. J., Brewer, D. T. and Blaber, S. J. M. 1995. Factors affecting distribution and abundance of small demersal fishes in the Gulf of Carpentaria. *Australian Journal of Marine and Freshwater Research.* 46: 909-20.

Millar, R.B. and Walsh, S.J. 1992. Analysis of trawl selectivity studies with an application to trouser trawls. *Fisheries Research*. 13: 205-220.

Millner, R.S., Whiting, C.L., and Howlett, G.L. 1993. Estimation of discard mortality of plaice from small otter trawlers using tagging and cage survival studies. *ICES CM* 1993/G:24.

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

Neilson, J.D., Waiwood, K.G., and Smith, S.J. 1989. Survival of Atlantic halibut (*Hippoglossus hippoglossus*) caught by longline and otter trawl gear. *Canadian Journal of Fisheries and Aquatic Science*. 46: 887-897.

Newton, G., Fowler, J., McLoughlin, K. and Staples, D. (Editors). 1994. Northern Fish-trawl Fishery and Northern Shark Fishery 1993, Fisheries Assessment Report compiled by the Fisheries Resource Assessment Group. Australian Fisheries Management Authority, Canberra.

Pender, P.J., Willing, R.S. and Ramm, D.C. 1992. Northern Prawn fishery bycatch study: distribution, abundance, size and use of bycatch from the mixed species fishery. Final report to the Advisory Committee Northern Territory Fishing Industry Research and Development Trust Account. Fishery Report 26. 70 pp

Pender, P.J., Willing, R.S., and Cann, B. 1992. NPF bycatch a valuable resource? *Australian Fisheries*. 51(2), 30-31.

Poiner, I.R. and Harris, A.N.M. 1996. The incidental capture, direct mortality and delayed mortality of sea turtles in Australia's Northern Prawn Fishery. *Marine Biology*. In Press.

Poiner, I.R., Buckworth, R.C., and Harris, A.N.M. 1990. Incidental capture and mortality of sea turtles in Australia's Northern Prawn Fishery. *Australian Journal of Marine and Freshwater Research*. 41: 97-110.

Pownall, P.C. 1994. *Australia's Northern Prawn Fishery: the first 25 years*, P.C. Pownall (Editor), NPF25, Cleveland, Australia.

Ramm, D.C., Mounsey, R.P. Xiao, Y. and Poole, S.E. 1993. Use of a semi-pelagic trawl in a tropical demersal trawl fishery. *Fisheries Research*. 15: 301-313.

Ramm, D.C., Pender, P.J., Willing, R.S., and Buckworth, R.C. 1990. Large scale spatial patterns of abundance within the assemblage of fish caught by prawn trawlers from northern Australian waters. *Australian Journal of Marine and Freshwater Research*. 41: 79-95.

Rawlinson, N and Brewer, D. 1995. Monsters, blubber and other bycatch - NPF operators' views on bycatch reduction. *Australian Fisheries*, May 1995.

Reifsteck, D.M. and DeAlteris, J.T. 1990. A methodology for investigating the behaviour and survival of bottom-trawl codend escapees and some preliminary results. Proceedings of the Fisheries Conservation Engineering /Workshop. Narragansett, Rhode Island, 4-5 April 1990.

Robertson, J.H.B. 1983. Square mesh codend selectivity experiments on whiting (*Merlangius merlangus* (L.)) and haddock (*Melanogrammus aeglefinus* (L.)). International Council for the Exploration of the Sea. CM 1983/B:25, 13 pp (mimeo).

Robertson, J.H.B. 1984. Square mesh codend selectivity for Haddock (*Melanogrammus aelgefinus* (L)) and whiting (*Merlangius merlangus* (L)) in a Scottish seine net. *ICES CM.* 1984/B:30, 4pp.

Robertson, J.H.B. and Stewart, P.A.M. 1988. A comparison of size selection of haddock and whiting by square and diamond-mesh codends. *Journal de Conseil*, International Council for the Exploration of the Sea. 44: 148-161.

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.

Sainsbury, K.J. 1987. Assessment and management of the demersal fishery on the continental shelf of northwestern Australia. In: J.J. Polovina and S. Ralston (Editors), Tropical Snappers and Groupers. Biology and Fishery Management. Westview Press, Boulder, CO, pp. 465-503.

Sainsbury, K.J. 1988. The ecological basis of multispecies fisheries and management of a demersal fishery in tropical Australia. In: J.A. Gulland (Editor), *Fish Population Dynamics* (2nd edition). John Wiley, London, pp. 349-382.

Sangster, G. 1990. The survival of fish escaping from fishing gears. *ICES CM* 1992/B:30.

SAS Institute Inc. 1988. *SAS/STAT Users Guide,* 6.03 Edition.

SAS Institute Inc. 1989 *SAS/STAT® User's Guide*, Version 6, Fourth Edition, Volume 2, Cary, N.C.: SAS Institute Inc., 864 pp.

Smith, M.M. and Heemstra, P.C. 1986. *Smith's Sea Fishes.* Johannesburg: Macmillan.

Snedecor, G.W. and Cochran, W.G. 1980. *Statistical Methods* (seventh edition). The Iowa State University Press. Ames, Iowa. 507 pp.

Soldal, A.V., Engås, A., and Isaksen, B. 1993. Survival of gadoids that escape from a demersal trawl. ICES Marine Science Symposium. 196: 122-127.

Soldal, A.V., Isaksen, B., Marteinsson, J.E., and Engås, A. 1991. Scale damage and survival of cod and haddock escaping from a demersal trawl. *ICES CM* 1991/B: 44, 7 pp.

Somers, I. 1994. Counting Prawns: Stock Assessment. In: Pownall, P.C. (editor). *Australia's Northern Prawn Fishery: the first 25 years*, NPF25, Cleveland, Australia.

Suuronen, P. 1995. Conservation of young fish by management of trawl selectivity. *Finnish Fisheries Research.* 15: 97-116.

Suuronen, P. and Millar, R.B. 1992. Size selectivity of diamond and square-mesh codends in pelagic herring trawls: only small herring will notice the difference. *Canadian Journal of Fisheries and Aquatic Science.* 49: 2104-21117.

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

Valdemarsen, J. W., Lehmann, K., Riget, F. and Boje, J. 1993. Grid devices to select shrimp size in trawls. ICES Statutory Meeting, Fish capture Committee.

von Kelle, W. 1976. Mortality rate of discarded flatfish. Meersforch. 25; 77-89.

Walsh, S.J., Millar, R.B., Cooper, C.G. and Hickey, W.M. 1992. Codend selection in American plaice: diamond versus square-mesh. *Fisheries. Research.* 13: 235-254.

Wassenberg, T.J., Salini, J.P., Heatwole, H., and Kerr, J.D. 1994. Incidental capture of sea snakes (Hydrophidae) by prawn trawlers in the Gulf of Carpentaria, Australia. *Australian Journal of Marine and Freshwater Research.* 45: 429-43.

Wassenberg, T.J. and Hill, B.J. 1989. The effect of trawling and subsequent handling on the survival rates of the bycatch of prawn trawlers in Moreton Bay, *Australia. Fisheries Research.* 7: 99-110.

Wassenberg, T.J. and Hill, B.J. 1990. Partitioning of material discarded from trawlers in Moreton Bay. *Australian Journal of Marine and Freshwater Research.* 41: 1-12.

Wassenberg, T.J. and Hill, B.J. 1993. Selection of the appropriate duration of experiments to measure the survival of animals discarded from trawlers. *Fisheries. Research.* 17: 343-352.

Watson, J. W. and Taylor, C. W. 1988. Research on selective shrimp trawl designs for penaeid shrimp in the United States: A review of selective shrimp trawl research in the United States since 1973. FAO expert consultation on selective shrimp trawl development, Mazatlan, Mexico, 24-28 November 1986. FAO Rome, 1986.

Watson, John, Ian Workman, Dan Foster, Charles Taylor, Arvind Shah, James Barbour, Dominy Hataway. March 1993. Status Report on the Development of Gear Modifications to Reduce Finfish Bycatch in Shrimp Trawls in the Southeastern United States 1990-1992. NOAA Technical Memorandum, NMFS - SEFSC - 327, 131 p.

APPENDICES

Appendix A: Published Papers

Brewer, David T., Eayrs, Steve, Mounsey, Richard P. and Wang, You-Gan. 1996. Assessment of an environmentally friendly, semi-pelagic fish trawl. *Fisheries Research* . 26: 225-237

Reprinted from

FISHERIES RESEARCH

Fisheries Research 26 (1996) 225–237

Assessment of an environmentally friendly, semi-pelagic fish trawl

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FISHERIES RESEARCH

Assessment of an environmentally friendly, semi-pelagic fish trawl

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Abstract

Minimising catches of non-target animals in a trawl fishery reduces the impact on a marine community and may help to sustain the fishery resource in the long term. Hence the desirability for trawls that minimise impacts on non-target species while maintaining catches of target species. This study resulted from a need to further develop easily handled, semi-pelagic style trawls for Australia's Northern Fish Trawl Fishery. In November 1993 we compared catches from three differently rigged versions of a demersal wing trawl: one fished in a standard demersal configuration with its footrope on the sea bed, and two fished semi-pelagically, with their footropes raised to either 0.4–0.5 or 0.8–0.9 m above the sea bed. At two sites in the northeast Gulf of Carpentaria, each trawl type was used on the same combination of sites, grids within sites and times of day.

Catches of the main target species (*Lutjanus malabaricus* and *Lutjanus erythropterus*) by the three trawl types were not significantly different. However, the mean catches of both these species and of other commercially important snappers, were highest in the semi-pelagic trawl raised 0.4–0.5 m above the sea bed. This increase could be due to a larger trawl spread or to the whole rig fishing higher in the water column.

Of the 107 species of fishes analysed, 61 were caught in greater abundance in the demersal trawl. Seven species were caught more effectively in the semi-pelagic trawl with the footrope 0.4–0.5 m above the substrate; none was caught most effectively with the footrope set at 0.8–0.9 m. Epibenthic byproduct species (squid and *Thenus orientalis*), fish bycatch, sponges and other epibenthic invertebrates were also caught in lower numbers in the semi-pelagic trawls. The semi-pelagic trawls convincingly caught less (in both numbers and biomass) of the unwanted species which are normally discarded. Semi-pelagic fish trawls of the types tested would be suitable for Australia's Northern Fish Trawl Fishery and probably other demersal trawl fisheries that would benefit from the conservation of non-target epibenthic communities.

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1. Introduction

The impact of trawling on marine ecosystems is of world-wide concern. particularly where critical habitats must be protected to sustain the fisheries. Several approaches to this problem are being studied intensively in Australia; our study is the first in a series by three collaborating Australian research organisations to assess methods that lessen the environmental impact of trawling in tropical waters.

Northern Australian waters on the continental shelf between 114 and 140°E support a multi-species demersal fish trawl fishery (for descriptions, see Edwards, 1983; Sainsbury, 1987; Blaber et al., 1994) that, like others in Australian tropical waters, has a large bycatch component (mainly fish), which is usually discarded at sea. Demersal fish trawling on the Australian Northwest Shelf in the 1960s and 1970s significantly reduced the abundances of sponges and associated benthos such as alcyonarians and gorgonians. This was thought to have led to a reduction in catches of the main target species. *Lethrinus* and *Lutjanus* (Sainsbury, 1988). New regulations for the Northern Fish Trawl Fishery, introduced in 1991, allow use of only semi-pelagic fish trawls—trawls rigged to operate with sweeps, bridles and net clear of the sea bed, though with the otterboards on the sea bed.

An earlier version of this style of trawl caught adequate catches of commercially important fish, had less impact on the substrate and retained fewer unwanted species (Ramm et al., 1993). The resultant cleaner catches of the commercially important fish resulted in a higher quality product. The trawl, known as the 'Julie Anne trawl', is a fork-rigged, semi-pelagic, four-seam box trawl that uses fly-wires (upper bridles) and floats to lift the headline. This, combined with the absence of a groundrope, raises the whole trawl off the sea bed (Ramm et al., 1993).

Although the initial trials of the 'Julie Anne trawl' gave promising results, in subsequent tests is was found that the trawl's geometry was sensitive to changes in towing conditions, including towing speed, water depth and length of warp. The trawl required constant monitoring and adjustment and took longer to deploy and retrieve.

An alternative semi-pelagic trawl was designed. We fished this demersal wing trawl (the 'McKenna wing trawl') on the sea bed and semi-pelagically, with the groundrope removed and footrope set at one of two heights above the sea bed. The results are further evidence that semi-pelagic trawls can be environmentally friendly and that they may be viable alternatives to standard demersal fish trawls.

2. Materials and methods

2.1. Trawl design

Two identical wing trawls were used in the trials: each had a headline length of 25.6 m, a fishing circle of 48.8 m, and 50 mm stretch-mesh polyethylene netting throughout the

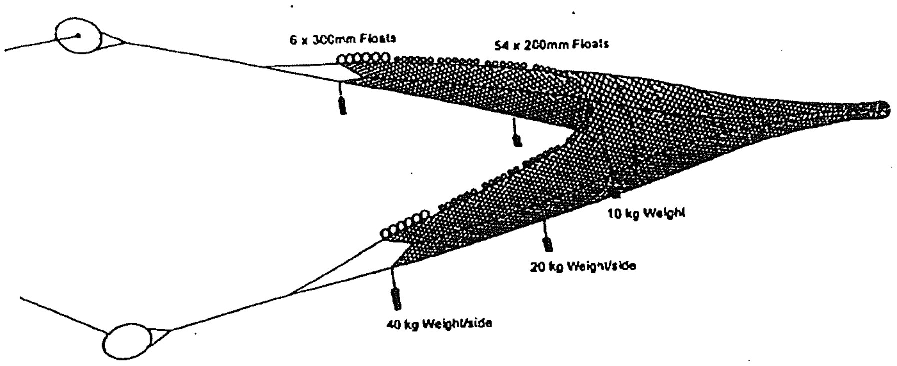

Fig. 1. The wing trawl used in this study, rigged to fish semi-pelagically; its footrope is 0.4–0.5 m above the sea bed.

cod-end (Fig. 1). Commercial trawlers use 110 mm mesh cod-ends, but the 50 mm mesh size enabled us to study a greater range of species. Trawl 1 was rigged for standard demersal operation and was used as a control to test the effect of footrope height on commercial fish catches. Its groundrope weighed 170 kg in air and total headline flotation was 157 kg. Trawl 2 had the groundrope removed and was rigged to operate at 0.4–0.5 m (Trawl 2a) and 0.8–0.9 m (Trawl 2b) above the sea bed. The desired heights were achieved through a combination of headline flotation and steel weights (10, 20 and 40 kg) attached to the footrope (Table 1). Fig. 1 shows the position of floats and footrope weights to operate the trawl at 0.4–0.5 m above the sea bed. Bridle and sweep lengths for all trawls were 50 and 40 m respectively. Single slot polyvalent otterboards were used throughout the trials. Each otterboard weighed 1000 kg and had a surface area of 3.8 m^2.

2.2. *Trawl performance monitoring*

The distance between the otterboards on all trawls was measured by 'Scanmar' acoustic sensors housed in brackets attached to the otterboards. Wing-end spread measurements of Trawl 1 were obtained by placing the sensors on the upper wing-ends, 0.3 m ahead of the netting. These were not measured for trawls 2a and 2b. Headline height was monitored with a 'Scanmar' height sensor attached to the second row of meshes behind the centre of the headline.

At the Australian Maritime College flume tank before the cruise, a small beam trawl (net removed) was towed with 2.5 m lengths of 10 mm 'dropper' chains attached at known

Table 1
Total groundrope weight, footrope weight, headline flotation and footrope height for the three trawl types

Trawl no.	Groundrope weight (kg)	Footrope weight (kg)	Headline flotation (kg)	Footrope height (m)
1	170	0	157	0.0
2a	0	130	245	0.4–0.5
2b	0	110	262	0.8–0.9

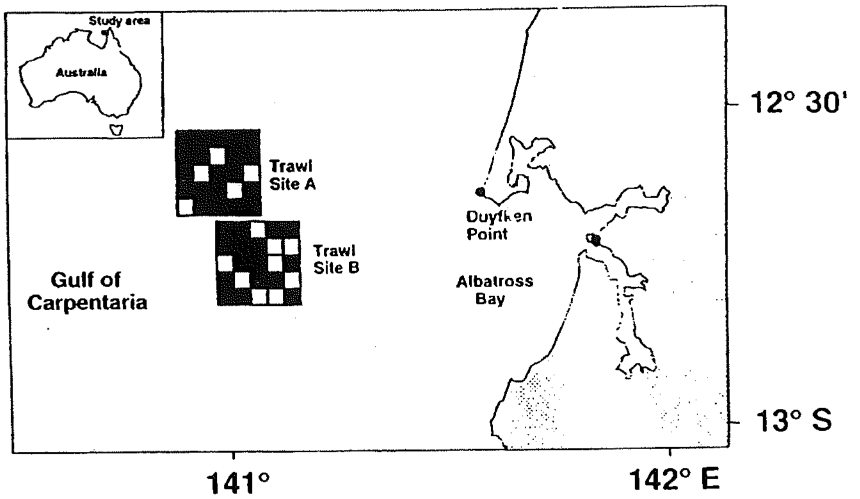

Fig. 2. Northeastern Gulf of Carpentaria, showing the sites and grids sampled in this study. Each grid was sampled by all three trawl types.

vertical heights. The number of polished links was recorded at the end of tows at a range of speeds. A plot of vertical height against number of unpolished links was generated. The footrope on the field nets was also fitted with the dropper chains. The number of unpolished links was then compared with the plot to determine footrope height.

Warp tension during sea trials was measured by recording hydraulic oil pressure of each winch with an A/S Hydraulik Brattvaag 'Synchro 2000' automatic trawl-control system. Video footage was recorded on a 'Sony Hi 8 Handycam' in an underwater housing attached to the trawl. All tows were made at 1.8 m s^{-1}, using a warp-to-depth ratio of 3:1. Tow duration was 30 min and trawl performance data were recorded midway through each tow. Trawl speed was recorded with a 'JRC' doppler log.

2.3. Study area and sampling strategy

The area chosen for trawl comparisons (Fig. 2) was within the waters of the Northern Fish Trawl Fishery Management Zone (described in Newton et al., 1994). It was chosen because previous studies had shown it had the two key components required for our comparison: commercial quantities of red snappers (Lutjanidae) and structural benthos (macrobenthos protruding above the seabed) (CSIRO unpublished data, 1990).

The trawl area was divided into two 18 km × 18 km sites (A and B, Fig. 2), each of which was divided into 25, 2 × 2 nautical mile grids. Sites were sampled alternately and for 3 days at a time (each day a different trawl gear type). Site A was sampled four times (4 visits × 5 grids × 3 trawl types = 60 tows), while Site B was sampled three times (3 visits × 5 grids × 3 trawl types = 45 tows), with one extra grid sampled by each trawl type at Site B: this gave a total of 108 trawls (Fig. 2). The net type was randomly re-ordered for each site visit. Each day's trawling consisted of five trawls, in five separate grids, one in each of five time slots (08:00–10:00, 10:00–12:00, 12:00–14:00, 14:00–16:00 and 16:00–18:00). These gave comparisons of each net type in the same grid (physical area) at the same time of day. The same five (randomly chosen) grids were used for each set of three trawl types before a new set of five grids was chosen. Depth in the sampling areas ranged between 41 and 58 m (mean 50.6 m, $n = 108$).

2.4. Data collection and analyses

We identified all fish to species, weighed each species group, counted individuals and measured the lengths of the smallest and largest in each catch. Fishes (including elasmobranchs) that were longer than about 500 mm, and all commercially important fishes, were measured and weighed individually (commercially important fishes were regarded as those currently marketed by commercial fishers or either targeted or kept by recreational or traditional fishers).

Where catches of smaller fishes were large (over about 50 kg), a subsample (usually around 30%) was taken and processed, and the remainder was weighed. For these trawls, the data for the total catch were calculated by multiplying up the sub-sample values to a total weight of smaller fish.

Invertebrates were treated in the same way as fish, with all large specimens measured and large numbers of smaller organisms subsampled. Invertebrates were often only identified to class.

The analyses described below were applied to all species individually and to the following categories of combined species:

1. 'sharks'—free swimming and usually pelagic (mostly Carcharhinidae);
2. 'other elasmobranchs' (mainly stingrays and shovelnose rays);
3. 'fish bycatch' (mainly small fishes);
4. 'sponges';
5. 'other invertebrates' (excluding sponges, squid and *Thenus orientalis* (Moreton Bay bugs), which were analysed separately).

Only species caught in five or more trawls were included in the analyses.

This study aims to test the null hypothesis that catches from the two semi-pelagic fish trawls (0.4 and 0.8 m above the sea bed) are the same as those from the demersal version of the trawl (footrope on the sea bed).

Dunnett's *t*-tests in PROC GLM (Statistical Analysis Systems Institute Inc., 1988) were used for each animal group to test for catch differences between each semi-pelagic trawl and the demersal trawl.

While the objective was to describe the difference in catches between these trawl gears, the catches can also be affected by site differences, time of day and grid series. These factors were included in a linear model to enable us to compare catches, after accounting for any variation caused by these factors. Thus

$$\text{Catch} = \text{gear} + \text{site} + \text{times} + \text{gear} \times \text{site} + \text{gear} \times \text{time} + \text{site} \times \text{time} + \text{gear} \times \text{time} \times \text{site} + \text{grid}\ (\text{site} \times \text{time}) + e$$

Table 2
Means and standard errors (in parentheses) of otterboard spread, headline height and warp tension for the three trawl types

Trawl no.	Mean otterboard spread (m)	Mean headline height (m)	Mean warp tension (t)
1	66.8 (0.75)	2.3 (0.09)	2.0 (0.03)
2a	71.1 (0.39)	3.5 (0.09)	1.97 (0.03)
2b	68.7 (0.74)	4.1 (0.08)	1.98 (0.03)

where gear was the trawl gear type used (footrope of the net at 0.0, 0.4–0.5 or 0.8–0.9 m above the sea bed); site was the trawl area A or B (Fig. 2); time was the diurnal time window in which the trawl was made (08:00–10:00, 10:00–12:00, 12:00–14:00, 14:00–16:00 or 16:00–18:00); grid represented the 36 individual grids (three for each combination of site and time) trawled by each gear; and e was the error term or gear × grid (site × time). All factors used in the model, except 'grid', are assumed to have fixed effects. Site was used as a fixed factor in the model because of the limited choice of the specific habitat required (see above).

Plots of residual versus fitted values of weights and numbers data from the model showed very little difference whether log or square-root transformed. Square-root transformed data were chosen to stabilise the variance of catch weights, which were then used separately in the model.

The significance tests for each effect in the model are based on the appropriate error terms as determined by the expected mean squares (type III). This was determined using a 'Random' statement with the 'test' option in PROC GLM (Statistical Analysis Systems Institute Inc., 1988).

3. Results

3.1. *Trawl performance*

Essential details of the trawls' performance are given in Table 2. Trawl 2a produced the largest average distance between otterboards—71.1 m. The wing-end spread of Trawl 1 was measured for only three tows, resulting in a mean spread of 14.7 m or 57% of headline length. From the mean otterboard spread of this trawl, the sweep and bridle angle to the direction of tow was calculated as 18°. No difference was detected in warp tension (total trawl drag) between trawls with or without the groundrope (Table 2). Trawl 1 was rigged for demersal operation and its headline height (2.3 ± 0.09 m) was equivalent to its vertical opening (i.e. the difference between headline and footrope heights). Based on observed footrope heights and mean headline heights, the vertical opening of trawls 2a and 2b was 3.0 m and 3.15 m, respectively.

Videos of trawls during the trials showed wide footrope spread. The footropes of trawls 2a and 2b were observed to be uniformly clear of the seabed for their entire length, with little change from the desired height.

3.2. Trawl catches

A total of 277 440 fish (196 species) weighing 12 413 kg was caught during the study. A total weight of 1680 kg of epibenthic invertebrates (34 species or species groups) was also taken. Trawl 1 caught 219 285 fish (190 species) weighing 8515 kg, and 1638 kg of epibenthic invertebrates (32 species or species groups); trawl 2a caught 33 704 fish (109 species) weighing 3153 kg, and 35.2 kg of epibenthic invertebrates (11 species or species groups); trawl 2b caught 24 451 fish (82 species) weighing 745 kg, and 7.7 kg of epibenthic invertebrates (10 species or species groups).

3.3. Catch comparisons

The catches of 20 selected animal groups (main commercially important species and other groups of interest) are described in Table 3 and nine of these are presented in Fig. 3. There were significant differences between the catches of the three trawl types for seven of these nine species groups. Trawl 1 caught more fish bycatch, more epibenthic invertebrate groups (sponge, other benthic invertebrates and *T. orientalis*) and more squid than either of the semi-pelagic trawls. Squid also showed a significant interaction between gear, time of day and trawl site, indicating that catch differences between gears were also affected by specific times of day and trawl sites.

Although the difference in catches between trawl gear type was particularly striking for the invertebrates, carcharhinid sharks and 'other elasmobranchs' were also caught in significantly higher abundance in trawl 1. The results for all of these animal groups were the same whether analysed by weights or numbers.

The two target species *Lutjanus malabaricus* and *Lutjanus erythropterus* showed no significant differences in catches between the trawl types. However, both species appear to be caught in greater abundance in trawl 2a. The lack of significance between these catches from trawl 2a and the other two trawl types shows the high degree of variability between catches of these two species during this study. This is demonstrated by the fact that *Lutjanus erythropterus* and *Lutjanus malabaricus* were represented in only 17.6% and 33.3% of trawls, respectively.

Ten other species of commercially important fish species and penaeid prawns also showed no difference in catches between the three trawl types (Table 3). Most of these were less abundant and less frequently caught than the two main target fishes.

Only four of the 20 selected animal groups (Table 3) showed differences in catches due to factors other than gear. Catches of sponges and mackerel, *Scomberomorus queenslandicus*, both showed differences between trawl sites, while catches of carcharhinid sharks and squid differed between sites but depending on the time of day (showed significant time by site interactions).

In total, 107 fish species and 15 invertebrate taxa were caught in more than four tows, and so were analysed for differences in catches between trawl types.

There were significant differences ($P < 0.05$) between trawl types in the catches of 68 (63.5%) species of fishes. For a further six species of fish, the probability values were between 0.05 and 0.1. All except seven of these 68 species were caught in greater abundance in trawl 1; these seven had highest catches in trawl 2a. All of these (***Dussumieria elopsoides*,**

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Table 3
Mean and standard errors of catches (kg h^{-1}) of selected animal groups in demersal wing trawls from the Gulf of Carpentaria site in November 1993. The trawls were rigged with their footropes 0.0 (trawl 1), 0.4 (trawl 2a) or 0.8 m (trawl 2b) above the sea bed. The total number of individuals caught and their percentage occurrence in trawls are also presented. + indicates a significant difference in catches from trawl type 1. The significant terms in the regression model are presented and they are denoted thus: G, gear; S, site; T×S, time by site interaction; G×T×S, gear by time by site interaction

Animal group[a]	n	Percent of trawls	Trawl 1		Trawl 2a		Trawl 2b		Significant terms
			Mean	SE	Mean	SE	Mean	SE	
Carcharhinid sharks	116	25.0	4.9	1.1	2.9+	2.4	1.4+	0.86	G, T×S
Other elasmobranchs	159	26.8	58.0	16.3	0.0+	–	0.0+	–	G
Fish bycatch	275097	100.0	189.7	25.5	61.6+	18.2	12.4+	4.7	G
Benthic invertebrates (not sponges)	4049	43.5	15.7	8.3	0.03+	0.0	20.1+	0.08	G
Sponge	164	30.6	28.5	5.7	0.70+	0.42	0.0+	–	G, S
Rachycentron canadus (C)	15	6.5	0.07	0.07	0.54	0.38	0.04	0.04	–
Gnathanodon speciosus (C)	253	10.2	0.67	0.61	19.08	14.56	0.41	0.34	–
Lutjanus argentimaculatus (C)	38	7.4	0.80	0.58	1.86	1.36	0.16	0.16	–
Lutjanus erythropterus (C, T)	845	17.6	1.43	1.10	21.89	14.92	5.94	4.15	–
Lutjanus malabaricus (C, T)	219	33.3	3.53	1.33	8.0	2.54	3.31	1.80	–
Lutjanus russelli (C)	244	16.7	2.21	1.25	0.28	0.14	0.18	0.15	–
Lutjanus sebae (C)	219	13.0	1.47	0.72	0.72	0.44	0.68	0.68	–
Diagramma pictum (C)	201	16.7	6.96	3.34	3.31	2.71	0.0	–	–
Lethrinus laticaudis (C)	32	6.5	1.18	0.87	0.11	0.11	0.0	–	–
Lethrinus lentjan (C)	129	9.3	1.41	1.02	0.63	0.46	0.03	0.03	–
Argyrops spinifer (C)	17	4.6	0.13	0.07	0.10	0.08	0.0	–	–
Scomberomorus queenslandicus (C)	17	8.3	0.31	0.15	0.15	0.10	0.08	0.06	S
Peneiodea (C)	271	8.3	0.45	0.45	0.0	–	<0.001	<0.001	–
Thenus orientalis (C)	146	13.0	1.2[illegible]	0.23	0.03+	0.02	0.002+	0.002	C
Squid (C)	1734	78.7	1.13	0.21	0.37+	0.12	0.14+	0.06	C, T×S, G×T×S

[a]C, commercially or recreationally important species; T, main target species.

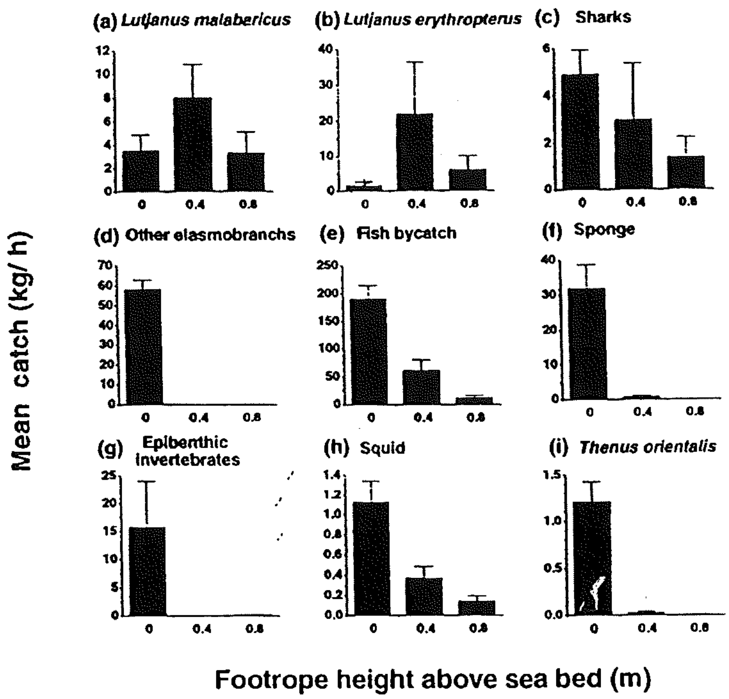

Fig. 3. Mean catches (and standard errors) of nine species from groups of particular interest to this study by the three trawl types. 0, demersal trawl (trawl 1); 0.4, trawl fished semi-pelagically at 0.4–0.5 m above the sea bed (trawl 2a); 0.8, trawl fished semi-pelagically at 0.8–0.9 m above the sea bed (trawl 2b).

Arius thalassinus, *Echeneis naucrates*, *Scomberoides tol*, *Selar crumenophthalmus*, *Parastromateus niger* and *Rastrelliger kanagurta*) are described by Smith and Heemstra (1986) as pelagic in habit, which would make them more likely to be caught higher in the water column. No species had highest catches in trawl 2b.

The 68 species that were caught in greatest abundance in trawl 1 came from 40 different families. Several families had many species caught mainly in this trawl type: three of the four carcharhinid sharks, two of three stingrays, all four synodontids, four of the five platycephalids, seven of the 17 carangids, four of the six leiognathids, all six nemipterids, both species of gerreids and mullids, all four species of bothids but none of the six species of lutjanid. The only representatives analysed, of 19 families, were caught in greatest abundance in trawl 1.

There were significant differences ($P<0.05$) between net types in catches of 12 of 15 groups of epibenthic invertebrates: they were all caught in greatest abundance in trawl 1.

4. Discussion

4.1. Trawl performance

The trials demonstrated the effectiveness of a demersal wing trawl rigged for semi-pelagic operation in maintaining catch rates of *Lutjanus malabaricus* and *Lutjanus erythropterus* while passing over most benthic species. The handling problems of the fork-rigged 'Julie Anne trawl' had been overcome by using the sweep and bridle configuration used in most demersal operations. When rigged semi-pelagically, the wing trawl is relatively simple to operate and consequently more likely to gain industry acceptance. Its onboard handling was little different to a standard demersal trawl: the footrope weights had to be removed before storing the trawl on the net drum to prevent fouling of meshes. The use of a groundrope of similar total weight to the five footrope weights might eliminate this.

The small amount of otterboard spread and headline height variation in all trawls suggests the trawl was stable during the fishing operation. This was confirmed by video observations and the consistent number of polished 'dropper' chain links. Its stability was attributable to the large spreading forces generated by the otterboards, which were bigger than normally required to spread this size of demersal trawl.

Trawl 1 attained a wing-end spread of 57% of headline length. While wing-end spread was not recorded for trawls 2a and 2b, their otterboard spread measurements implied their wing-end spreads were greater than that of trawl 1. Trawls operated with large distances between wing-ends are often considered to be overspread, which, according to Engås and Godø (1986), increases footrope tension and reduces trawl contact with the seabed. As one of the criteria examined by these trials was minimal trawl impact on the benthic community, reduced seabed contact is a desirable characteristic of this trawl. The use of appropriately sized otterboards to generate large wing-end spreads, combined with the selective use of floats and footrope weights may be necessary to achieve desired footrope clearances.

The larger wing-end spreads in the semi-pelagic trawls may explain the higher catches of some species in trawl 2a. Alternatively, these fish may simply occur higher off the sea bed than the species that had higher catches in the demersal trawl. The fishes with the highest catches in trawl 2a (0.4–0.5 m above the sea bed) were always caught in lower abundance in the trawl raised to 0.8–0.9 m (trawl 2b). The obvious explanation is that when the footrope is raised to this height it gives enough clearance between it and the sea bed to enable the fish to escape. However, the behavioural reaction of fish to such trawls is largely unknown.

4.2. *Fish catches*

Catches of all fishes combined were considerably larger in the demersal fish trawl (trawl 1) than the semi-pelagic versions (trawls 2a and 2b) of the same trawl. Trawl 1 caught 6.5 times more fish (by number) than trawl 2a (0.4–0.5 m above the sea bed) and 9.0 times more than trawl 2b (0.8–0.9 m). The fish biomass was 2.7 and 11.4 times higher than in trawls 2a and 2b, respectively. The catches are higher than are likely in the commercial fishery because the legal cod-end mesh size is 110 mm, whereas we used 50 mm mesh, but the difference would nonetheless be substantial.

When the whole trawl rig is lifted off the sea bed, much less small fish bycatch is caught. As the only difference between the demersal and semi-pelagic rigs is the raising of the trawl, it is likely that many of these fish escape under the footrope, sweeps or bridles.

The greatest concern to the fishing industry when introducing new gear is its ability to maintain catches of the target species. Our results support those of Ramm et al. (1993) that catches of both red snappers (*Lutjanus malabaricus* and *Lutjanus erythropterus*) and two other commercially important snappers (*Lutjanus argentimaculatus* and *Lutjanus russelli*) are not decreased by using a semi-pelagic trawl. Further, we found that the catches of all other lutjanids (including *Lutjanus sebae*) were essentially the same in the demersal and semi-pelagic trawls. In fact, the mean catches of *Lutjanus malabaricus*, *Lutjanus erythropterus* and *Lutjanus argentimaculatus* were higher in the trawl at 0.4–0.5 m above the sea bed, although these were due to one or two unusually large catches. Most of these commercial species of *Lutjanus* appear to be aggregated and so this type of non-targeted sampling regime is likely to result in high variability between catches. Consequently, although the highest catches of the main target species were clearly highest in the trawl at 0.4–0.5 m above the sea bed, it is difficult to be confident of this result from this study.

We can be confident, however, that the semi-pelagic trawls do not decrease catches of the target species. It is apparent that these species do not escape enmasse under the footrope when it is raised to 0.4–0.5 m, but raising the whole trawl results in catches of more individuals that swim higher in the water column. The trawl fished at this height caught more of the target fishes than the 0.8–0.9 m trawl rig.

The species of fishes that are not caught by the semi-pelagic trawls are from a range of families. They include benthic groups (e.g. stingrays, synodontids, platycephalids, mullids and bothids), and many common epibenthic groups (e.g. carcharhinid sharks, leiognathids, nemipterids and gerreids). Our results clearly show that by using semi-pelagic instead of demersal trawls, catches of many of these common non-target trawl species are reduced.

4.3. Invertebrate catches

Catches of epibenthic invertebrates are dramatically lower in the semi-pelagic version of the fish trawl. Trawl 1 caught 46 and 213 times more benthos (by weight) than trawls 2a and 2b, respectively. The footrope of the semi-pelagic trawls simply passes over most of the benthos, with only the highest forms being captured. Personal observation also suggests that some benthos is picked up by the sweeps and bridles (in contact with the sea bed) and a proportion of this ends up in the net. The amount of damage to the benthos from this cause was not measured. Neither semi-pelagic trawl caught many benthic invertebrates.

Other commercially valuable species, which are often kept as a byproduct, were seldom caught in the semi-pelagic trawls (e.g. squid, *T. orientalis*).

4.4. Benefits to industry

Relatively simple modifications to a demersal wing trawl enabled it to fish semi-pelagically and conform to the regulations for the Northern Fish Trawl Fishery, while maintaining its ability to catch the target species. The main advantages over a demersal trawl are:

1. catches of the target species (red snappers) are the same or greater;
2. catches of unwanted bycatch of small fishes and benthic invertebrates are very much smaller;
3. catches contain fewer non-target species and therefore are of a higher quality;
4. the trawl is less likely to be damaged on rough sections of the sea bed.

Goudey, C.A., 1987. The development of a semi-pelagic trawl for squid and butterfish. In: The Ocean—An International Workplace. Proc. of Oceans '87, Vol. 2. Marine Engineering; Policy, Education and Technology Transfer. 28 September – 1 October 1987, Halifax, N.S., Marine Technology Society, New York, pp. 645–648.

Kailola, P.J., Williams, M.J., Stewart, P.C., Riechelt, R.E., McNee, A. and Grieve, C., 1993. Australian Fisheries Resources. Bureau of Resource Sciences, Department of Primary Industries and Energy, and the Fisheries Research and Development Corporation, Canberra, Australia, 422 pp.

Newton, G., Fowler, J., McLoughlin, K. and Staples, D. (Editors), 1994. Northern Fish Trawl Fishery and Northern Shark Fishery 1993. Fisheries Assessment Report compiled by the Fisheries Resource Assessment Group. Australian Fisheries Management Authority, Canberra.

Ramm, D.C., Mounsey, R.P., Xiao, Y. and Poole, S.E., 1993. Use of a semi-pelagic trawl in a tropical demersal trawl fishery. Fish. Res., 15: 301–313.

Sainsbury, K.J., 1987. Assessment and management of the demersal fishery on the continental shelf of northwestern Australia. In: J.J. Polovina and S. Ralston (Editors), Tropical Snappers and Groupers. Biology and Fishery Management. Westview Press, Boulder, CO, pp. 465–503.

Sainsbury, K.J., 1988. The ecological basis of multispecies fisheries and management of a demersal fishery in tropical Australia. In: J.A. Gulland (Editor), Fish Population Dynamics, 2nd edn. John Wiley, London, pp. 349–382.

Smith, M.M. and Heemstra, P.C., 1986. Smith's Sea Fishes. Macmillan, Johannesburg.

Statistical Analysis Systems Institute Inc., 1988. SAS/STAT Users Guide, 6.03 edn. SAS Institute Inc., Cary, NC.

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Appendix B: Visit to Centres of Excellence in Bycatch Reduction Research — Trip Report

David Brewer[A] and Steve Eayrs[B]

A - CSIRO Division of Fisheries, Cleveland, Queensland

B - Australian Maritime College, Tasmania

1. Background and Justification

FRDC has granted funds to CSIRO, AMC and NT Fisheries for the project, *The effects of Trawl Design on Bycatch and Benthos in Prawn and Fin-fish Fisheries*. Funds were requested by CSIRO and AMC staff for an overseas visit to centres carrying out bycatch reduction research, but FRDC did not approve this part of the application. Because CSIRO and AMC regarded this as an essential part of the project, they decided to use their own funds to send two staff overseas. The purpose of the visit was the following:

(a) To find out of the current bycatch reduction techniques being tested elsewhere before deciding on techniques that may be applicable to Australia.

(b) To obtain current information which is either not yet published, or will never be published; as is the nature of much of the world's technical fisheries gear technology information.

(c) To obtain technical advice on topics such as the correct 'setting up' and deployment of Bycatch Reduction Devices (BRD's) which would greatly reduce (i) the time to de-bug new trawl gears and (ii) the risk of ineffective trials due to the incorrect use of a BRD.

(d) Discussions with scientists and technicians experienced in issues of bycatch reduction would also be invaluable to the future direction of the project. First hand experience of existing BRD's would, it was predicted, greatly assist the projects' principal gear technologist (Steve Eayrs) in his ability to produce and best apply these devices to tropical prawn fishery research.

It was agreed that the investment in time (3 weeks) and money ($12 000) would be more than compensated for (especially in cost of cruise time) due to streamlining of (a) the initial choices on the best types of BRD's to research in tropical Australian prawn fisheries, (b) The best method of applying particular BRD's, and (c) elimination of the most likely problems that could be encountered and how to avoid them.

2. Itinerary

Research centres that were visited by David Brewer (CSIRO) and Steve Eayrs (AMC) were chosen mainly from their relevant contributions to the literature and international conferences. Efficiency in the cost of travel was also considered. All centres contacted were agreeable to the visit. However, a restricted agenda did not allow all of these places to be visited. The trip itinerary was as follows:

Dates	Centre visited	Main contact
1-Feb-94	NMFS, Mississippi Laboratories Pascagoula, USA	Dr. John Watson
3-Feb-94	Fisheries Technology Service, Maine, USA	Dr. Phillip Averill
4-Feb-94	University of Rhode Island Fisheries Center, USA	Assoc. Prof. Joe DeAlteris
7-Feb-94	Danish Institute for Fisheries Technology and Aquaculture Hirtshals, Denmark	Klaus Lehmann
9-Feb-94	Institute of Marine Research Bergen, Norway	John Valdemarsen, Auld Soldal
14-Feb-94	Sea Fish Industry Authority Hull, England	Phil MacMullen, , Ken Arkley
16-Feb-94	Marine Laboratory, Aberdeen, Scotland	Dr. Clem Wardle, Chris Glass

Although our initial contacts were the people listed above, visits to most of the centres involved meetings and discussions with many other people involved in bycatch reduction research.

3. General Commentary

Visits to all centres were well received and we found that there was considerable interest in the progress of bycatch reduction research and technology in Australia. The following list summarises the trips activities:

1. NMFS, Mississippi Laboratories, Pascagoula, USA

- Held discussions with John Watson and his team of biologists and gear technologists
- Attended a seminar by JW on his past and current research
- Presentation of a seminar describing relevant Australian research, our research institutions, and the methods and results of the current study to date.
- Studied the laboratory's large collection of BRD's, their BRD manufacturing laboratory and research vessels.
- Examined other facilities and equipment such as their research video library and underwater cameras and housings.
- Collected relevant on site literature.

2. Fisheries Technology Service, Maine, USA

- Had discussions with Phillip Averill regarding his research interests and his opinions on our project's direction.
- Visited several fishing ports in Bristol and interviewed fisherman about BRD's used in that fishery (Nordmøre grid).
- Viewed underwater videos of several types of BRD's produced by P. Averill
- Visited the main fishing port at Portland, Maine and examined fishing gears.

3. University of Rhode Island, Fisheries Center, USA

- Presentation of a seminar describing relevant Australian research, our research institutions, and the methods and results of the studies to date.
- Attended a series of seminars presented by Dr. Joe DeAlteris and several other of his colleagues and students from the north eastern region of the USA.
- Had discussions with several of these fishery scientists (including A. J. Blott, NOAA, V. E. Nulk, NOAA, and H. A. Carr, DMF) regarding their research interests and their opinions on application of US technology to Australian fisheries.
- Visited the fishing port and examined several varieties of the local fishing gears.
- Collected relevant on site literature.

4. Danish Institute for Fisheries, Technology and Aquaculture, Hirtshals, Denmark

- Had both group and individual discussions with several fishery scientists, engineers and an economist regarding our project's status and direction.
- Presentation of a seminar describing relevant Australian research, our research institutions, and the methods and results of the current study to date.
- Examined the research facilities of the laboratory
- Viewed several scale models of BRD's in their flume tank and had discussions with their flume tank operator.
- Visited the fishing port and examined fishing gears.

- Visited the fish auctions and a commercial fishing gear manufacturer.
- Used the DIFTA library to collect additional information.

5. ***Institute of Marine Research, Bergen, Norway***
    - Had discussions with John Valdemarsen and other scientists regarding both their and our projects.
    - Examined their BRD's and research vessels.
    - Viewed several videos made by the IMR of BRD research .
    - Presentation of a seminar describing relevant Australian research, our research institutions, and the methods and results of the current study to date.
    - Collected relevant on site literature.
6. ***Sea Fish Industry Authority, Hull, England***
    - Had discussions with Phil MacMullen and other scientists regarding both their and our projects.
    - Presentation of a seminar describing relevant Australian research, our research institutions, and the methods and results of the current study to date.
    - Viewed several scale models of BRD's in their flume tank and had discussions with their flume tank operator.
    - Viewed several videos made by SEAFISH of BRD research .
    - Studied their latest pieces of underwater video equipment.
    - Visited their net making facilities.
    - Collected relevant on site literature.
7. ***Marine Laboratory, Aberdeen, Scotland***
    - Had discussions with Dr. Clem Wardle and other scientists regarding both their and our projects.
    - Presentation of a seminar describing relevant Australian research, our research institutions, and the methods and results of the current study to date.
    - Visited their equipment stores and examined underwater camera facilities, fishing gear, net making facilities and fish behavioural tanks.
    - Used the Marine Laboratory library to collect additional information.

4. Benefits to the Project

It is the opinion of all project participants that the information gathered from this trip will be a very important benefit to the project and ultimately to the project's influence on future advances in gear technology in many Australian trawl fisheries. Benefits include:

- A large increase in knowledge of most aspects of international bycatch reduction research for two key personnel involved in the current project.
- New ideas including a new direction for the main thrust of the project. e.g:

  - to test during one cruise which of many BRD's are likely to be successful in our fishery. On subsequent cruises to focus on the best one or two devices for more rigorous testing. This method ensures the shortest path to fully testing the most appropriate gear(s).

  - the latest ideas in BRD's which are a result of many years of research but can be applied directly to Australian fisheries, such as the latest version of the 'Watson Super Shooter' and Dr. C. Wardles' 'black mouth stimulus device' used to increase the numbers of fish that escape.
- Acquisition of the latest information about bycatch reduction research results, sampling, gear trials and underwater video techniques and equipment.
- Acquisition of much of the latest and/or hard-to-get literature on bycatch reduction research.
- The establishment of important contacts in most of the key centres for bycatch reduction research. These will ensure that this and future projects remain up to date with research results and technological advancements.
- Direct input into our research by international experts via visits to Australia stemming from contacts made during this trip. A leading expert in bycatch reduction technology from Norway, Bjørnar Isaksen, has already visited the Australian Maritime College as a direct result of the contacts made through this trip.
- An increase in Australia's worldwide profile for this type of research.

Appendix C: Articles in fishing industry literature, community literature and newspapers

1. Articles in fishing industry magazines:

RESEARCH

New prawn and fish trawl gear reduces non-target bycatch

Square mesh codends can reduce the amount of unwanted fish bycatch in the northern prawn fishery according to recent research trials off northern Au·tralia. David Brewer and Steve Eayrs report that the preliminary results of the recent research cruise also show that semi-pelagic fish trawls' avoid damaging vital sea bed habitats.

In recent years, fisheries institutions around Australia have increasingly focussed on reducing levels of bycatch in trawl fisheries. Research has included the use of square mesh panels in prawn trawl codends by the NSW Fisheries Research Institute and the development of the 'AUSTED', an inclined grid, by the Queensland Department of Primary Industries and Northern Territory Fisheries Division (see *Australian Fisheries* 51(12), December 1992).

The first cruise of a new Fisheries Research and Development Corporation funded research project took place in November 1993. The three-year project is primarily aimed at reducing unwanted bycatch from prawn trawls and testing a new semi-pelagic environmentally friendly fish trawl. The project brings together the expertise of biologists and gear technologists from CSIRO Division of Fisheries, the Australian Maritime College (AMC) and the Northern Territory Fisheries Division.

Modified prawn trawls are being developed to reduce unused bycatch while maintaining levels of prawns caught.

Tank and sea trials of the new gear

The technical and hydrodynamic performance of the trawl rigs used during the recent cruise were tested at the AMC. Firstly, scale models were assessed based on their flume tank performance and then full scale versions were trialed on the AMC vessels *Bluefin* and *Reviresco* in Tasmanian coastal waters.

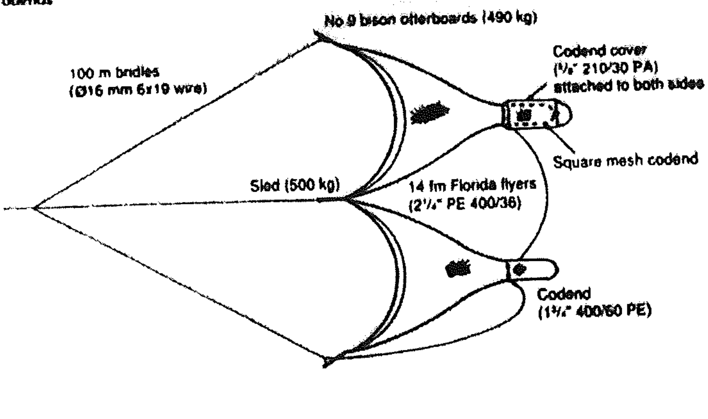
At-sea trials of the new trawl gear were performed during the November cruise of the CSIRO research vessel *Southern Surveyor* in NPF waters off Albatross Bay in the Gulf of Carpentaria.

Square-mesh codends reduce fish bycatch from prawn trawls

The first gear trials in this project included a comparison of two sizes of square mesh (45 mm, and 38 mm) with a standard diamond mesh codend (45 mm mesh size). Comparisons were made using dual rigged 14 fathom Florida Flyer prawn trawls (see Figure 1).

One net was rigged with the standard diamond mesh codend while the other used a square mesh codend. Small mesh (16 mm) codend covers were used to catch species that escaped through each codend type. Researchers made 43 half hour trawl comparisons with the 45 mm square mesh codend and 40 trawls with the 38 mm square mesh codend.

Figure 1 The dual rigged prawn trawls which were used to compare catches of prawns and bycatch from square and diamond mesh codends



[1]Semi-pelagic fish trawls include trawls operated with otter boards, sweeps and lower bridles in seabed contact with the footrope flying above the seabed.

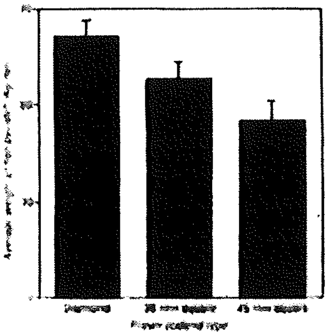


Figure 2. Square mesh codends catch less unused bycatch than the standard diamond mesh prawn trawl codends.

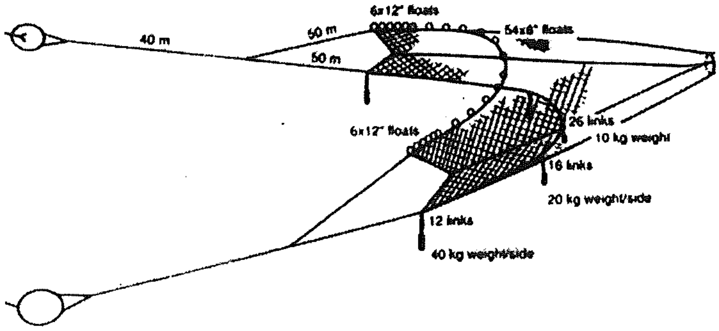
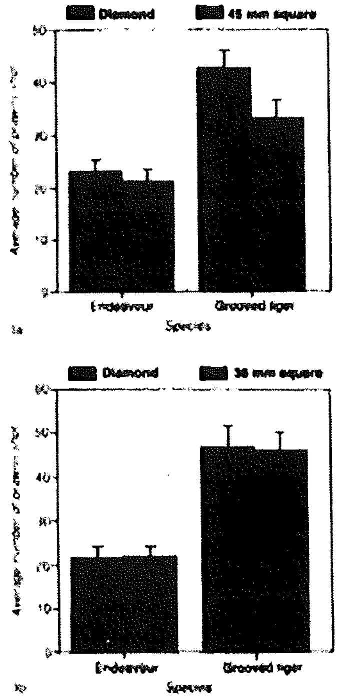


Figure 4. The Frank and Bryce trawl rigged to fish with the footrope flying 0.4–0.5 m above the sea bed.

The square mesh codends caught less unused fish bycatch than the diamond mesh codend (Figure 2). The larger square mesh (45 mm) reduced the amount of fish bycatch by 33 per cent, on average, compared to the diamond mesh.

Catches of red endeavour prawns (*Metapenaeus ensis*) were similar for both the 45 mm square and diamond codends, but numbers of grooved tiger prawns (*Penaeus semisulcatus*) were 13 per cent less in this size of square mesh than the diamond mesh codend (Figure 3a).

Figure 3. The square mesh codends catch similar amounts of endeavour prawns but only the smaller sized codend (38 mm mesh, Figure 3b) also maintained tiger prawn catches.



The smaller square mesh (38 mm) reduced the amount of fish bycatch by about 17 per cent on average compared with the diamond mesh (45 mm) and maintained the same catch rates of both of the abundant prawn species (Figure 3b).

Broadhurst and Kennelly (in press) found that in the NSW school prawn fishery a 40 mm square mesh codend caught less prawns and less bycatch, but a codend with square mesh in the forward half only, caught the same number of prawns as a conventional codend but less bycatch. They also concluded that square mesh in codends has great potential for reducing fish bycatch in prawn trawls.

When compared with the current study, the results of Broadhurst and Kennelly show that the size of square mesh used should be assessed separately for different fisheries.

Benefits to the fishery

The future reduction in the amount of unwanted bycatch would have immediate benefits including an increase in the quality and therefore value of the catch through a reduction in the number of prawns damaged by unwanted bycatch species; a decrease in sorting time; and reduction of large numbers of small, floating dead fish and therefore in concern about the impact of fishing.

The greater selectivity of square-mesh codends may also greatly decrease the fishing mortality of the juveniles and sub-adults of commercially important fishes and prawns.

Semi-pelagic fish trawls avoid bottom damage yet maintain catches

Ramm et al. (1993) found that the catch rates of commercial species from the semi-pelagic trawl (trawled with its groundrope off the bottom) known as the *'Julie Anne'*, were comparable with those from a demersal fish trawl (groundrope on the bottom). However, the semi-pelagic trawl caught less fish bycatch and had less impact on the substrate.

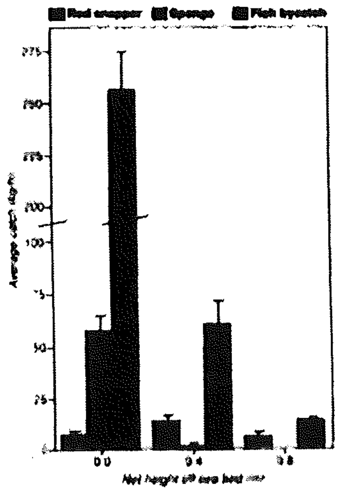
Unlike conventional fish trawls, the *Julie Anne* uses fly wires to lift the headline, in the same way that increased height is achieved when using banana prawn trawls. The current study used a *Frank and Bryce* wing trawl rigged:

- as a standard demersal trawl, that is, groundrope in contact with the seabed,
- groundrope removed, footrope 'flying' at 0.4–0.5 m above the seabed (semi pelagic); and
- groundrope removed, footrope flying at 0.8–0.9 m above the seabed (semi-pelagic).

The changes in footrope height were achieved by a combination of headline flotation and steel weights attached to the footrope (Figure 4). This gave a direct comparison of the same fish trawl in three different modes.

Results from these three trawl rigs show that all three net configurations catch about the same amount of the target species of red snapper (*Lutjanus malabaricus* and *L. erythropterus*), but the semi-pelagic trawls caught less fish bycatch and benthos (sedentary animals

Figure 5. Comparison of the catches of target species (red snappers), benthic species (sponges) and unused fish bycatch.



Semi-pelagic fish trawls avoid damage to sponges and other seabed animals which may be critical to the long term maintenance of the ecosystem and the fishery.

that live on the bottom, for example, sponges and sea fans) (Figure 5). Video footage also clearly shows the semi-pelagic rigs avoiding much of the benthic animals.

Sainsbury's (1987) research on the north-west shelf found that many of the commercial fish species in this fishery are dependant, directly or indirectly, on the benthos which provide seabed habitat. The ability of the semi-pelagic trawl to avoid damage to benthos populations is an important advancement in the long term maintenance of this fishery.

Convincing evidence

These preliminary results support those of Ramm *et al.* (1993) and together provide convincing evidence that semi-pelagic trawls are the most suitable rig for the northern demersal trawl fishery. This type of trawl is able to produce high quality fish catches that are at least equal to those of conventional demersal fish trawls, while not damaging the sea bed habitat and could thus maintain the fishery in the long term.

Future research

The second and third years of the project will incorporate video assessment of the behaviour of bycatch species in prawn and fish trawls. This will lead to other refinements in net and codend design aimed at further enhancing escapement of bycatch from trawls.

Other bycatch reduction devices, such as inclined grids and accelerator funnels, will be assessed and may also be trialed along with successful codend designs. The damage to, and survival of, fishes that escape from the different codends will also be compared.

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REFERENCES

Broadhurst, M.K. and Kennelly, S.J. (in press). Reducing the bycatch of juvenile fish (mulloway) in the Hawkesbury River prawn-trawl fishery using square mesh panels in codends. *Fisheries Research*, in press.

Ramm, D.C., Mounsey, R.P., Xiao, Y. and Poole, S.E. (1993). Use of a semi-pelagic trawl in a tropical demersal trawl fishery. *Fisheries Research* 15, 301-313.

Sainsbury, K.J. (1987). Assessment and management of the demersal fishery on the continental shelf of northwestern Australia. In Polovina, J.J. and Ralston, S. (Eds.) *Tropical Snappers and Groupers: Biology*, Fisheries and Management. Westview Press. London.

Australian Fisheries Management Authority

NPF fishermen view bycatch reduction devices

The fisheries research vessel 'Southern Surveyor' recently spent four weeks in the Northern Prawn Fishery (NPF) testing several devices to reduce prawn trawl bycatch. Prawn fishermen operating in Albatross Bay during this time were invited onboard to give their opinion on these devices and to discuss relevant bycatch issues. Steve Eayrs, David Brewer and Neville Gill report.

As part of a Fisheries Research and Development Corporation (FRDC) funded project, researchers took part in a 'Southern Surveyor' research cruise in October 1995 to test modified versions of Bycatch Reduction Devices (BRDs) that had showed promise during previous trials in February 1995 (*"Australian Fisheries"*, May 1995). The new BRD versions included large animal ('monster') excluders and fish excluders in combination for the first time, as well as the 'AusTED' developed by the Northern Territory Fisheries Division and Queensland Department of Primary Industry and Fisheries.

Prawn fishermen operating in Albatross Bay during the trial period were invited onboard to view these devices in action. Fishermen included Ivor Jones ('Roper Therese'), Greg Patrick ('Comac Endeavour'), Ray Hazel, Marie and Steve ('Four Seasons'), Alan Smith and 'Sharky' ('Aqua Sam'), Stuart Carter ('Miss Providence') and Keith Burnell ('Kelana'). CSIRO scientists and fisheries technologists from the Australian Maritime College and the Northern Territory Fisheries Division were on hand to demonstrate the range and capabilities of the BRDs.

BRDs trials encouraging

In addition to the AusTED (shown on page 26), two other 'monster' excluders were tested: the Supershooter, now being used in the Gulf of Mexico, and the Nordmore grid, which has been adopted by many countries including Norway, Canada and the United States. All 'monster' excluders were used in combination with either fish eyes or square mesh windows to further reduce catches of unwanted fish bycatch. A standard 14 fathom Florida Flyer with no BRD attached was used to provide a comparison.

In contrast to the standard trawl, no turtles, large sharks or stingrays were caught by trawls fitted with the 'monster' excluders. The results of the BRD performance, in terms of small fish exclusion and prawn retention, have still to be analysed, however first indications were promising.

The best of these BRDs will be trialled on NPF trawlers in 1996. The results are likely to provide fishermen with a range of devices designed to exclude different bycatch species from prawn trawls, depending on the area fished.

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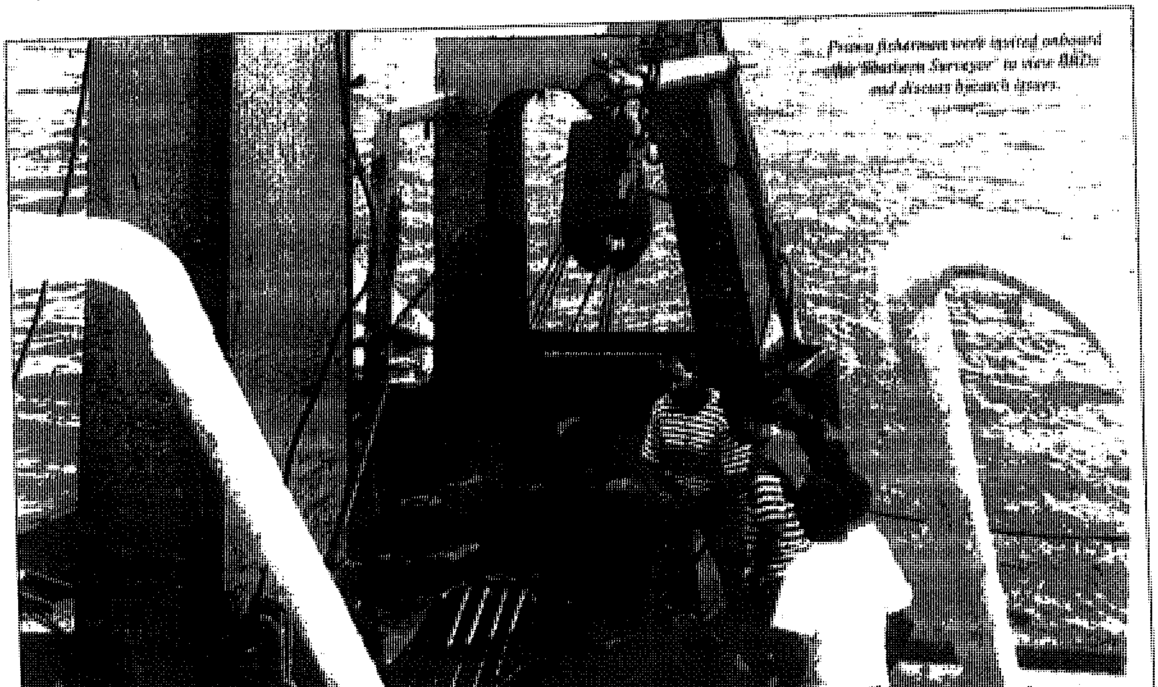

NPF fishermen view bycatch reduction devices

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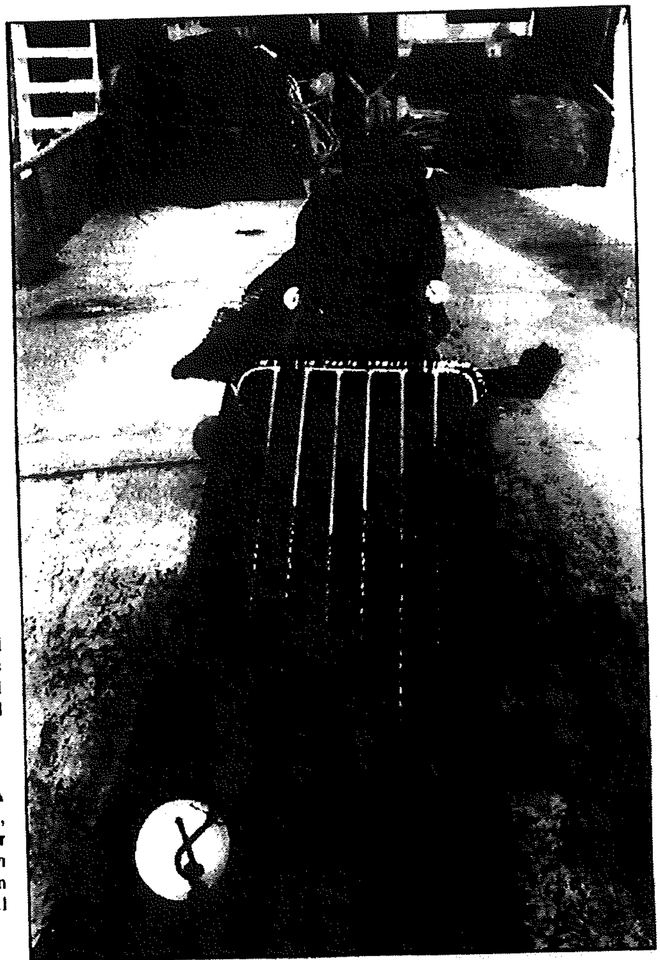


Fishermen comment on BRDs

Fishermen also viewed underwater footage of the BRDs in action, taken during the cruise. The footage showed BRDs excluding large animals such as stingrays, sharks and sponges and also provided an insight into fish behaviour in prawn trawls.

Fishermen provided information about their main bycatch problems and how they thought the BRDs would best benefit their fishery. For example, minimising prawn damage through the exclusion of 'monsters' was seen as an important goal, particularly with the growing trend toward 'finger packing' high quality, undamaged prawns into export packs of 3 kg or less. The fishermen agreed that 'monster' excluders could increase the value of the catch by decreasing damage in the codend.

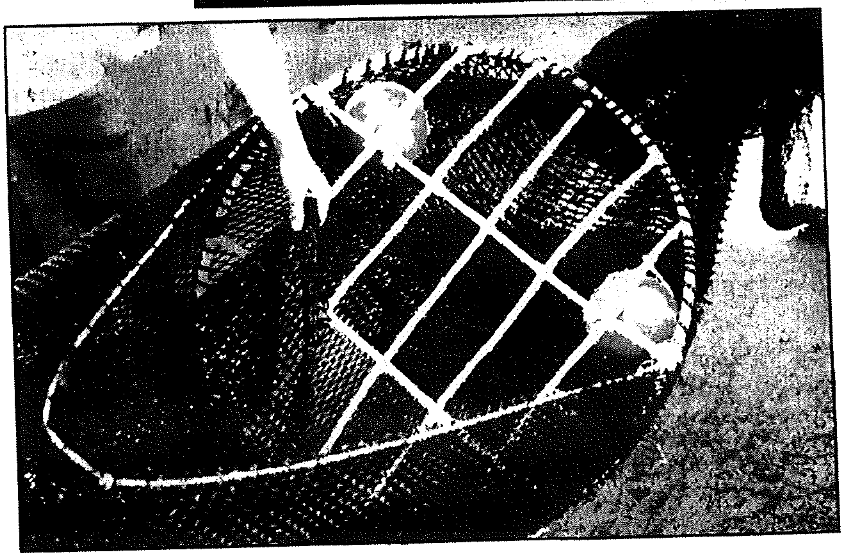
The use of BRDs to exclude fish bycatch was also regarded as a benefit to the fishery, particularly in areas where fish catches are high. Problems associated with large catches of fish include a need to reduce tow times, and a reduction in catching efficiency due to a reduction in trawl spread. The BRDs were examined and stimulated discussion on how they could best be adapted to commercial operations.

Of concern to the fishermen was the potential loss of prawns and byproduct. The latest BRD trial results from this project will be available in 1996 and will include descriptions of what fishermen using BRDs can expect to catch and exclude, compared to the full array of prawns and bycatch now caught by standard trawls.

The next step

The next step needs to be taken by industry. A number of devices have shown considerable potential, however, the real measure of success will be their eventual adoption by industry. It is hoped that prawn fishermen will examine these initial concepts and, in collaboration with researchers, develop practical methods for reducing bycatch.

Steve Eayrs is a fisheries technologist at the Australian Maritime College, David Brewer is a fisheries biologist with CSIRO Division of Fisheries and Neville Gill is a fisheries technologist with Northern Territory Fisheries Division. Contact Steve Eayrs, AMA PO Box 21 Beaconsfield Tasmania 7270, tel (003) 354 424 or fax (003) 354459.



Above right: The Nordmore grid fitted with a square mesh window.

Right: The AusTED uses an inclined flexible grid to exclude 'monsters' from the trawl.

BYCATCH DEVICES

NPF fishers inspect bycatch reduction devices

Work on bycatch reduction devices (BRDs) in northern waters is continuing, as Steve Eayrs, David Brewer and Neville Gill* report.

IN October 1995, the CSIRO fisheries research vessel *Southern Surveyor* tested several devices to reduce prawn trawl bycatch in the Northern Prawn Fishery (NPF).

Prawn fishers operating in Albatross Bay during this time were invited onboard to give their opinion on these devices.

The fishers included Ivor Jones (*FV Roper Therese*), Greg Patrick (*Comac Endeavour*), Ray Hazel, Marie and Steve (*Four Seasons*), Alan Smith and 'Sharky' (*Aqua Sam*), Stuart Carter (*Miss Providence*) and Keith Burnell (*Kelana*).

CSIRO scientists and fisheries technologists from the Australian Maritime College and the Northern Territory Fisheries Division were on hand to demonstrate the range and capabilities of the bycatch reduction devices (BRDs).

Bycatch reduction trials

In October, *Southern Surveyor* spent one month in Albatross Bay testing new versions of BRDs that showed promising results in bycatch reduction and prawn retention during a previous research cruise in February 1995.

BRDs tested in the latest trials included, for the first time, 'monster' excluders and fish excluders in combination, as well as the 'AUSTED' developed by the Northern Territory Fisheries Division and Queensland Department of Primary Industries.

Two other monster excluders were tested: the 'Supershooter', now being used successfully in the Gulf of Mexico, and the 'Nordmore grid' which has been adopted by many countries.

No turtles, large sharks or stingrays ('monsters') were caught by trawls fitted with these devices.

All 'monster' excluders were used in combination with either 'fish eyes' or 'square mesh windows', further reducing catches of small unwanted fish.

A standard 14-fathom Florida Flyer with no BRD fitted was tested to provide a comparison.

The BRD performance results, in terms of small fish exclusion while maintaining prawn catches, have not been analysed. However first indications look promising and the results will be published in the near future.

The best of these BRDs will be tested on NPF boats this year (1996), and are likely to provide fishers with a range of devices designed to exclude different bycatch species from prawn trawls, depending on the area fished.

Fishers provide comments on BRDs

Fishers also viewed underwater footage taken during the cruise.

NPF fishermen inspected a bycatch reduction device tested by fisheries researchers.

This demonstrated how BRDs exclude large animals like stingrays and sponges and also gave an insight into fish behaviour in prawn trawls.

Fishers provided information about their main bycatch problems and how they thought the BRDs would best benefit their fishery.

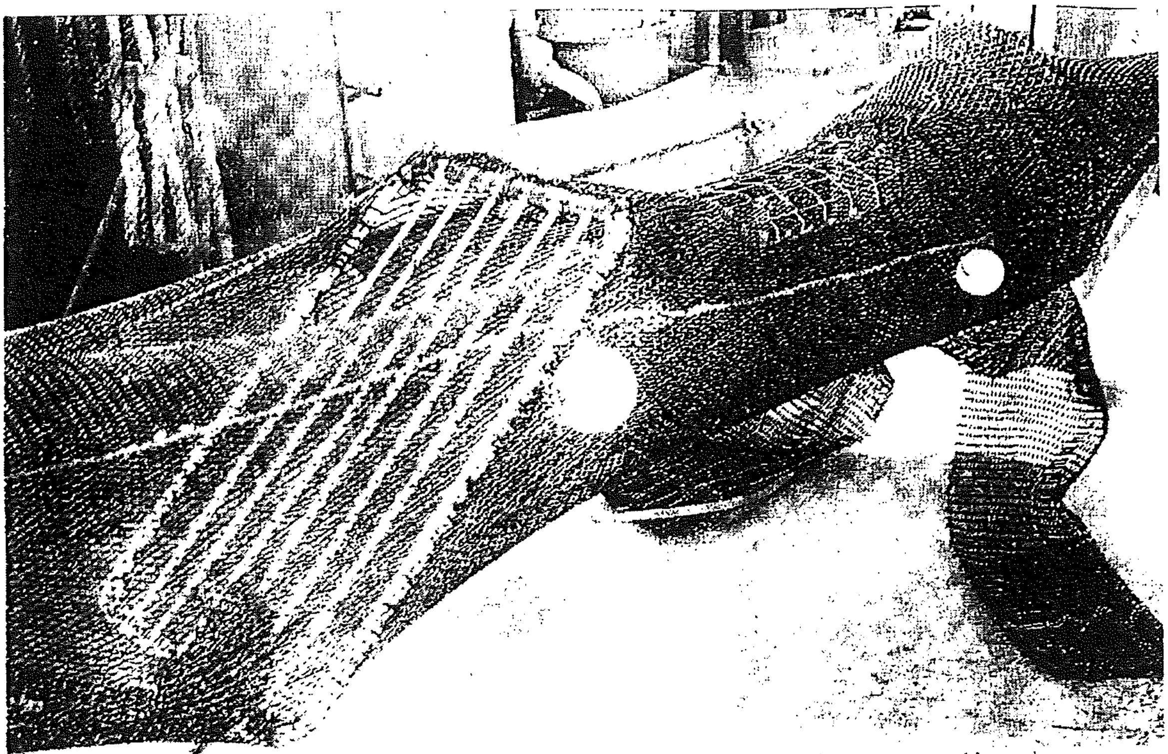
Minimising prawn damage by reducing the number of 'monsters' caught was seen as an important goal (especially with the growing trend towards "finger packing" high quality, undamaged prawns into export packs of 3 kg or less).

The fishers agreed that monster excluders could increase the value of the catch by decreasing prawn damage in the codend.

The use of BRDs to exclude fish bycatch was also regarded as a benefit to the fishery.

Fish bycatch problems include the need to reduce tow times in areas where fish catches are high and lower catching efficiency when large bags of fish cause a reduction in trawl spread.

The fish excluders on *Southern Surveyor* were examined and stimulated discussion on how they could best be adapted to commercial operations.



This bycatch reduction device was tested in northern waters to examine its effectiveness in reducing unwanted bycatch.

Concern was expressed that the use of BRDs could lead to losses in prawns and byproduct. The latest BRD trial results from this project will be available this year and will include descriptions of what fishers using BRDs can expect to catch and exclude, compared with the full array of prawns and bycatch now caught by standard trawls.

What next?

Industry must take the next step. This project has shown the potential of a number of bycatch devices, but the real measure of success will be their eventual adoption by industry.

It is hoped that the experienced fishers will examine these initial concepts and, in collaboration with researchers, develop practical methods for bycatch reduction.

* The authors are: Steve Eayrs, fisheries technologist, Faculty of Fisheries & Marine Environment, Australian Maritime College; David Brewer, fisheries biologist, CSIRO Division of Fisheries; and Neville Gill, fisheries technologist, Northern Territory Fisheries Division.

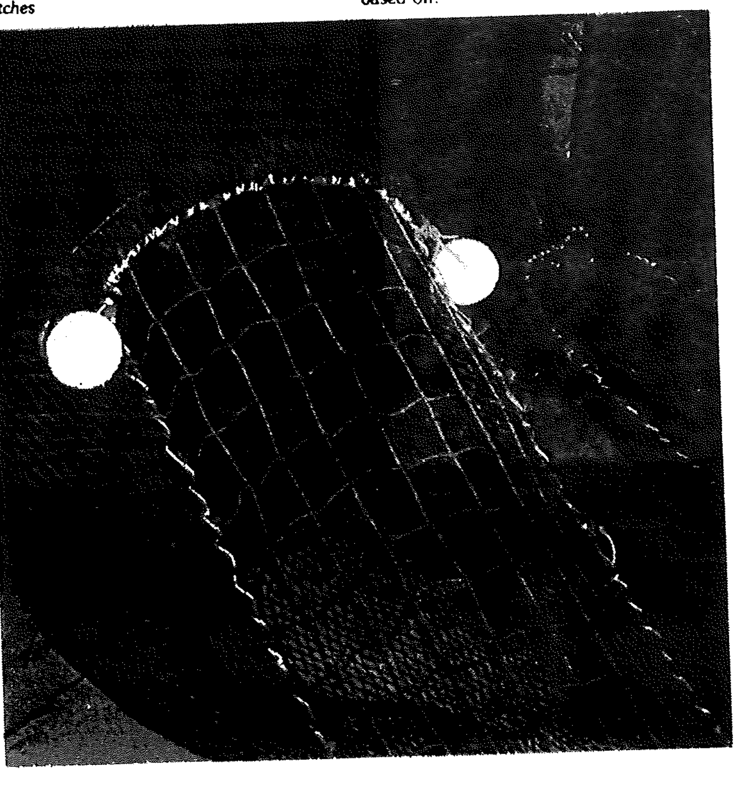
RESEARCH

Bycatch reduction devices show promise in the NPF

Bycatch Reduction Devices show potential to reduce the amount of unwanted bycatch in Australia's Northern Prawn Fishery. David Brewer, Steve Eayrs and Nick Rawlinson report on how several devices can reduce bycatch, but retain prawn catches.

A number of Bycatch Reduction Devices (BRDs) were tested during a *Southern Surveyor* research cruise in the Gulf of Carpentaria in February and March 1995. This was the second cruise in a Fisheries Research and Development Corporation (FRDC) funded project aimed at reducing unwanted bycatch from prawn trawls.

Figure 1. The Nordmore Grid excluded turtles and most other large animals from prawn trawl catches



Participants included scientists and fisheries technologists fron the CSIRO Division of Fisheries, the Australian Maritime College (AMC) and the Northern Territory Fisheries Division. The main objective of the cruise was to assess the abilities of eight BRDs to reduce unwanted bycatch while catching the same amount of prawns as a standard prawn trawl.

Choice of BRDs to test

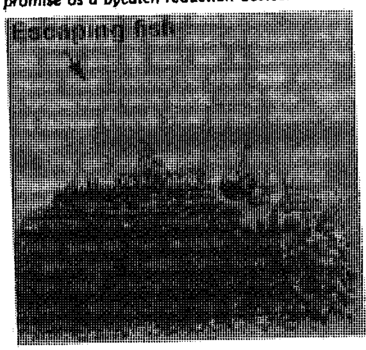
The decision of which BRDs to test was based on:

- information gathered from international scientific and fisheries literature;
- information collected during visits undertaken by Steve Eayrs and David Brewer to seven key institutions involved in bycatch reduction research in the United States, Norway, Denmark and United Kingdom; and
- the results of a survey of NPF skippers and owners in Darwin and Cairns during the mid-season closure of 1994 to determine which types of bycatch were of greatest concern to NPF fishers. The results showed that fishers would most like to reduce the amounts of large animals (for example rays, sharks and turtles), sea eggs and small fish caught. These results influenced which BRDs should be tested during the remainder of the project.

Flume tank observations

BRDs were observed in the AMC's flume tank to ensure functional operation before the trials in the NPF. Two of these, the Supershooter and Radial Escape Section (RES), were constructed in the United States while the other BRDs used here were constructed at the AMC.

Figure 2. The square mesh window shows promise as a bycatch reduction device.



Prawn trawls and BRDs

The prawn trawls were operated in a dual rig arrangement —two identical 14 fathom Florida Flyers spread by No. 9 Bison boards and a sled for inner wingend attachment. Mesh size of the trawls was 57 mm with 45 mm mesh used in the 150 x 150 mesh codend. All codends were divided into three 50 mesh deep sections, with all BRDs except the Supershooter and Nordmore grids placed in the middle section. This position allowed the lifting strops to remain in a position consistent with industry practice. The Supershooter and the Nordmore grid were placed in the first 50 mesh section.

BRDs tested during this cruise are described below. They include two inclined grids, aimed mainly at excluding large animals, and six other BRDs aimed mainly at excluding small fish. A codend of 45 mm mesh throughout was also tested in conjunction with these others to allow comparisons with standard fishing gear.

NORDMORE GRID

Originating from Norway, the Nordmore grid is an inclined aluminium grid angled at 55° from the vertical and with a bar spacing of 100 mm (Figure 1). A panel of netting, guides all species towards the bottom of the grid. Large animals (most commonly turtles, sharks and rays) meet the grid and escape through a triangular-shaped opening in the codend at the top of the grid (Figure 3). Smaller species such as prawns exit the funnel and pass through the grid and into the codend.

SUPERSHOOTER GRID

The Supershooter is an oval-shaped inclined grid originally designed in the US to exclude turtles from the Gulf of Mexico shrimp fishery. As with the Nordmore grid, all species pass through a guiding funnel, but large animals contact the grid and are guided down through an escape opening in the floor of the codend. A flap of buoyant polyethylene netting covers this escape opening to minimise prawn loss.

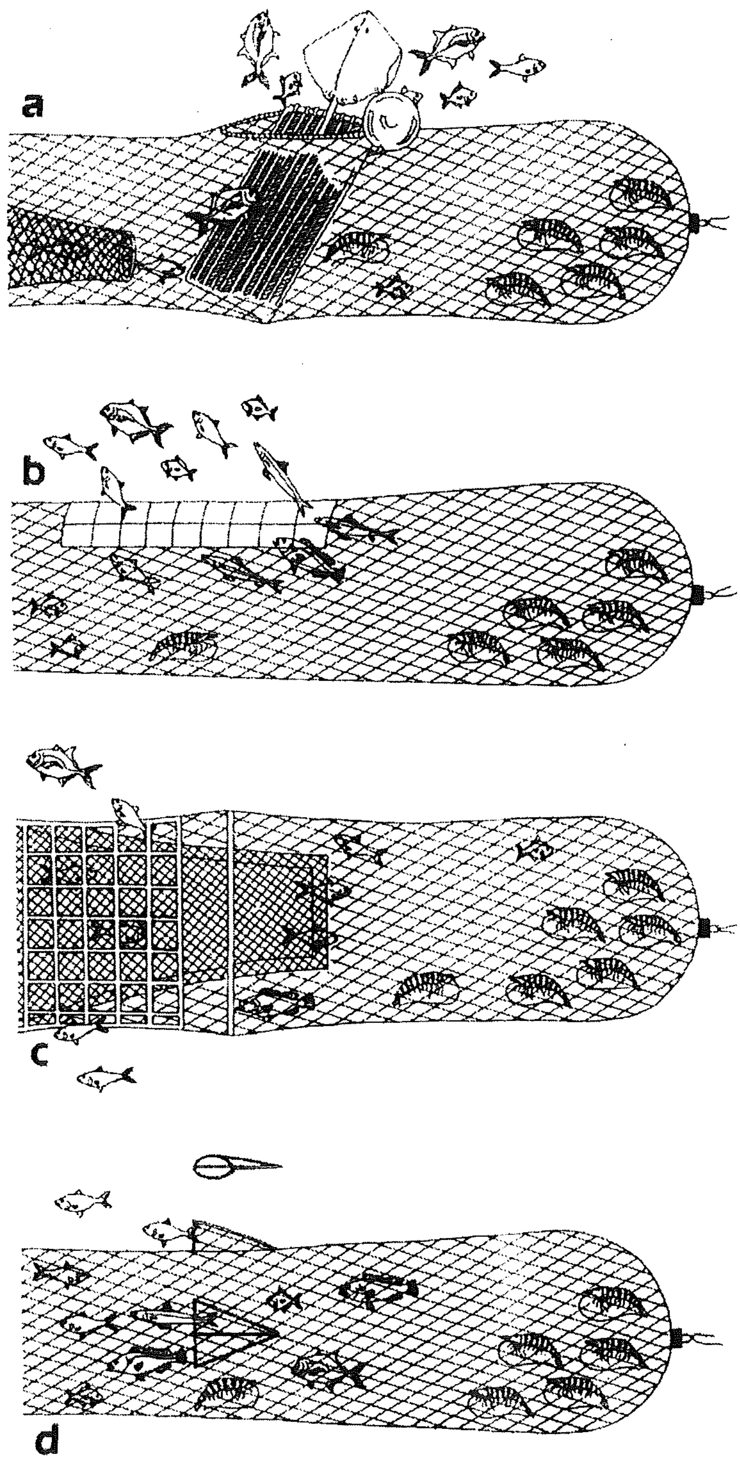
Behind the grid is a hummer device and openings to allow fish escapement. The hummer is an aluminium hoop crossed by several tightly strung, parallel, thin steel wires. It is tied vertically into the codend where it is designed to stimulate fish to swim forward and out through the escape openings on either side.

SQUARE MESH WINDOW

The Square mesh window was one of the simplest BRDs trialed, consisting of a 150 mm (6 in) polyethylene netting panel measuring 8 bar lengths wide by 13 bar lengths long. The window allows fish to escape upwards (Figures 2 and 3), while the prawns that do not swim as well as fish, pass into the codend.

Three other variations of the square mesh window were also tested. One with a hummer placed five meshes behind the window; another with a 1.5 m long black canvas cylinder inside the net behind the window; and another with the window

Figure 3. Four of the bycatch reduction devices trialed: (a) Nordmore Grid, (b) Square Mesh Window, (c) Radial Escape Section and (d) Fish Eyes.



constructed of square mesh netting that glows in the dark.

The hummer and black cylinder have been shown in other studies to stimulate fish to stay forward of them, thereby improving their chances of escape through the square mesh window. The glow netting emits a green glow under dark conditions highlighting the square mesh window at night.

RADIAL ESCAPE SECTION (RES)

The RES consisted of a netting funnel designed to guide the catch past a section of 9 inch square meshes three bars wide extending around the codend (Figure 3). The catch passes through the funnel and some species are able to turn, swim forward and escape through the large meshes.

A unique RES feature was a wire hoop encased in plastic used to support the codend. This ensured that the meshes remained open during the tow but were flexible enough to withstand the rigours of trawling without permanent deformation.

FISH EYES

The Fish Eye (the name is based on its shape) is a simple steel frame attached to the codend to provide a small elliptical opening for fish to escape through (Figure 3). It faces forward in the top of the codend. Animals pass into the codend and must turn to swim forward to escape through this device (Figure 3).

Several devices show promise

Although the results from this cruise are preliminary, several of the BRDs showed potential for use in the NPF. Two devices — Fish Eye and Square Mesh Window — caught about the same weight or more of commercially valuable prawns (tigers and endeavours) as the standard codend being used in the fishery, while catching less bycatch (Figures 4 and 5).

Several others (for example the Nordmore Grid and Radial Escape Section) showed particular promise as bycatch reduction devices but need further refinement to reduce prawn losses.

Large animals rated highly on the fishers' list of least-desired bycatch in trawl catches (see article in this issue). Two inclined grids — the Nordmore grid and the Supershooter — were tested for this purpose. Their effectiveness can be measured by the number of large animals retained by these devices compared to those with no inclined grid (Figure 6).

The Nordmore grid appeared to exclude large animals most effectively. The codends fitted with either of the inclined grids never caught turtles. Although these grids caught some sharks and rays, none were more than 2 kg in weight. Turtles, sharks and rays were caught in the codends of all other devices.

Underwater video reveals fish behaviour

Underwater video footage taken during the cruise provided invaluable information about the reactions of bycatch species, in the trawl and to each device. This information along with catch data provides a springboard to understand the diverse range of species behaviours that will further development and refinement of BRDs.

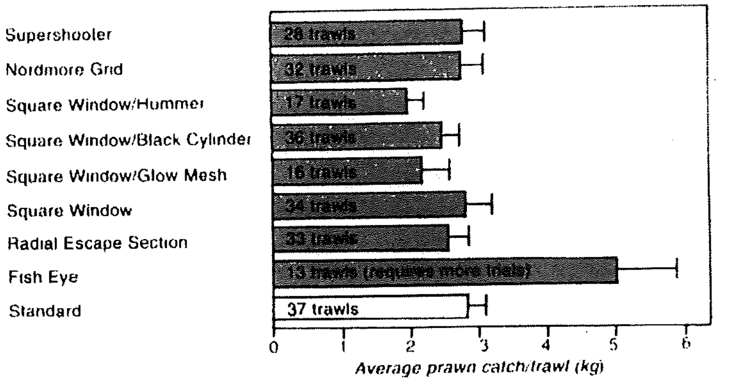


Figure 4. Comparison of catches of commercially valuable tiger and endeavour prawns (combined) between a standard codend and eight different bycatch reduction devices.

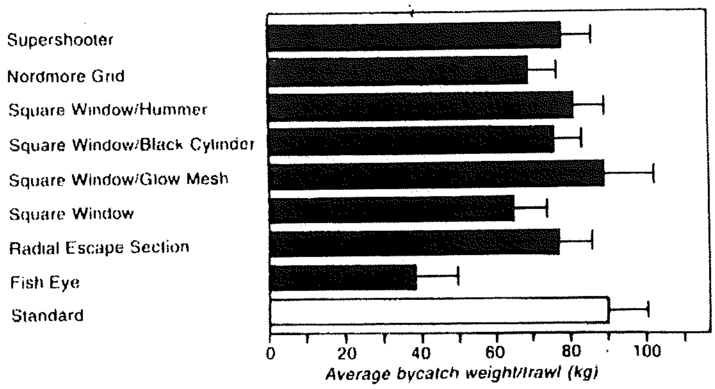
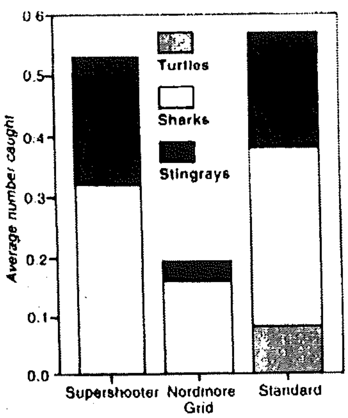


Figure 5. Catches of unwanted fish bycatch from a standard prawn codend and eight different bycatch reduction devices

Figure 6. Catches of large animals from a standard prawn codend and three different bycatch reduction devices.



Choices for the industry

The project aims to provide the NPF fleet with a range of BRDs to suit different circumstances. The installation of an effective large animal excluder (for example, the Nordmore Grid) in an area where large animals are abundant, could protect the catch from damage and maximise the value of the prawns in the codend. The same process could apply to areas where fishers would like to reduce the amount of small fish in the catch. Skippers might choose to have a fish excluder of their choice (for example, a Fish Eye or Square Mesh Window) permanently installed or used in conjunction with a monster excluder.

Gear refinement and commercial boat trials

Further scientific trials to refine and re-test the most promising BRDs will be conducted later in 1995. Selected BRDs will then be tested on some NPF boats in 1996 to assess their performance under commercial fishing conditions.

David Brewer and Nick Rawlinson are fisheries biologists with the CSIRO Division of Fisheries. Steve Eayrs is a fisheries technologist with the Australian Maritime College. Contact: CSIRO Division of Fisheries, Marine Laboratories, PO Box 120, Cleveland, QLD 4163.

RESEARCH

'Monsters', 'blubber' and other bycatch

NPF OPERATORS' VIEWS ON BYCATCH REDUCTION

A team of researchers is currently tackling the problem of how to reduce the amount of bycatch in the Northern Prawn Fishery. Nick Rawlinson and Dave Brewer surveyed fishers in the region to find out their main concerns on the subject.

In recent years, increasing attention has been focussed on how to reduce bycatch from trawl fisheries. The Fisheries Research and Development Corporation (FRDC) is currently funding a project to address this problem in the Northern Prawn Fishery (NPF). The project has drawn together scientists and gear technologists from the CSIRO Division of Fisheries, the Australian Maritime College and the Northern Territory Fisheries Division, who are now working to identify effective Bycatch Reduction Devices (BRDs).

During the 1994 NPF closed season, a questionnaire survey involving 32 skippers, five owner/skippers and one owner was undertaken in Cairns, Darwin and Brisbane, to gather industry views and concerns regarding bycatch.

A standardised questionnaire was used to collect information about bycatch from tiger prawn trawling operations. Questions focussed on: the frequency of capture of different bycatch groups; the problems caused by the capture of each species; and the bycatch groups which the fishers would most like to exclude from their catch. This information was used to help select the BRDs to be tested.

For the purpose of this study, bycatch was grouped in the following categories: fish; large animals such as stingrays, shovelnose sharks, other sharks and turtles; area-specific seabed organisms including heart urchins (commonly known as sea eggs), sponges and corals; and seasonally occurring animals such as jellyfish. Squid, bugs and scallops were classified as by-product rather than bycatch, because they have a commercial value to the fishers.

A major point made by the fishers was that many of the bycatch categories were mainly found in specific areas. For example, catches from the Weipa area are dominated by fish, while there is a higher incidence of sponges taken in the trawls around Bountiful Island.

The variation across areas makes it difficult to generalise about the occurrence of different bycatch groups in catches throughout the NPF. Fishers also made the point that areas that have been regularly fished over the years have been cleared of much of the large seabed organisms such as sponges.

Fish — the most common bycatch

Survey results showed that small fish are the most common components of the bycatch; 97 per cent of respondents reported them in every haul of the net. The main problem caused by the capture of small fish is delays in sorting the catch.

Large hauls of fish also lead to loss of prawns, because the weight of the bycatch forces the net to close and reduces trawling efficiency. This situation can be avoided by regularly checking the 'try-net', a small trawl which can be routinely hauled after short periods to monitor the composition of the catch. If large proportions of fish are evident then skippers generally shorten the length of the tow.

Twenty six per cent of respondents said small fish bycatch caused them no problems. The introduction of sorting hoppers on some vessels has improved the quality of prawns by reducing delays, which can occur when prawns are separated from the rest of the catch by hand.

'Monsters' damage prawns

Ten per cent of survey respondents reported catching large animals in every shot, while 55 per cent said these animals appeared in every second to tenth shot. The majority of the remaining skippers said they were caught less often.

The biggest problem caused by large animals — or 'monsters' as they have become known — is the damage they inflict on prawns during capture. Their sheer size and weight squashes prawns as they tumble around in the codend and crushes others as they hit the sorting table. Live 'monsters' can also sweep prawns over the side of the boat when they thrash about on the table.

Large animals can also damage nets during capture. Shovelnose sharks, considered by fishers to be the strongest and most violent of the group, are a particular problem.

A number of skippers also reported that sharks could force their snouts through the codend exit and loosen the securing knot causing an opening and therefore further prawn loss. Sharks in the water can bite holes in nets while attempting to eat the catch. Sawsharks are able to split open the side of a net with their blade-like snouts.

'Monsters' may even cause injuries to crew while on deck. The serrated stinging spines on the tails of stingrays can inflict severe wounds and the thrashing of large sharks can turn prawns and small fish into dangerous projectiles. The extra care required to deal with these animals results in delays with sorting the catch.

All of these problems are compounded by the size and numbers of each large animal caught in the net.

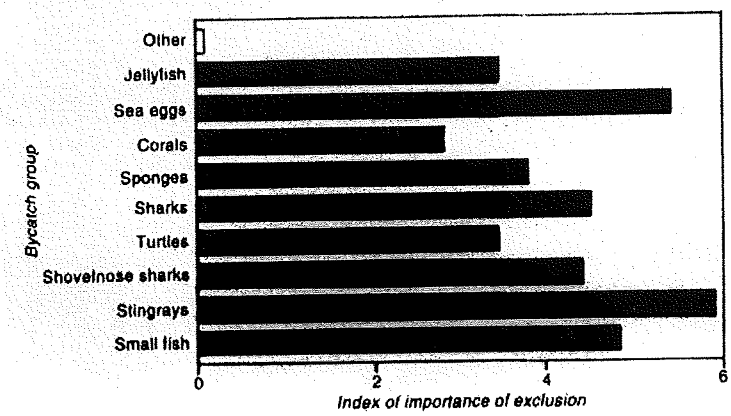
Seabed organisms

The number of seabed organisms captured, including heart urchins (sea eggs), corals and sponges, depended on the area fished, according to reports. Where abundant, they may be caught in every shot — but not at all in other areas.

Large sponges and corals crush prawns and can cause further loss through the build-up in bycatch weight which reduces the efficiency of the gear. Damage to the nets is also reported to occur.

Sea eggs are perceived as a growing problem with reports of increased abundance over recent years. In some areas they occur in such large numbers that they can quickly fill a trawl and cause the net to 'blow out' resulting in the loss of both prawns and fishing time.

Figure 1. Relative priority of exclusion of bycatch groups as indicated by questionnaire of NPF operators (blue = seabed animals, green = large animals).



Large quantities of sea eggs also cause delays in processing the catch and leave behind a trail of sore fingers among crew members who have to sort them. Their spines also damage the prawns.

Catches of sea eggs can be reduced by regular monitoring of the try net. Most skippers reported that they would avoid areas where sea eggs occurred in large numbers. However, when no alternative fishing areas are available fishers in the NPF employ techniques to make the gear fish 'lighter' to avoid the sea eggs. Most skippers agreed that a loss of prawns had to be accepted when the gear was altered for this purpose.

Skippers reported that their nets suffer increased amounts of 'chaffing' when they are towed through beds of heart urchins.

'Blubber'

Large numbers of jellyfish sporadically occur in the Gulf — 1985 was a year most vividly remembered by fishers. If a careful eye is not kept on the build up of jellyfish, or 'blubber' as they are called by operators in the fishery, they can split open the net. Certain innovations such as 'blubber' shoots have been incorporated in gear to try to alleviate this problem, but generally skippers look for alternative fishing grounds.

By-product

Less than five per cent of bycatch is retained as by-product. This includes species such as scallops, bugs, squid and larger fish which are valuable (Pender et al, 1992) and make an important contribution to the vessel's earnings. Other products like shark fins and trunks, and ray wings are also sold by some fishers. The value of such by-products may influence some fishers' views on which animals they label 'unwanted' and wish to be excluded from their catch.

Stingrays and sea eggs are top priority

During the course of the interview, skippers and owners were asked which of the bycatch groups they would most like to exclude from their catch, if the technology were available. Fishers ranked each group in order of priority and this information was then used to calculate an overall index of priority of exclusion for each group.

Stingrays ranked highest overall as the group skippers would most like to exclude from their catch (Figure 1) followed by sea eggs. Although 63 per cent of respondents reported sea eggs to be the most important to exclude, the remainder did not perceive them as a problem.

Small fish rated third, followed by sharks, shovelnose sharks, sponges, jellyfish, turtles and corals. Overall, large animals and fish were identified as the most important components of the bycatch to be excluded. This finding influenced the selection of BRDs that were tested during a research cruise in February and March this year (see page 25).

Fishers see benefits

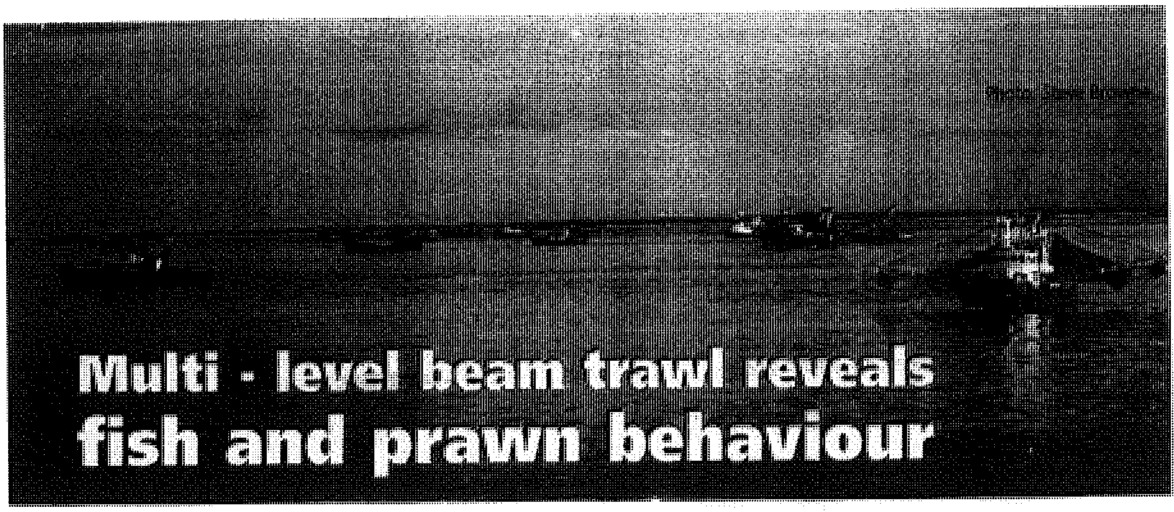
Fishers generally agreed that there would be advantages in reducing bycatch as long as there was no associated loss of prawns. Benefits would include improved quality of product, due to less damage inflicted on prawns and shorter sorting times; increased gear efficiency with smaller amounts of bycatch to tow around; and reduced net damage. As one skipper stated 'a reduction in bycatch would produce a better quality product and a happier crew'.

ACKNOWLEDGMENT

Thanks are expressed to all members of the NPF who gave up their time to be interviewed and respond to the questionnaire. Thanks also to Carolyn Robins who assisted in the survey

REFERENCES

Pender, P., Willing, R., and Cann, B. (1992) NPF by-catch a valuable resource? — Is it worth the effort? *Australian Fisheries* 51(2), 30–31



Multi - level beam trawl reveals fish and prawn behaviour

A multi - level beam trawl (MBT) has been used in the Northern Prawn Fishery (NPF) to examine the vertical distribution and behaviour of prawns and fish entering a trawl. Trials were conducted on the FRV 'Southern Surveyor' in 1994, as part of a Fisheries Research and Development Corporation (FRDC) funded project on the effects of trawl design on by-catch in tropical prawn fisheries. This is a collaborative project, between the Australian Maritime College (AMC), the CSIRO Division of Fisheries (Cleveland) and the Northern Territory Department of Primary Industry and Fisheries (Darwin).

MBT REVEALS PRAWN AND FISH BEHAVIOUR

It is widely recognised that a knowledge of fish and prawn behaviour is important in developing techniques to reduce by-catch while retaining valuable prawns. In recent years, researchers have developed a variety of By-catch Reduction Devices (BRDs) to reduce the capture of small fish species that usually dominate prawn trawl by-catch.

Many of these BRDs, such as fish eyes and square mesh windows, rely on the superior swimming performance of fish to assist their exclusion from the trawl. These BRDs are placed in the top of the codend where the more active fish swim through an escape opening and the prawns are swept passively into the codend.

A common technique to observe behaviour to trawls is the use of underwater video cameras. Prawn trawling, however, mainly occurs at night and in turbid water conditions where good quality video footage is difficult to get. Under these conditions, expensive low light cameras struggle to film at effective ranges, and lighting is of limited benefit due to backscattering and potential influence on natural behaviour patterns.

Daylight filming allows the use of relatively cheap video cameras however the species of interest may not be present in the trawl during the day and observed behaviour may differ to behaviour at night. To overcome these shortcomings and gather evidence of prawn and fish behaviour to prawn trawls, the Australian Maritime College constructed a multi-level beam trawl.

TRIALS IN THE NPF

The MBT measured four metres wide and 1.8 metres high and was constructed from aluminium (Figure 1). The height of the beam trawl was chosen to represent the maximum height of otter boards currently used in the NPF, and the width was selected to provide adequate sample numbers. If required, these dimensions also allow the MBT to be towed as a try-net by NPF trawlers, allowing catch data to be collecting without hampering the commercial operation.

A four seam trawl based on a Florida Flyer design was towed from the aluminium frame and divided into three equally spaced vertical compartments (0 - 600mm; 600mm - 1,200mm; 1,200mm - 1,800mm). Each compartment was divided by horizontal panels of identical design so that prawns and fish reacting vertically to ground chain contact could enter any one of the three compartments. A lead-ahead panel was attached to the upper headline and extended directly between wingends to prevent animals from escaping over the headline. A mesh size of 50mm was used throughout the trawl.

Sea trials were conducted in Albatross Bay in the Gulf of Carpentaria over eight nights. A total of 49 half hour tows were performed at an average tow speed of 2.7 knots.

WHERE DO FISH AND PRAWNS ENTER THE TRAWL?

The codend on the lower compartment caught the highest numbers of fish (40 per cent) and commercial prawns (81 per cent). This suggests either that their usual habitat is close to the seabed (already known for prawns), that the escape response of most fish and prawns is close to the seabed, or a combination of these behaviours.

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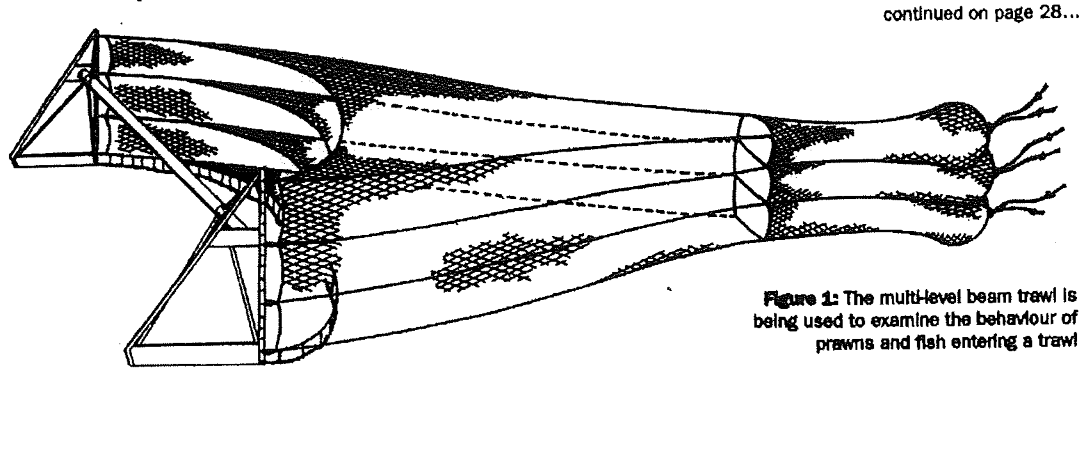

Figure 1: The multi-level beam trawl is being used to examine the behaviour of prawns and fish entering a trawl

Multi - level beam trawl reveals fish and prawn behaviour

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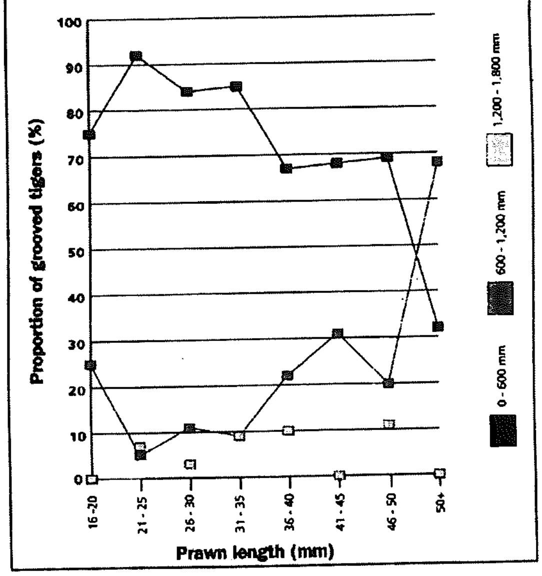
The top and middle compartments caught 39 and 20 per cent of the total fish catch respectively, and 14 and five per cent of the prawn catch. This suggests that the lead-ahead panel guided many animals into the trawl that otherwise would have escaped over the upper headline.

A more detailed analysis of the results revealed some interesting species-specific behaviour (Figure 2). For example, a species of "dollar" fish *(Leiognathus splendens)* was caught mainly in the upper codend, as was a species of sardine *(Sardinella albella)*. A number of sardines were also caught in the meshes of the lead-ahead panel.

These results suggest that a BRD placed in the top of the codend such as a square mesh window or fisheye, may be successful in excluding these species. As might be expected, a species of flatfish *(Pseudorhombus arsius)* was caught mainly in the lower codend, suggesting that a bottom opening BRD may best exclude this species. The common "grinner" *(Saurida micropectoralis)* was more evenly dispersed between the three codends, indicating a less directed response to the trawl.

Over 78 per cent of grooved tiger prawns *(Penaeus semisulcatus)* and 86 per cent of red endeavour prawns *(Metapenaeus ensis)* were caught in the lower codend (Figure 3). With increased prawn length, there was an increased proportion of grooved tiger prawns caught by the upper codend. This suggests that larger prawns are more active and either enter the upper codend after contact with the groundchain or are swimming at the time of capture. It was impossible to analyse the behaviour of blue endeavour prawns *(Metapenaeus endeavouri)* and brown tiger prawns *(Penaeus esculentus)* due to insufficient numbers.

Figure 4: Proportion of grooved tiger prawns caught in each codend



BENEFITS TO THE NPF

The headline height of a prawn trawl in the NPF may reach 1.8 metres, and is not necessarily related to the vertical distribution of prawns. Instead, it is designed to maintain trawl geometry as the headline of the trawl is attached to the aft trailing edge of the otter board. Therefore, the potential exists to reduce the headline height without significant loss of prawns and with a significant reduction in fish by-catch.

Future trials with the MBT will test the effectiveness of lead-ahead attachment to the lower compartments and will test claims by industry that the current headline height is required to catch large swimming prawns.

THE NEXT STEP

Future trials will be conducted in the NPF with headline height modifications to a commercial prawn trawl. Preliminary trials have been conducted at the AMC with a six fathom prawn trawl operated at 50 per cent of otter board height. Trawl spread and warp tension data suggested that an increase in swept area may result from this modification, and no change in otter board orientation was detected.

In summary, the MBT is providing researchers with valuable behavioural information that is difficult to obtain using underwater video cameras. This will assist researchers to develop BRDs to exclude by-catch more effectively while retaining the valuable prawn catch. The study is also providing information on the viability of headline height modifications to improve trawl performance.

Figure 2: Proportion of catch per codend for five fish species

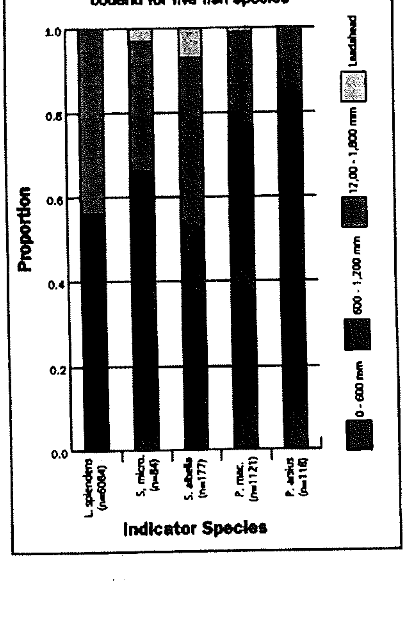
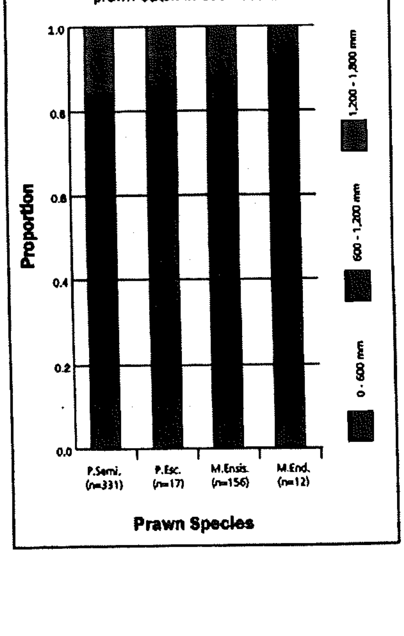
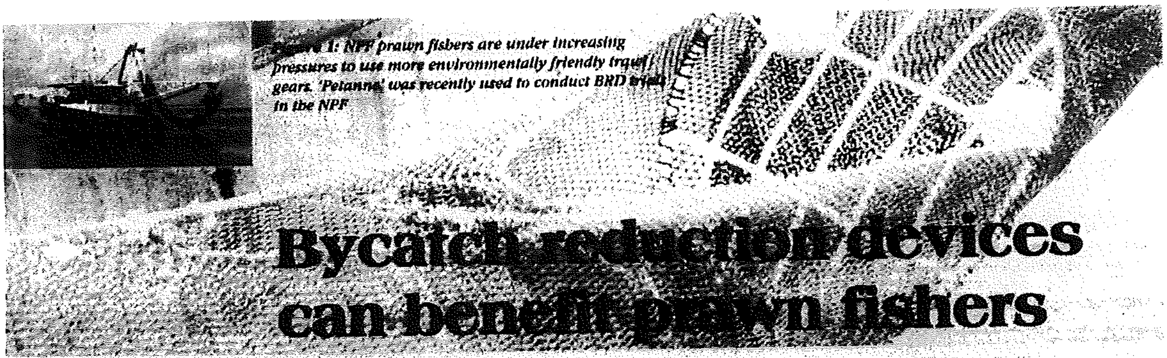


Figure 3: Proportion of commercial prawn catch in each codend



Steve Eayrs is a fisheries technologist and Shekar Bose is a bioecomomist with the Australian Maritime College. David Brewer is a fisheries ecologist with the CSIRO Division of Fisheries, Queensland, and Rik Buckworth is a biologist with the Northern Territory Department of Primary Industry and Fisheries.

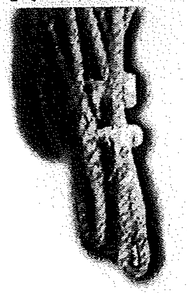
For details contact: AMC, PO Box 21 Beaconsfield. Tasmania 7270. PH: (003) 354424, FX: (003) 354459.



1: NPF prawn fishers are under increasing pressures to use more environmentally friendly trawl gears. 'Petanne' was recently used to conduct BRD in the NPF

Bycatch reduction devices can benefit prawn fishers

Scientific trials have shown that bycatch reduction devices can greatly benefit fishing practices in Australia's Northern Prawn Fishery. David Brewer, Nick Rawlinson, Steve Eayrs and John Salini describe how several devices reduce significant amounts of bycatch without losing catches of valuable prawns.



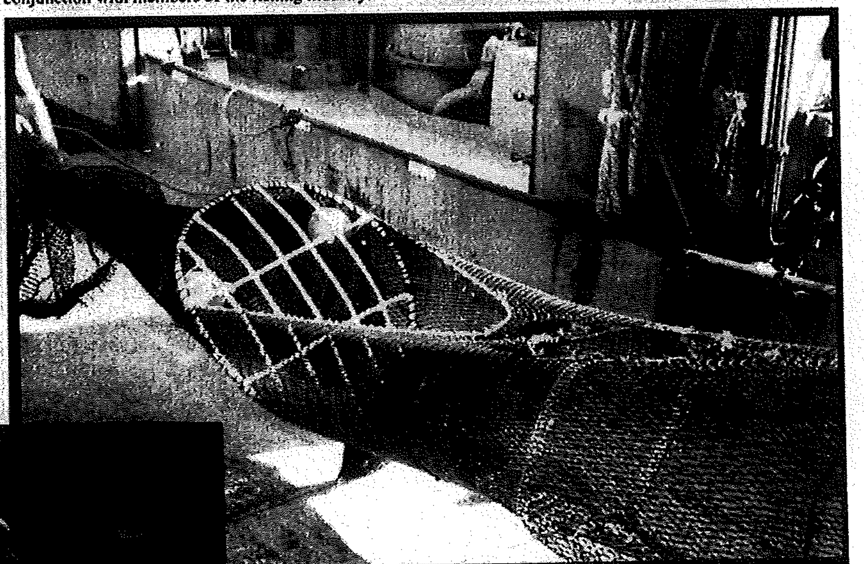
Fishers in the Northern Prawn Fishery (NPF) will soon be in a position to address many of the concerns relating to trawl impacts on bycatch. Recent research has shown that bycatch reduction devices (BRDs) successfully exclude turtles from prawn trawls while maintaining or even increasing prawn catches. Other BRDs also significantly reduce the amount of unwanted fish bycatch as well as excluding under-commercial-sized prawns from their catch.

Australia's Fisheries Research and Development Corporation (FRDC) funded research that has greatly advanced fishers' ability to counter claims that their harvesting method is indiscriminate, and not compatible with the Commonwealth Government policy of encouraging ecologically sustainable practices. This research has been carried out by biologists and fisheries technologists from the Australian Maritime College, CSIRO, Northern Territory Department of Primary Industry and Fisheries, NSW Fisheries Research Institute, Queensland Department of Primary Industries, and in conjunction with members of the fishing industry.

Turtle catches eliminated

The recent scientific trials have shown that turtles and most other large animals, such as large sharks and stingrays, can be eliminated from prawn trawl catches by using inclined grids such as the Super Shooter, the Nørdmore grid or the AusTED (Figure 2). Each of these BRDs physically blocks large objects from entering the codend by guiding them out of the net. There is also evidence that the Super Shooter and the Nørdmore grid can exclude other large objects such as sponges, that can damage prawns and be a nuisance in the catch. The angle of the grid (about 45°) allows most objects to "roll" out, either through a bottom opening grid (Super Shooter) or a top opening grid (Nørdmore grid), without blocking the grid and therefore allowing prawns to pass freely into the codend.

In addition to greatly reducing catches of large animals, the Super Shooter (Figure 2a) has also been shown to consistently maintain prawn catches during scientific trials in the NPF. Preliminary results from trials on board the NPF trawler, 'Petanne' (Figure 1) appear to



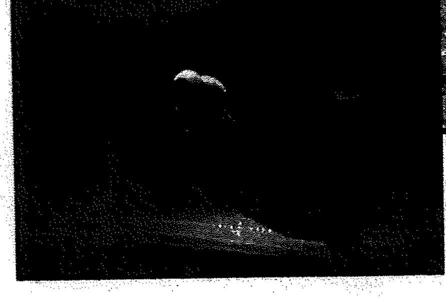


Figure 2 photos of some bycatch reduction devices trialed in the NPF.
above figure 2c: AusTED — turtles and most sharks and rays excluded, no prawn loss in "clean" areas, 27% fish exclusion.
left figure 2a: Super Shooter — turtles and most sharks and rays excluded; no prawn loss

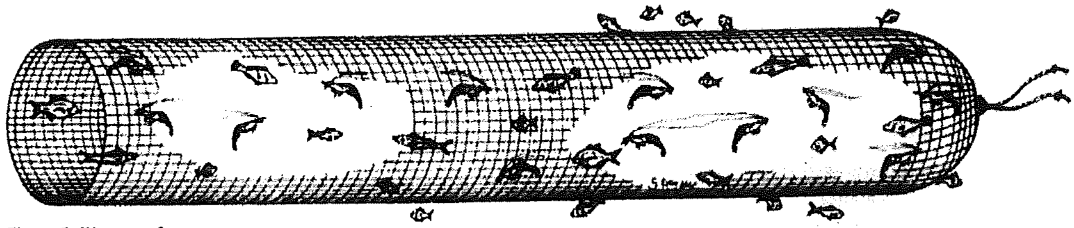


Figure 3: Diagram of a square-mesh codend — 2% loss of commercial sized prawns, 22% fish exclusion, >58% escapement of "over 30s" prawns = drawing of square-mesh codend

support this finding. The Nørdmore grid — shown here combined with a square-mesh window to increase fish exclusion (Figure 2b) — required some modifications to decrease prawn losses recorded during scientific surveys, and these were made before the trials on board 'Petannè'. Different versions of the AusTED have been extensively trialed in different locations with varying levels of prawn retention (Figure 2c). In one set of trials north of Groote Eylandt, the AusTED eliminated turtle catches, and decreased unwanted fish bycatch with no loss of prawns.

These devices will greatly assist fishers to reduce catches of turtles and other bycatch without losing valuable prawns. Fishers are already voluntarily beginning to test these devices. This will greatly increase our understanding of which devices work the best in different fishing grounds and under different conditions. Fishers will also improve the performance of these BRDs as their experience with them increases.

Value adding through bycatch reduction

The importance of maximising the catch of high quality undamaged prawns is now greater than ever. This is because most operators in the NPF maximise their returns by finger packing tiger prawns for export and these prawns must be in near perfect condition. Large animals will crush or break prawns in the codend and on the sorting tray.

Recent research has shown that approximately five to 10% more tiger prawns are damaged compared to catches without large animals. These prawns are known as "broken" and are of a lower market grade and fetch much lower prices. Even a small increase in the amount of undamaged prawns would translate into a significant increase in annual profit.

By using BRDs to reduce catches of large animals, fishers can increase the value of the catch by increasing the proportion of near perfect condition prawns. These devices are now "ready to go" and given the expected financial benefits to fishers, BRDs could be widespread throughout the NPF within a few years.

Avoiding catches of under-commercial-sized prawns

Most Florida Flyer trawls currently used throughout the NPF are rigged with 45 mm diamond mesh netting throughout the codend. This mesh size and type allows only the smallest of animals to escape through the narrow mesh openings.

Trials of 45 mm square-mesh codends have shown that not only are catches of commercial sized tiger prawns ("under 30s") maintained (only a 3% loss), but 28% of the bycatch is excluded (Figure 3). Equally important is the fact that in the NPF, most under-commercial-sized tiger prawns (between 58 and 98%) ("over 30s") can escape, avoiding probable death on the sorting tray. This will mean that large numbers of small tiger prawns can be left to enhance future stocks and be re-caught when they are far more valuable.

BRDs may increase prawn catches

There is growing evidence that effective BRDs can increase catches of prawns. NSW Fisheries Research Institute scientists have developed the composite square-mesh panel which reduces the amount of unwanted bycatch by up to 41% and increases catches of prawns by four to 14% in their offshore prawn fishery (Broadhurst and Kennelly 1996b). This panel has already been widely adopted in New South Wales and there is also some voluntary use by several fishers in the NPF.

There is also some circumstantial evidence of unusually high prawn catches from the NPF research when large amounts of bycatch were excluded using fisheye BRDs (Brewer et al. 1995 pp 24-26). Although more evidence is needed to confirm this result, it adds weight to the argument that use of some bycatch reduction devices can increase prawn catches.

Increased prawn catches by using BRDs could be explained as follows. The exclusion of bycatch by using a BRD decreases the overall weight of catch in the codend, which reduces drag and promotes the maintenance of a wider wingend spread compared to a standard trawl. So a trawl fitted with an effective BRD can have a wider swept area over the duration of the tow than a standard trawl, resulting in higher prawn catches. Improvements in prawn catches will become more widespread as fishers adopt effective BRDs and make their own performance enhancing adjustments.

Ongoing gear improvements

Although recent BRD research has made significant steps towards providing prawn trawl fisheries with devices that are ready to use, there is plenty of scope for improvement in BRD technology. Even the most effective BRDs will be improved by fishers' experience and ingenuity once they are used more extensively on commercial trawlers. As BRD technology improves and new devices are developed, a greater range of options will be available to fishers that will allow them to select the device most suited to their needs and fishing conditions.

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Preliminary results... show increased catches of prawns by four to 14%

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References

David Brewer, Steve Eayrs and Nick Rawlinson. Bycatch reduction devices show promise in the NPF. Australian Fisheries, May 1995. pp 24-26.

Matt K. Broadhurst and Steven J. Kennelly. Solving by-catch problems in New South Wales estuarine prawn-trawl fisheries. Professional Fisherman June 1996a. p 28.

Matt K. Broadhurst and Steven J. Kennelly. Reducing by-catch while increasing commercial prawn catches. Professional Fisherman July 1996b. p 24.

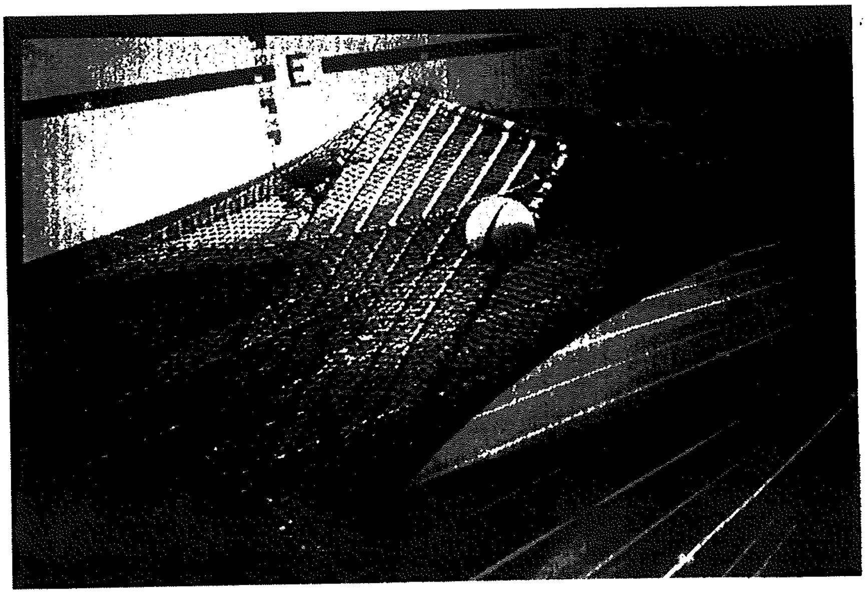

Figure 2b: *Nørdmore grid + square-mesh window — turtles and most sharks and rays excluded, 14% prawn loss, 28% fish exclusion*

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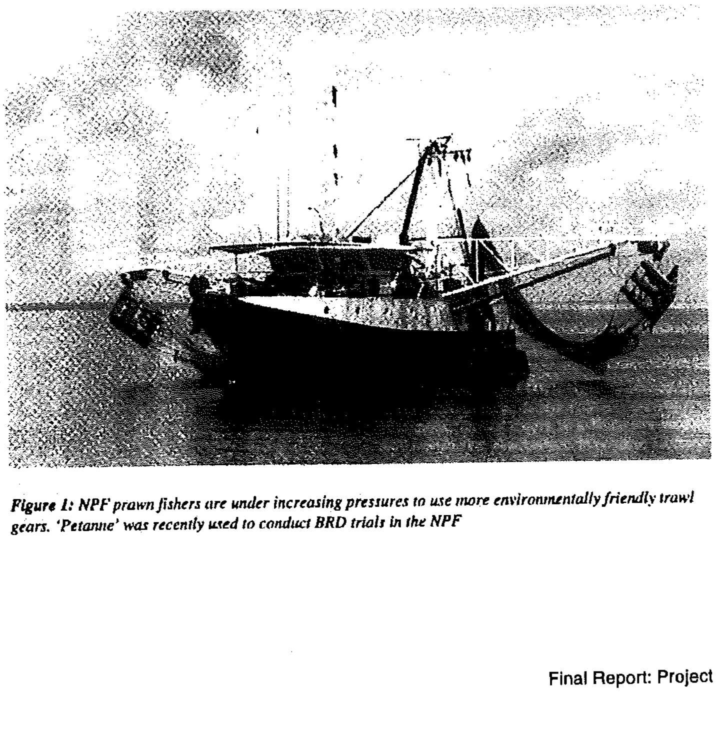

Figure 1: NPF prawn fishers are under increasing pressures to use more environmentally friendly trawl gears. 'Petanne' was recently used to conduct BRD trials in the NPF

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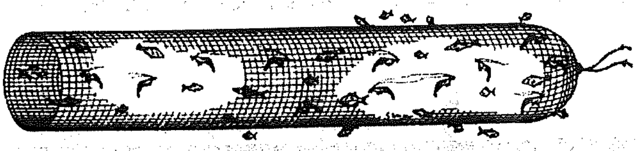

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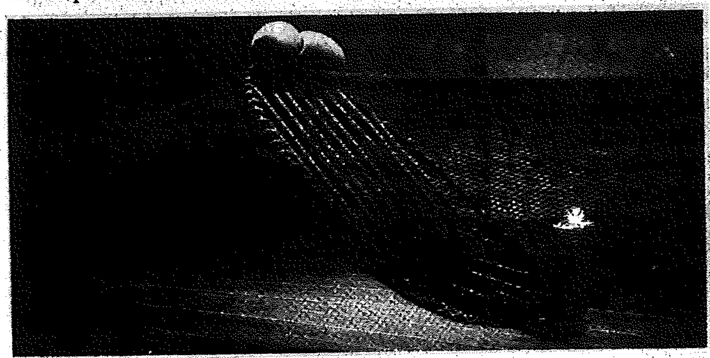

Figure 2 photos of some bycatch reduction devices trialled in the NPF.
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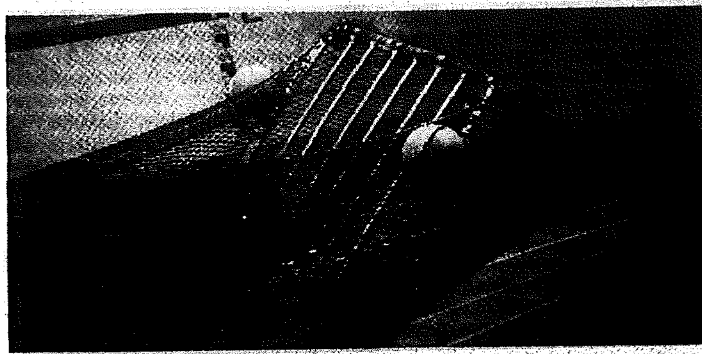

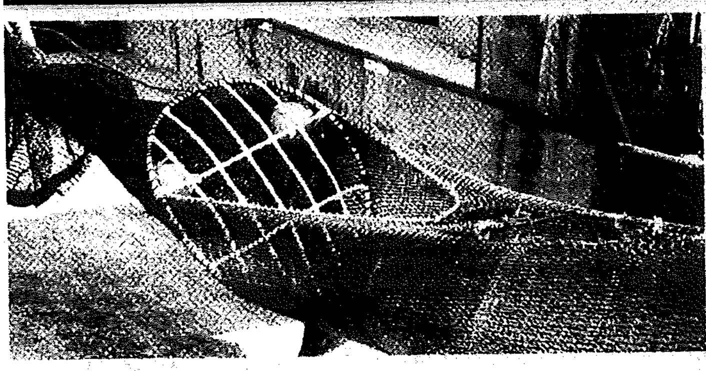

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Australian Fisheries Management Authority

NPF fishermen view bycatch reduction devices

The fisheries research vessel 'Southern Surveyor' recently spent four weeks in the Northern Prawn Fishery (NPF) testing several devices to reduce prawn trawl bycatch. Prawn fishermen operating in Albatross Bay during this time were invited onboard to give their opinion on these devices and to discuss relevant bycatch issues. Steve Eayrs, David Brewer and Neville Gill report.

As part of a Fisheries Research and Development Corporation (FRDC) funded project, researchers took part in a 'Southern Surveyor' research cruise in October 1995 to test modified versions of Bycatch Reduction Devices (BRDs) that had showed promise during previous trials in February 1995 ("*Australian Fisheries*", May 1995). The new BRD versions included large animal ('monster') excluders and fish excluders in combination for the first time, as well as the 'AusTED' developed by the Northern Territory Fisheries Division and Queensland Department of Primary Industry and Fisheries.

Prawn fishermen operating in Albatross Bay during the trial period were invited onboard to view these devices in action. Fishermen included Ivor Jones ('Roper Therese'), Greg Patrick ('Comac Endeavour'), Ray Hazel, Marie and Steve ('Four Seasons'), Alan Smith and 'Sharky' ('Aqua Sam'), Stuart Carter ('Miss Providence') and Keith Burnell ('Kelana'). CSIRO scientists and fisheries technologists from the Australian Maritime College and the Northern Territory Fisheries Division were on hand to demonstrate the range and capabilities of the BRDs.

BRDs trials encouraging

In addition to the AusTED (shown on page 26), two other 'monster' excluders were tested: the Supershooter, now being used in the Gulf of Mexico, and the Nordmore grid, which has been adopted by many countries including Norway, Canada and the United States. All 'monster' excluders were used in combination with either fish eyes or square mesh windows to further reduce catches of unwanted fish bycatch. A standard 14 fathom Florida Flyer with no BRD attached was used to provide a comparison.

In contrast to the standard trawl, no turtles, large sharks or stingrays were caught by trawls fitted with the 'monster' excluders. The results of the BRD performance, in terms of small fish exclusion and prawn retention, have still to be analysed, however first indications were promising.

The best of these BRDs will be trialled on NPF trawlers in 1996. The results are likely to provide fishermen with a range of devices designed to exclude different bycatch species from prawn trawls, depending on the area fished.

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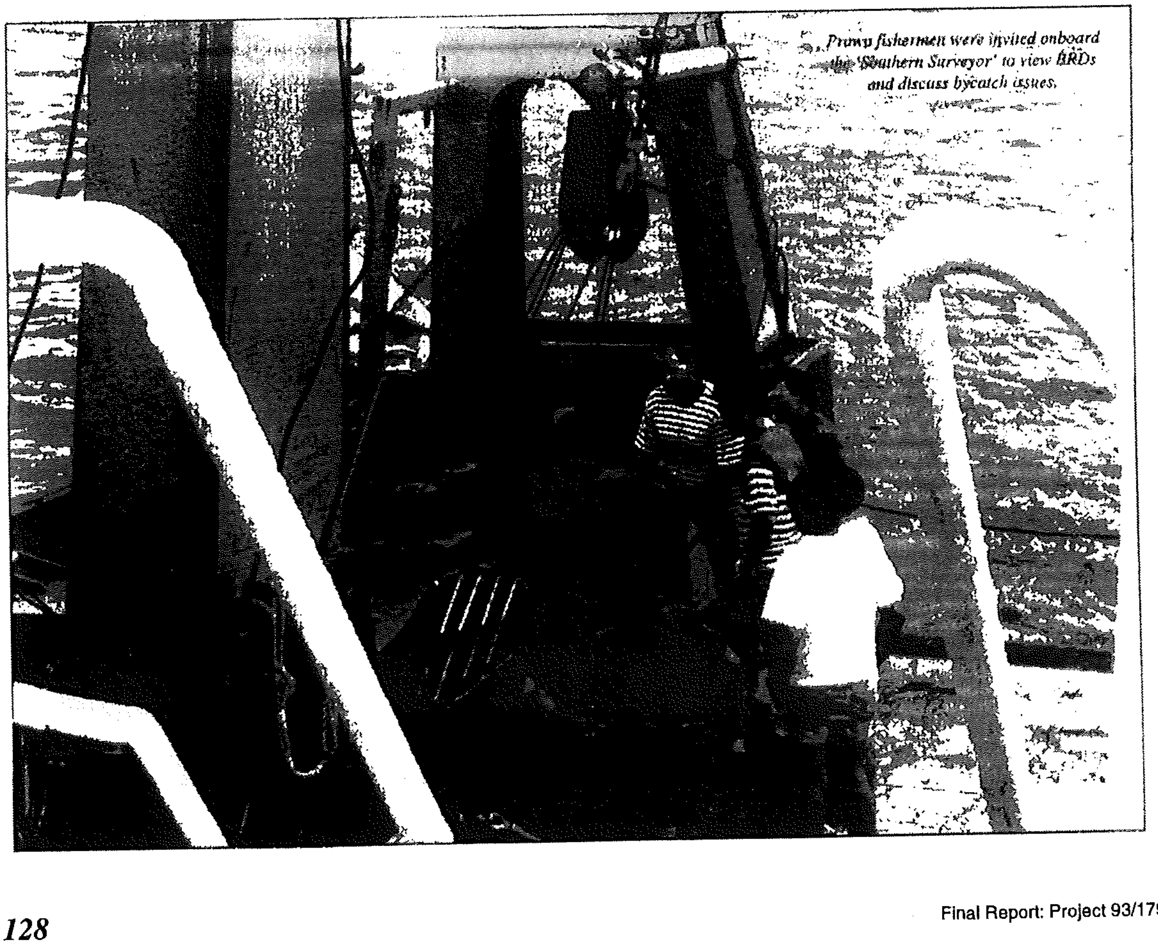

Prawn fishermen were invited onboard the 'Southern Surveyor' to view BRDs and discuss bycatch issues.

NPF fishermen view bycatch reduction devices

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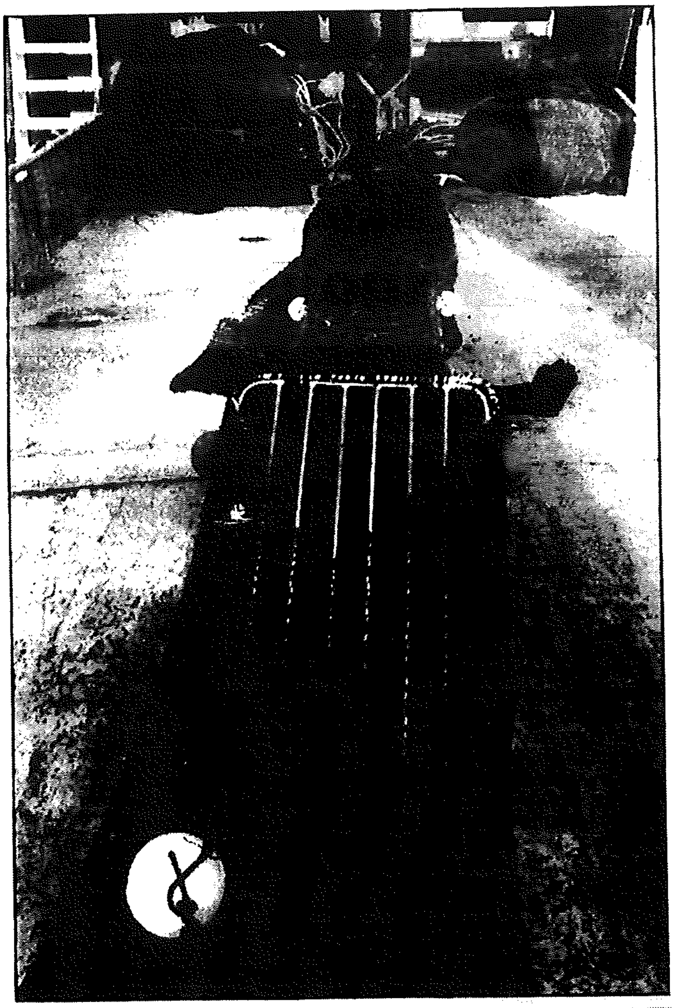
Fishermen comment on BRDs

Fishermen also viewed underwater footage of the BRDs in action, taken during the cruise. The footage showed BRDs excluding large animals such as stingrays, sharks and sponges and also provided an insight into fish behaviour in prawn trawls.

Fishermen provided information about their main bycatch problems and how they thought the BRDs would best benefit their fishery. For example, minimising prawn damage through the exclusion of 'monsters' was seen as an important goal, particularly with the growing trend toward 'finger packing' high quality, undamaged prawns into export packs of 3 kg or less. The fishermen agreed that 'monster' excluders could increase the value of the catch by decreasing damage in the codend.

The use of BRDs to exclude fish bycatch was also regarded as a benefit to the fishery, particularly in areas where fish catches are high. Problems associated with large catches of fish include a need to reduce tow times, and a reduction in catching efficiency due to a reduction in trawl spread. The BRDs were examined and stimulated discussion on how they could best be adapted to commercial operations.

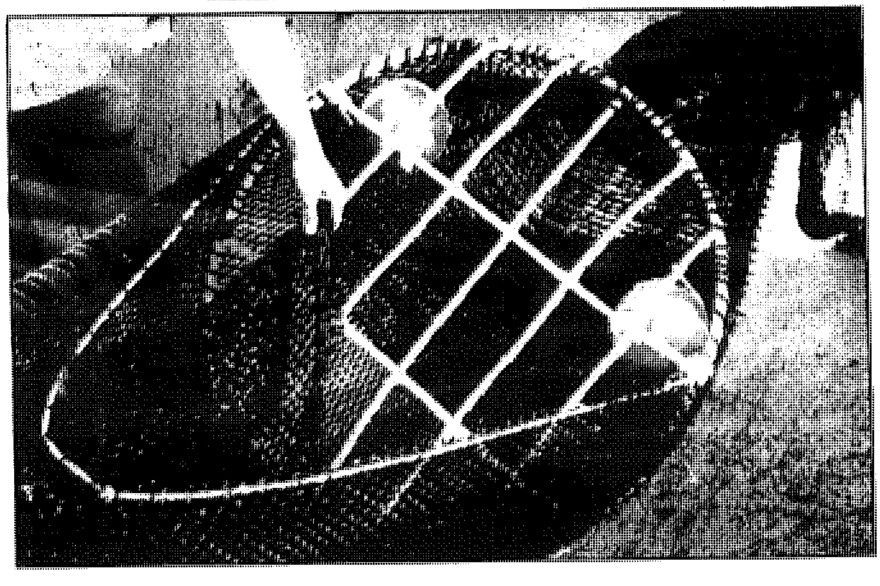
Of concern to the fishermen was the potential loss of prawns and byproduct. The latest BRD trial results from this project will be available in 1996 and will include descriptions of what fishermen using BRDs can expect to catch and exclude, compared to the full array of prawns and bycatch now caught by standard trawls.



The next step

The next step needs to be taken by industry. A number of devices have shown considerable potential, however, the real measure of success will be their eventual adoption by industry. It is hoped that prawn fishermen will examine these initial concepts and, in collaboration with researchers, develop practical methods for reducing bycatch.

Steve Eayrs is a fisheries technologist at the Australian Maritime College, David Brewer is a fisheries biologist with CSIRO Division of Fisheries and Neville Gill is a fisheries technologist with Northern Territory Fisheries Division. Contact Steve Eayrs, AMA PO Box 21 Beaconsfield Tasmania 7270, tel (003) 354 424 or fax (003) 354459.



Above right: The Nordmore grid fitted with a square mesh window.

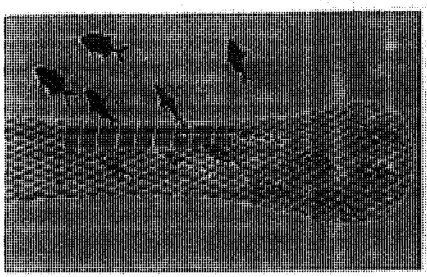
Right: The AusTED uses an inclined flexible grid to exclude 'monsters' from the trawl.

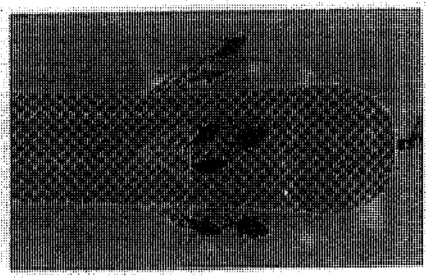
2. Articles in science magazines:

Spectrum

'Escape nets' reduce fish bycatch

New prawn nets to be trialled in the Gulf of Carpentaria near Weipa early next year are expected to reduce the unwanted fish bycatch by up to 70%. This amounts to tens of thousands of tonnes of fish each season in the northern Australian prawning industry.





Two of the many bycatch reduction devices to be tested off Weipa in January. The 'square mesh window' net (left) and the 'fish eye' net both allow fish to escape by active swimming. The prawns fall into the back of the codend.

The trials are part of efforts by scientists and the fishing industry world-wide to make commercial fishing ecologically sustainable. If successful, they will also bring immediate economic benefits for commercial fishers.

A study of one prawn fishery season in northern Australian waters found that 47 000 tonnes of unwanted bycatch were taken for the harvesting of 4100 tonnes of prawns. Revised fishing gear used so far has cut the bycatch by between 17 and 30%. It is hoped that the continued research will at least double this result.

The bycatch reduction project, begun in July 1993, brings together biologists and gear technologists from the CSIRO Division of Fisheries, the Australian Maritime College in Tasmania and the Northern Territory Department of Primary Industries and Fisheries. New gear is tested in a special flume tank at the Maritime College.

More than 10 combinations of net designs will be tested in the tank before the January trials off Weipa. Past trials tested nets featuring square mesh 'codends'. These allowed some of the bycatch to escape, while retaining the prawns in the codend or sack part of the net.

The January trials will test different types of escape pathways to encourage the fish to swim out of the net. Each escape device has an intriguing name such as 'radical escape section', 'inclined grid' and 'fish eye'. The fish will be recaptured after their escape to gauge the fish survival rates of the nets tested.

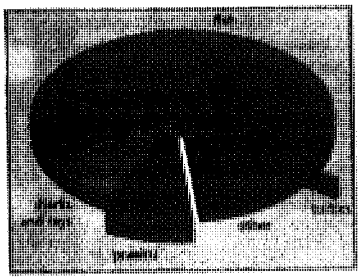
The importance of the new nets is recognised by the fishing industry. In addition to reducing the unnecessary capture of turtles and other fish, the new nets will prevent the crushing of prawns by large fish such as stingrays. Keeping the bycatch in the sea also means that the larger prawn predators have an alternative menu.

Reducing the unwanted bycatch will also bring benefits for recreational fishers. In the northern rivers country of northern New South Wales, the new nets have reduced the bycatch of juvenile mulloway, or 'jewfish', which are enthusiastically targeted by anglers in their mature form. It is the project's aim that the new types of nets do not reduce the size of commercial prawn catches.

The research team has also been devising ways of keeping fin-fish trawl nets off the sea floor. Work so far has shown that improved nets minimise habitat damage while maintaining catches of the target fish species.

Contact: David Brewer, CSIRO Marine Laboratories, PO Box 120, Cleveland, Qld 4163, (07) 286 8246, fax (07) 282 2582.

Paul Lewer



Breakdown by weight of catch from Gulf of Carpentaria prawn trawling.

Thresher says Australia's isolation, its dependence on shipping for international trade, the high volume of dry bulk exports, and marine quarantine procedures that world wide are poorly developed, have contributed to this exotic invasion.

He says at least three pests, – toxic dinoflagellates, the alga *Undaria*, and the Northern Pacific seastar *Asterias amurensis* – are likely to cost the shipping, mariculture and fishing industries millions of dollars annually. In addition, both *Undaria* and *Asterias* have the potential to cause major changes to the structure of temperate coastal marine ecosystems.

'The Northern Pacific seastar is now established in south eastern Tasmanian waters, where it is a voracious predator of mussels, scallops and oysters,' Thresher says. 'This pest was probably introduced from Japan in the mid-1980s in ballast water dumped by bulk carriers.'

The east coast waters of Tasmania are also infected with *Undaria*, a brown algae (also from Japan) which can overgrow and smother other marine life, and toxic dinoflagellates, small planktonic algae which can poison commercially grown shellfish and cause paralysis or even death when these shellfish are eaten.

Thresher says because Tasmania has a relatively small and undiverse marine flora and fauna, introduced marine pests have been readily detected, but elsewhere in Australia, the search for introduced species has not been thorough.

A safe, effective, practical and cost-effective method of killing marine pests in ballast water has not yet been developed, Thresher says. Flushing ballast water tanks at sea is one option for international shipping, but this can only be done when safety requirements can be met. Another option is to heat ballast water to kill any organisms, but it has proved difficult to make this effective on the scale required.

Contact: Christine Ward, CSIRO Division of Fisheries, GPO Box 1538, Hobart, Tas. 7001, (002) 32 5222, fax (002) 32 5530.

Nets designed to set fish free

Conventional nets capture tonnes of unwanted fish

SURPRISING as it may seem, commercial fishermen do not seek to catch everything that swims within reach of their nets. In fact, as much as 70 per cent of some catches can be unwanted species.

The CSIRO magazine, *Ecos 81*, reports that a recent study of one prawn fishery season in Australia's northern waters found that 47 000 tonnes of unwanted bycatch was netted with the harvesting of 4100 tonnes of prawns.

In a bid to eliminate bycatch species, biologists and gear technologists from several Australian institutions and the fishing industry are collaborating on the design of nets and other equipment which will catch only the species targeted.

More than 10 combinations of net designs, with built-in escape hatches, have been tested in special flume tanks at the Australian Maritime College in Tasmania and have cut the bycatch yield by between 17 and 30 per cent. Further research should lead to designs capable of bringing even better results.

Another benefit of new net design is that eliminating the capture of turtle, stingray and other large species stops a proportion of prawns being crushed.

The research team also is looking at ways of stopping trawl nets dragging along the seabed and damaging fish habitat.

For further information, contact:
Mr David Brewer,
CSIRO Marine Laboratories,
PO Box 120, Cleveland, Qld 4163.
International telephone 61-7-286 8246

3. Articles in local community newspapers:

BYCATCH REDUCTION DEVICES IN THE GULF OF CARPENTARIA

The second cruise of the collaborative AMC-CSIRO-NT Fisheries bycatch reduction project was recently conducted in the Gulf of Carpentaria (GOC) on board CSIRO's *FRV Southern Surveyor*.

The primary aim of the cruise was to test a range of Bycatch Reduction Devices (BRDs) designed to exclude unwanted bycatch from prawn trawls. Secondary aims included daylight video recording of fish behaviour towards the BRDs, and further refinements to a semi-pelagic trawl.

The AMC was represented by Steve Eayrs and ex-staff member Marcus Strauss. A total of eight BRDs were trialed with most being constructed at the AMC, and two being purchased from overseas.

All BRDs were fitted to commercially designed prawn trawls and towed in 30 minute shots throughout the night. Two trawls were towed simultaneously, allowing catch rates of BRD equipped trawls to be compared with those from an unmodified trawl.

Two BRDs were designed to exclude large stingrays, sharks and turtles, collectively referred to as 'monsters'. Exclusion of these species was achieved by an inclined metal grid that guides the 'monster' through an escape opening in the trawl. One BRD was designed to exclude through an opening in the trawl's upper panel (Figure 1), and the other through the lower panel.

Both BRDs successfully exclude all 'monsters' with the upward excluding BDR additionally excluding all fish species greater than 2kg in weight. Exclusion of 'monsters' is desirable due to their potential to damage the prawns and significantly reduce the quality and value of the catch.

The remaining BRDs were designed to exclude unwanted fish species while retaining the prawns. By providing large mesh openings in the trawl, such as a square mesh window (Figure 2), many species will swim through the meshes and escape. The relatively poor swimming prawns, on the other hand, are unable to swim through the openings and are subsequently captured.

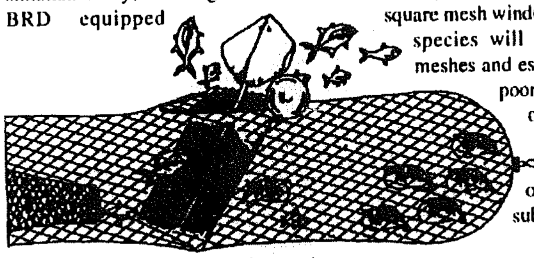


Figure 1

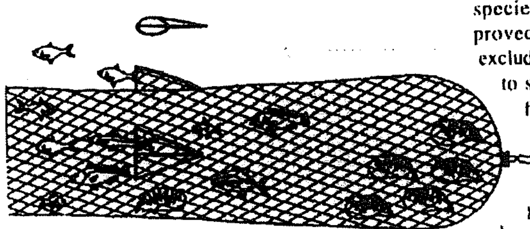


Figure 2

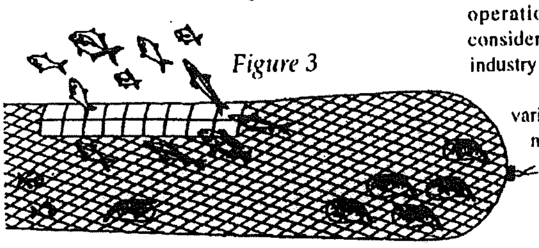


Figure 3

All six BRDs reduce fish bycatch, particularly the larger pelagic species. Smaller species proved more difficult to exclude due to their inability to swim long enough to find the escape openings. The fish eye (Figure 3) excluded the greatest amount of bycatch and, being of relatively simple design and operation, shows considerable potential for industry use.

A number of variations to the square mesh window were trialed, including use of a number of 'stimulators' to assist the fish in detecting the escape openings and to prevent passage to the codend. In addition, a square mesh window constructed of netting material that glows in the dark was trialed, but no increase in exclusion rates was detected.

The semi-pelagic trawl is designed to operate at a steady 0.5m above the seabed, and thereby reduce damage to benthic species (eg. sponges, corals) caused by the trawl. Trials included varying the length of sweep wires between the trawl and otterboards, in an attempt to further reduce seabed contact.

Earlier trials in the GOC (November 1993) demonstrated this trawls' effectiveness in maintaining the desired operating height while reducing benthic damage. Target species catch rates were maintained, and the capture of unwanted bycatch was also significantly reduced. Extremely rough weather and associated vessel motion during the latest trials resulted in the trawl frequently contacting the seabed and then rising to a height of one or two metres. Trial results are therefore likely to be inconclusive.

Underwater video footage of BRDs was taken to provide researchers with details of fish behaviour in BRD equipped trawls. While all footage was taken during the day, it did provide a valuable insight into how the same species may react at night. For example, the exclusion of a common species of school shark was more successful using the upward excluding BRD than the downward excluding BRD. Video footage showed that this species follows the upper panels of netting as it passes along the trawl, and is therefore more likely to encounter the escape opening in the upper panel.

Future trials are planned in which the best of the current range of BRDs will be trialed more extensively, as well as attempting to continue trials with the semi-pelagic trawl.

AMC NEWS *December 1995*

4. Articles in local and large newspapers:

New net to cut trawl bycatch

By MARGO ZLOTKOWSKI

A NEW type of prawn-trawling net being trialled by CSIRO scientists could help reduce the amount of trash-fish dumped in Far Northern waters by up to 70 per cent.

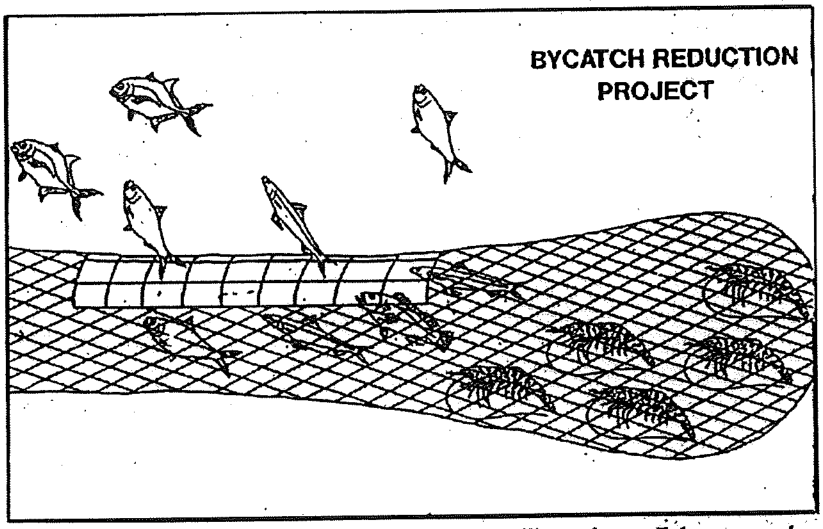
But fishing industry representatives say the beauty of the new by-catch reduction equipment is that it does not also cut back normal-sized catches of prawns.

Initial trials of the nets have so far reduced fish bycatches by about 20 per cent but project scientists believe they can realistically expect 50 to 70 per cent reductions.

Queensland Commercial Fishermen's Organisation spokesman Mark Doohan yesterday welcomed the new net designs as a way to address widespread community opposition to the dumping overboard of thousands of tonnes of unwanted bycatch each year.

However, Mr Doohan said fishermen needed to be assured the nets were efficient and did not result in fishermen losing some of their catch.

"If we're not losing prawns and the nets are efficient and easy to handle we'd definitely support the project and its continued funding," he said.



AN artist's impression of how the new net will work — fish can swim through the top of the net while prawns are trapped in the cod end.

A CSIRO spokesman yesterday said square mesh holes in the nets allowed unwanted fish to escape instead of being fatally trapped with the target prawn species.

This meant less damage to the prawns resulting in a higher proportion of export quality catch, shorter sorting times and a decrease in the amount of marine life killed.

The spokesman also said commercial fishermen would only require simple modifications to their current gear to start reaping the benefits of the new design.

Gear testing is being carried out in a flume tank at the Australian Maritime College in Tasmania and sea trials in Tasmanian and Northern Prawn Fishery waters.

CSIRO fisheries biologist David Brewer said by protecting the ecosystem, they were ensuring a healthy fishery was maintained.

"The work we are doing will ultimately put more dollars in the pockets of commercial fishermen," he said.

Studies made during the past five years have produced evidence of the fishery's enormous bycatch problem with one study showing 47,000 tonnes of bycatch taken in a catch of 4100 tonnes of prawns.

The project has brought together biologists and gear technologists from the CSIRO Division of Fisheries' Cleveland Marine Laboratory, the Australian Maritime College and the Northern Territory Department of Primary Industries and Fisheries.

It is also strongly supported by the Fishing Industry Research and Development Corporation.

2 *The Weipa Bulletin*

One of a kind fish experiment

The Embley River in Weipa has been the site of a unique experiment to measure the survival rates of fish escaping from specially constructed trawl nets.

The project is part of a wider study aimed at reducing the amount of unwanted bycatch caught in nets when fishermen are trawling for prawns and other target fish.

CSIRO Division of Fisheries, the Australian Maritime College and the Northern Territory Department of Primary Industries and Fisheries are jointly funding the bycatch studies.

Several bycatch reducing devices are being tested to see which gives the best results for northern Australian trawl fisheries.

The reduction of bycatch is important for many reasons including the long term survival of fish species and the protection of the target species such as prawns.

David Brewer from the CSIRO said bycatch costs fishermen money in a couple of ways.

Firstly there is the expense associated with sorting the unwanted bycatch from the target species and secondly the bycatch physically damages the target.

In the case of tiger prawns Mr Brewer said the target product is extremely valuable and each prawn which is damaged means losses for the fishermen.

The section of the study David and co worker Nick Rawlinson have been engaged in at Weipa during recent weeks measured the long term suitability of square mesh panels in nets. The mesh panels allow small unwanted fish to escape back to sea and it is important to establish survival rates after the escape.

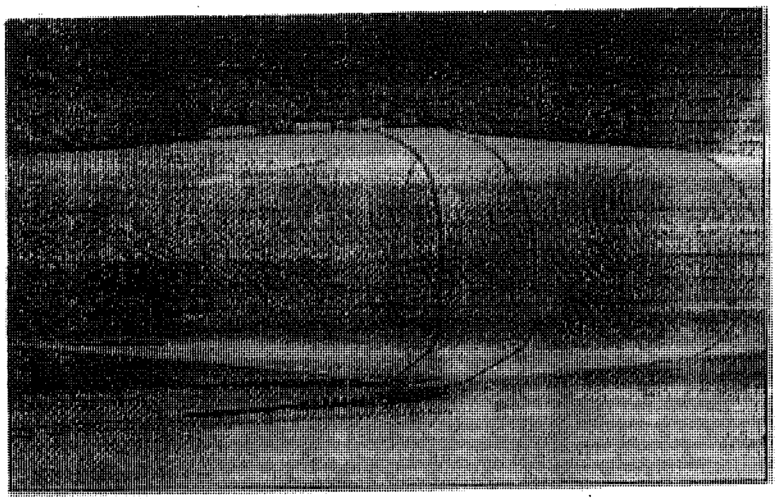
One of the more laborious tasks invloved in the CSIRO research is measuring hundreds of tiny fish. Nick Rawlinson tries to look happy about the painstaking work.

David and Nick recaptured fish which escaped through the panels in larger nets and have watched their development and recorded fatalities.

The fish have been kept in large pools at the CSIRO laboratory at Evans Landing and in sea cages moored in the Embley River. Survival rates have been excellent according to David, with more than eighty percent of fish surviving. The fish survival trial ended in Weipa yesterday but further studies may be carried out in Moreton Bay.

Next January CSIRO scientists will return to Weipa to continue the study of different types of equipment which could eventually lead to a large reduction in the bycatch currently trapped in nets.

Lester Shephard has been assisting the CSIRO with their research by making his fishing vessel *Island Girl* available for fish collection trips. He is pictured with Nick, displaying the square mesh which allows small fish to escape capture.



The experimental net . . . hopes to cut bycatch by half at least

Fishermen aim to cut slaughter

SCIENCE TODAY
JOHN COKLEY

NORTHERN prawn fishing fleets should soon reap the benefits of experimental work by CSIRO scientists on Moreton Bay, targeted at reducing the large amount of bycatch (unwanted species) caught in trawler nets.

Significant progress is being made in the search for environmentally friendly prawn and fish trawling methods.

One of the major industry and conservation concerns in recent years has been the vast trawl net bycatch.

It is a global problem which sees thousands of tonnes of bycatch a year dumped overboard.

The dead, unwanted fish are usually eaten by scavenging birds and fish.

The project brings together the expertise of biologists and gear technologists from the CSIRO fisheries division at Cleveland on Moreton Bay, the Australian Maritime College in Tasmania, and the Northern Territory Primary Industries and Fisheries departments.

A reduction in the bycatch would have immediate benefits, including an increase in quality and value of the targeted catch.

THE fishing industry's conservation image will also receive a considerable boost when the new bycatch-reducing trawl gear receives the final seal of approval from scientists and commercial fishermen.

CSIRO fisheries biologists David Brewer and Nick Rawlinson, under the project leadership of fish ecologist Dr Stephen Blaber, have reported encouraging results so far.

Using square mesh cod-ends on prawn trawl nets, initial tests have reduced the fish bycatch by about 20 percent while still maintaining normal-sized catches of tiger and endeavour prawns.

The square mesh cod-end allows unwanted fish to escape from the net instead of being trapped with the target fish.

Major benefits for commercial trawlers from a reduced bycatch include:

- Less damage to target species, such as prawns, resulting in a higher proportion of export quality catch.
- Shorter sorting time.
- A decrease in the amount of marine life killed and therefore less criticism of the fishing industry from tourist and conservation groups.

"By protecting the ecosystem, we are ensuring that a healthy fishery is maintained," said biologist David Brewer.

"The work we are doing will ultimately put more dollars in the pockets of commercial fishermen."

Studies made during the past five years have produced evidence of the enormous bycatch problem — one study of catch records showed that in catching 4100 tonnes of prawns, 47,000 tonnes of bycatch was also taken.

Scientists are also concerned at the effect this massive amount of bycatch has on local birdlife.

"Birds can become dependent on the bycatch for food," Dr Blaber said.

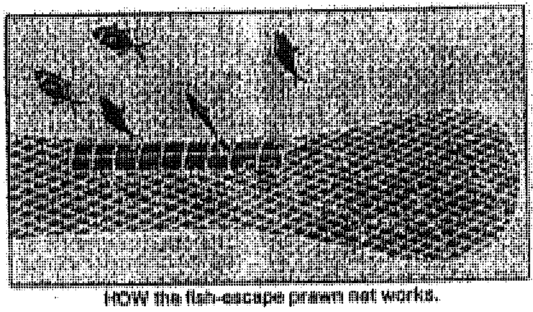
"Studies in the United Kingdom have shown that when the trawlers move elsewhere the bird populations can plummet."

New net trials aim to cut loss of marine life

THOUSANDS of turtles, sharks, rays and fish could be saved if north Queensland trials of environmentally-friendly prawn nets succeed this summer.

It was hoped the amount of unwanted by-catch could be slashed by up to two-thirds, CSIRO Fisheries Division marine scientist David Brewer said.

A study of one trawling season in northern Australia showed 47,000 tonnes of unwanted by-catch was taken during the harvesting of 4100 tonnes of prawns.



HOW the fish-escape prawn net works.

Dolphins usually managed to avoid nets and dugongs — large, endangered marine mammals — were rarely caught because they lived in very shallow waters.

But turtles, sharks, rays and large numbers of fish were regularly trapped.

"Fishermen really do not like catching turtles, they do their best to save them and most don't die," he said.

The thrashing of trapped turtles caused a lot of damage to nets, so fishermen were very eager to avoid catching them if they could.

About eight combinations of nets have been chosen for a one-month trial off Weipa, on Cape York, in February.

Past trials tested nets featuring square-mesh "codends", which allowed some of the by-catch to escape, while retaining the prawns in the codend or sack end of the net.

The Australian Maritime College and the Northern Territory Department of Primary Industries and Fisheries were joining forces with the CSIRO on the three-year project, which could save fishermen money and save the environment.

Mr Brewer said the nets might increase prawn catches by releasing by-catch and therefore stopping nets from prematurely closing.

"One of the biggest challenges we will have is producing gear that will not reduce the prawn catch," he said.

"But we might even catch more prawns and their quality will definitely be better."

Fishermen would also benefit from having to spend less time separating by-catch from prawns.

■ THERE should be plenty of prawns available during the Christmas-New Year period despite reports of potential shortages, the Fish Distributors Association of Queensland has said.

New net means more fish and less damage

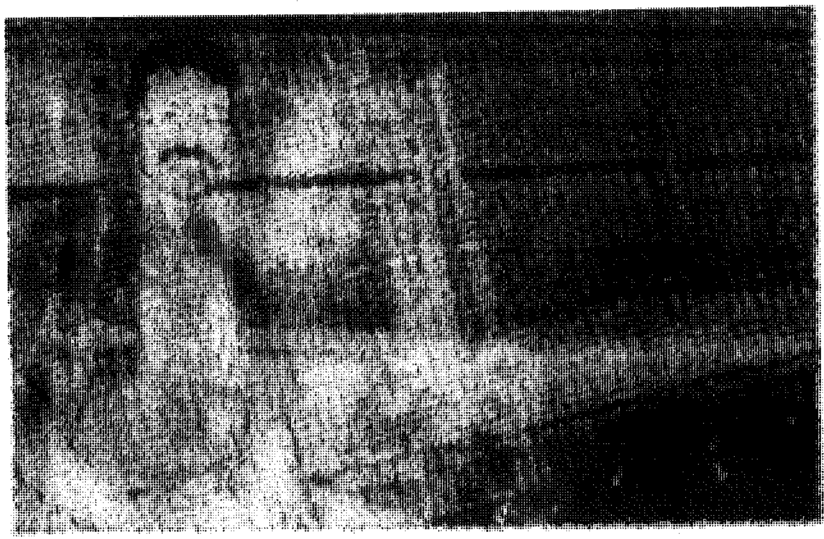
By PETER COLLENETTE

On the video screen, a net blunders across the sea bed, destroying sponges and coral and accidentally trapping huge sting rays as it catches red snapper off Northern Australia.

Across the room, in a large glass-fronted tank, lies an answer to this environmental distress.

Riding in a continuously pumped flow of water is a one-10th scale model of a net that clears the sea bottom and therefore does no harm.

Upstairs at the Australian Maritime College's Beauty Point campus are other newly invented nets, cunningly designed to reduce waste by excluding fish that are too big, too small or the wrong species.



Fishing technologist Steve Eayrs with the flume tank, which is used to test trawl nets.

Visiting VIPs this week said the AMC's fisheries research was a huge hidden asset to the nation.

"It is unique in Australia," said Brian Hickman, deputy chairman of the national Fisheries Research and Development Corporation.

Touring the AMC's facilities at Beauty Point and Newnham were seven members of the FRDC board, which allocates more than $13 million in grants each year.

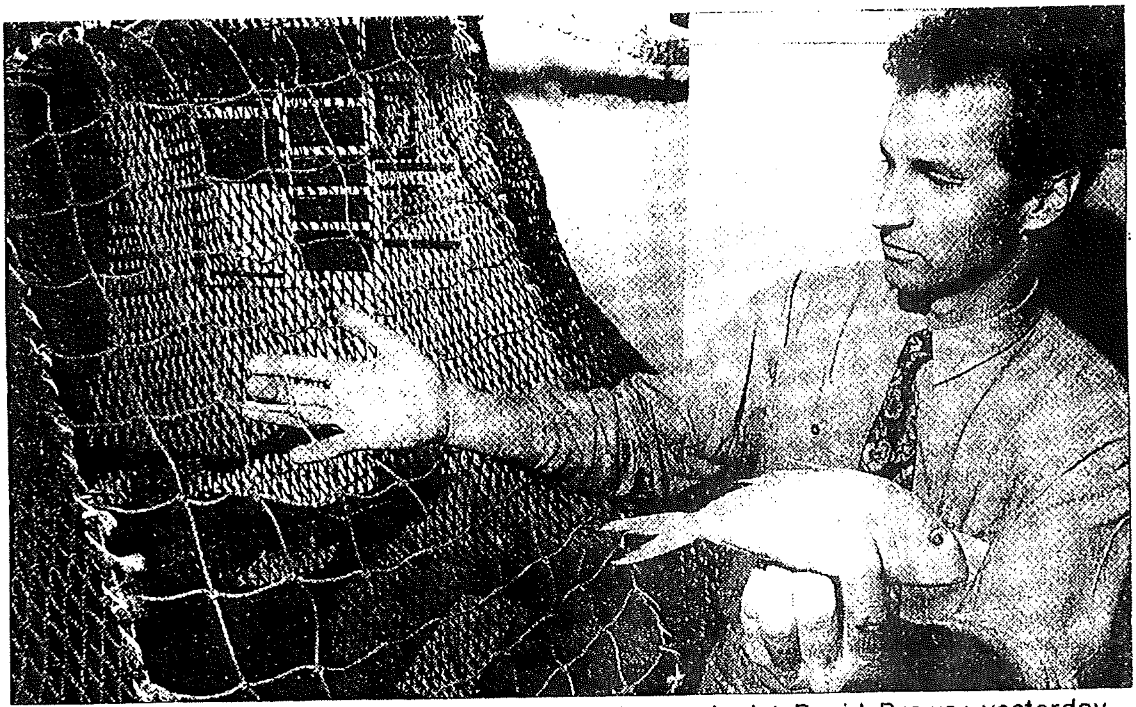
They praised the college's research programme and its courses in fishing and fisheries management. The work runs from biology, netting and engineering right through to seafood processing and marketing.

Ian Cartwright, director of the AMC's faculty of fisheries and marine environment, said: "It's got to be good from start to finish."

Much of the focus is on conserving not only the environment but also fish stocks — a concern in almost every Australian fishery.

"They're just about sustainable, but they won't stand a lot of increase," Mr Cartwright said.

As a result, work had to be done on adding value and reducing costs.



CUTTING the sea slaughter ... CSIRO fisheries ecologist David Brewer yesterday demonstrates how a wider-mesh window in a prawn-trawling net allows fish to escape.

Nets with a catch - fish escape

By **BRENDAN O'MALLEY**

ADVANCED nets which dramatically cut the slaughter of marine animals during prawn trawling will start commercial trials in north Queensland next year.

Marine scientists yesterday said results from summer trawling experiments showed the amount of bycatch, or unwanted animals killed while trawling, could be halved. One net excluded all the turtles, large sharks and rays which accidentally strayed into it.

The $200 million prawning industry has concerned conservationists because studies have shown 10kg of marine animals die for every 1kg of prawns caught.

CSIRO's Division of Fisheries at Cleveland, south-east of Brisbane, the Australian Maritime College in Tasmania and the Northern Territory Fisheries Division have been testing "green" nets for two years.

CSIRO fisheries ecologist David Brewer said yesterday the most promising bycatch-reduction devices would be put through more trials in the Gulf of Carpentaria in October.

A better way to fish, by hook or crook

Gulf of Carpentaria prawn fishermen take 9kg of "trash" for every kilogram of prawns. SIMON GROSE talks to scientists seeking to avoid the waste.

PERCHED on the riverbank near the Weipa wharf, a day's cruise from the top of Cape York, the Stubby Hut is little more than a big veranda with a bar and a fence around it. Now it's quiet, only the local hard-doers preferring it as a drinking hole, but by the end of the month it will be raging.

Around 300 fishermen with bad and politically incorrect habits will be charging up for the northern prawn season opening on April 1. Stubbies, cans, Winfield Blues and B&Hs, bad language, and other things not suitable for a family newspaper will be indulged in with gusto. The night of March 31 will not be for the faint-hearted.

From the crack of dawn the next day, their heads full of hammers and their bellies half-full of booze, they'll be going for it until at least the end of May, catching banana prawns. Then they'll take a break and return in late winter for another run, this time mainly for tiger prawns. More than a hundred big trawlers and a few bigger mother ships will steam along the coast to plunder the bounty that pours out of the mangrove-lined rivers every summer.

But this week the Stubby Hut was host to a smaller, soberer group with a similar mission. About 20 scientists

copied or varied from developments in the United States, Britain and Scandinavian countries, of which Norway is the most advanced. They have eliminated at least two ideas and over four weeks of 24-hour-a-day trawling this summer — sometimes with two different nets side by side to provide direct comparison — they intend to close the net further.

CSIRO's John Salini, the project's senior scientist, says, "We're hoping at the end of this trip to end up with two or three favoured devices and either develop them further or plan to trial them on a commercial trawler."

Three lines of research are being followed:

- By-catch-reduction devices. These include simple ideas, like the turtle-exclusion device, a grid of aluminium bars at the mouth of a net. This stops turtles and large fish from entering

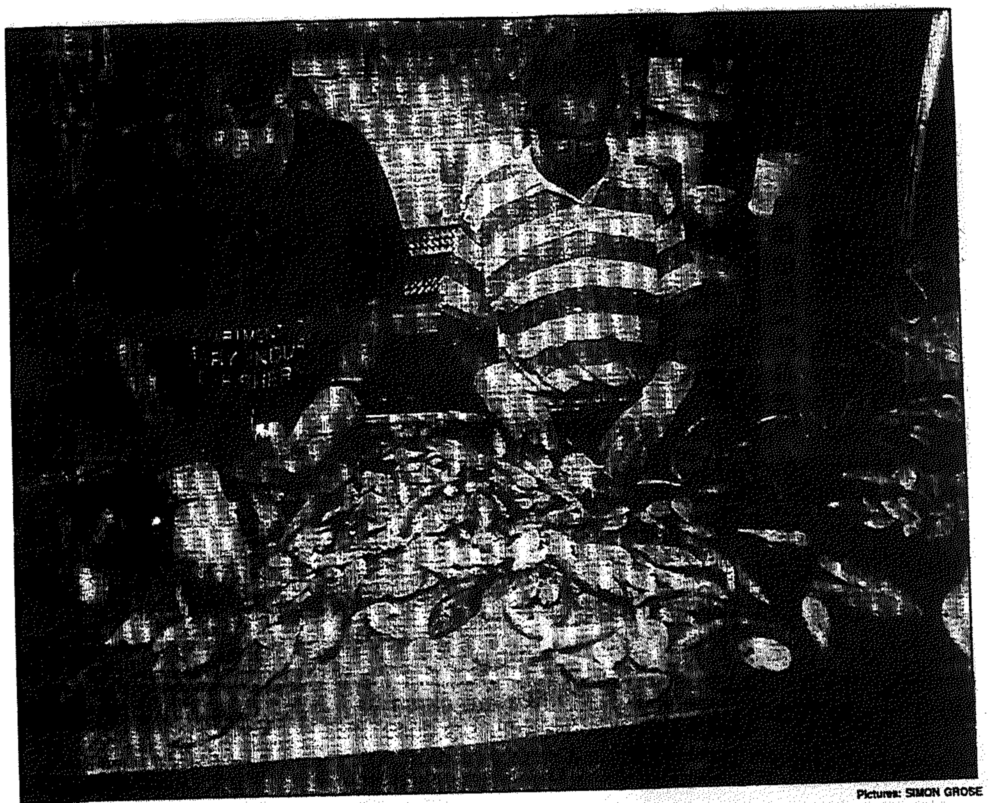
smaller mesh to catch what they lost. With larger square mesh of the same diameter as standard diamond mesh (45mm) they reduced the by-catch by an average of 33 per cent. However, some fish were caught by the gills in the square mesh and there was a marginal loss of prawns.

Salini says, "There's a trade-off between reducing the by-catch and starting to lose prawns," as he defines the challenge they confront: to achieve sustainability and environmental sensitivity while not compromising the commercial efficiency of the industry on which thousands of people rely.

"The industry won't tolerate any loss of prawns, so whatever device we recommend, it has to be very good at retaining prawns otherwise the fishermen won't accept it."

- Multi-level beam trawl. When the boats fan out on April 1 and drop their nets they will drag them along the bottom, picking up everything in the way and causing structural destruction to organisms such as sponges which attach themselves to the seabed. This is currently accepted as essential for catching prawns because prawns poke around on the bottom of the sea.

But how high do prawns swim? Does the disturbance of the trawler churning by 40m above affect their behav-



Pictures: SIMON GROSE

Rik Buckworth, of Northern Territory Fisheries, and graduate volunteer Fiona Manson sort the "trash" caught in experimental prawn trawl nets.

A $100m sustainable industry

But this week the Stubby Hut was host to a smaller, soberer group with a similar mission. About 30 scientists and crew of the Southern Surveyor, the CSIRO's fisheries research vessel, enjoyed a few ales before they embarked on a two-week mission. They too would be hunting prawns, but something bigger besides, something that could mean that the great-grandchildren of this year's fishermen will also have reason to drink at the Stubby Hut before a long stint at sea: a better way to fish.

When the trawlers haul in their nets they find about 90 per of the weight of their catch is everything but prawns. "By-catch", they call it. Turtles, rays, sharks and other big items cause some drama and can damage the soft-bodied prawns as they thrash in the net. Some commercial fish species are caught, but they are more a hindrance than a bonus in a system geared to process high-value prawns. Mostly it will be lots of little fish, molluscs, sponges, squid, etc — "trash" in the trade — that are no good for anything but cutting fishermen's fingers and taking up their time sorting through it when they could be setting the net again.

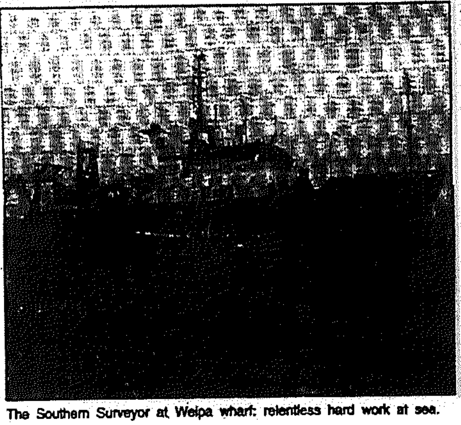
Most of the 90 per cent dies on the deck or in the sorting bin. When it gets tossed over the side the scavenging birds and bottom feeders think it's Christmas. What this does to the erstwhile balanced food chain in our northern waters is unknown, but common sense says it can't be productive. Clearly an example of humans taking the main chance before they understand the full implications, it is not a recipe for sustainability. It is a hallmark of almost all wild-harvest fishing around the world.

The three-year research project on the Southern Surveyor is an attempt to erase the hallmark. Funded by the Fishing Industry Research and Development Corporation, it involves researchers in marine biology and fishing technology from the CSIRO, the Australian Maritime College and the Northern Territory Fisheries Division.

Now halfway through the project, in two earlier voyages they have tried nine separate devices and techniques

exclusion device, a grid of aluminium bars at the mouth of a net. This stops turtles and large fish from entering the net. They cop a thump as they bounce off it and over the net, but they live to cruise another circuit.

Strategically placed openings in the



The Southern Surveyor at Weipa wharf: relentless hard work at sea.

side of nets also reduce by-catch of smaller fish by providing escape routes. Video monitoring during the trials shows fish swimming vigorously along with the net after they enter it, then tiring within a few minutes and falling back into the cod-end at the end. The video also shows a small proportion of fish successfully darting out through escape routes if they are available.

There is some video evidence that fish escape more readily from the mouth of a net when it carries a turtle-excluding grid, as if the grid gives them a stronger visual cue than an empty space. This leads researchers to realise how they need to improve their understanding of fish behaviour.

Dave Brewer, of CSIRO, the leading fish biologist on the project, says, "Fish can actively swim more so than a prawn and they react to different stimuli. Down the track, the more we learn about fish behaviour the more we'll be able to adapt our by-catch-reduction horizons."

Changing the size and shape of net mesh is another approach. In the first phase of research they tried square mesh against the standard diamond mesh and experimented with different sizes. Behind these they carried a

But now high do prawns swim? Does the disturbance of the trawler churning by 40m above affect their behaviour? These and other questions will begin to be answered when the results of trawls with a net separated into three layers are assessed.

Brewer says, "It simulates a prawn net in terms of net height and towing speed but it's compartmentalised horizontally. We're looking at what levels the prawns enter and the fish enter."

Across the top of the net they will experiment with a "veranda panel" of net at different angles and configurations which may exclude by-catch. Perhaps a shallower net, carried at a certain height, will eliminate significant amounts of by-catch without lowering prawn capture.

"That's a different angle. Rather than catching it and trying to dump it out the end, let's try and avoid catching it in the front," Brewer says. "That could be a very simple way of reducing by-catch."

● Environmentally friendly trawl. A number of commercial fish species exist in northern waters but poor understanding of stock sustainability and the judgment that Indonesian waters are being fished too heavily has led to licence restrictions on fish trawling in the Gulf. The distance to market and the logistics of fish species also limit viability to the extent that only one trawler works the Gulf for fish. But, like the prawn trawlers, he also drags his net along the seabed like a scythe.

Work led by Steve Eayrs, from the Australian Maritime College in Hobart, has developed a fish-trawl net that hovers up to a metre above the seabed between a bank of floats that lifts it up and an array of weights that keeps it down. In earlier trials it captured amounts of target species such as red snapper which were comparable to standard fish trawls but caught less by-catch and did less damage to the bottom and the organisms that live there. In the current trials they are experimenting with ways to lift the net's wires off the bottom as well.

Related research on the Southern Surveyor is concerned with understanding the food chain in the Gulf. Unrelated research involves collecting specimens of marine organisms for the Queensland Museum in a joint venture with a pharmaceutical firm to find raw materials for new drugs.

It sounds exotic, cruising around in the Gulf of Carpentaria in summertime in a happy ship like the Southern Surveyor. But it's definitely work. The shifts are 12 hours on, 12 hours off, the weather forecasts bristle with cyclone possibilities, it's hot and steamy, the ship heaves and r..'s full of noise and diesel smells, and every 40 minutes a new catch of trash and prawns pours into the sorting bin.

A real fisherman picks out his prawns and tosses the rest away. The scientists, laden with PhDs et al, sort their catch into little piles, calling Latin names to each other as they decide whether a morsel from the deep is a spotted dwarf toadfish or a lesser spotted dwarf toadfish, weigh and measure piles and individual specimens, then record it all on paper and computer while the winch roars above their heads dragging in the next netful.

This is the dogged labour of basic research. They are building a database which will be a foundation for what will have to be [illegible] verer science of wild-fishery management.

"Obviously to have a healthy maintained productivity from the fishery the best thing is to maintain the stability of the environment, which means everything from plankton right up to the top carnivores," Salini says.

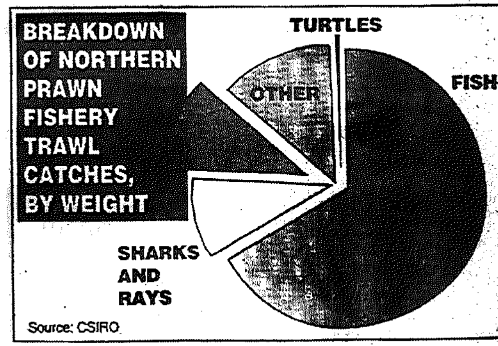
Brewer agrees: "We're not out to do the standard fisheries thing of maximising sustainable yield, to get as much as we can without killing the stock. We're actually trying to preserve the ecosystem as close to the virgin state as possible by just taking out what we want.

"If you take everything out and dump back a lot of the dead you're changing the ecosystem all the time, and that's gotta be dangerous for the fishery in the long term because the fishery developed in the ecosystem."

Salini, Brewer and their colleagues are Australia's pioneers in this field, just like the first prawn fishermen in the Gulf in the 1960s. They also share with fishermen a dependence on the ecosystem for their livelihood. Their methods are similar, their desire for the industry's survival is the same, and they like a feed of fresh tropical prawns or fish as much as anybody else.

But, unlike many of the Gulf fishing boats, the Southern Surveyor is officially a "dry boat": no booze after a 12-hour shift unless you've got a contraband private stash.

The Stubby Hut stands ready to serve when they return. May many more generations of fish biologists and fishermen have good reason to enjoy a drink there.



A $100m sustainable industry

PUMPING out of the fecund ecosystem of the tropical Top End, the northern prawn fishery is one of Australia's most valuable fisheries, earning around $100 million a year. In the nation's total annual fishery income of about $1.3 billion, only the cultured-pearl industry beats it, with revenue of about $180 million.

Extending from the tip of Cape York to the north coast of Western Australia, the northern prawn fishery has been worked commercially for less than 30 years. In that time it has reached and exceeded its sustainable yield, moving swiftly from being a new frontier to a regulated domain where some of the most dramatic cutbacks in Australian commercial fishery effort have been im-

In 1986, 238 trawlers worked the area during the March to September season, putting in about 35,000 boat-days. In 1993, 127 boats spent about 21,600 boat-days catching the tiger prawns and banana prawns which comprise the bulk of the resource.

These comparisons are not simple. Improvements in sonar and global positioning technology enable boats to waste less time fishing unproductively in the 1990s — but mandatory reductions in net sizes since 1987 have effectively reduced the effectiveness of trawlers. Overall, the goal of reducing the total fishing capacity to 60 per cent of 1990 levels has almost been achieved.

This has required a mixture of co-operation, arm-twisting, and dollar-power. It involved government, the industry, and researchers running fast to catch up with the rapid use of a resource which is still poorly understood. The restructuring was done by dividing the fishery into units among trawler operators on the basis of their past catch histories. They could either sell them and get out, or buy them and stay in. Forcing them to take either option was a compulsory surrender regime which was triggered if effort-reduction targets were not achieved.

The catch peaked in the mid-1970s and early '80s at around 14,000 tonnes. In recent years it has hovered above 7000 tonnes. These figures are affected by the vagaries of the seasons and the amount of fishing effort expended, but current estimates of a sustainable annual yield of 10,000 tonnes are broadly accepted.

The 10,000 tonnes is made up of 6000 tonnes of tiger prawns and 4000 tonnes of banana prawns, both big, fat, luscious species of prawn flesh. The banana prawns come out in one big flush between March and May along the eastern and southern coasts of the Gulf. Tiger prawns come through from autumn till spring and are found along the whole fishery. The bulk of the catch is sold for export.

Both species grow quickly, turning into an adult as long as your foot in a year. They start life when the previous generation moves from the estuaries into the coastal seagrass zone as the wet season begins.

John Salini, from CSIRO Fisheries, says, "We think the cue there is salinity and rainfall. It may not be a physical push from river flow, it may be a behavioural thing whereby as soon as they detect a change in salinity they react differently.

"The new generation are planktonic for a couple of weeks and are at the mercy of the tides and currents. The way they are transported back to the estuary is affected by how they move up and down in the water column. They'll tune in to the tides, coming in on the flood tide and settling on the bottom in the ebb tides."

In the estuary they can grow as fast as a centimetre every 10 days, thriving on the nutrients in the system and becoming an important part of the food chain. Since the 1960s, humans have installed themselves at the top of that chain in a major fashion, but the equation can find a new balance if the supporting ecosystem is managed correctly.

A catch of 10,000 tonnes of prawns a year could involve up to five billion individuals. But a tiger prawn can spawn twice a year, producing a total of up to 800,000 eggs. On that basis, the northern prawn fishery can withstand regular harvesting as long as the environment remains fit to feed it.

— SIMON GROSE

The KILLING BEDS

The world's burgeoning fishing fleet is threatening to turn the oceans into a marine desert. **Julian Cribb** *reports on a rare Australian initiative attempting to restore the ecological balance*

NEIL Loneragan is head down in thick, oozy black mangrove muck, duck-diving for handfuls of weed. Rob Kenyon keeps a lookout in the boat, shrewd eyes probing the shallows for reptilian movement, the bulky Smith & Wesson .38 loaded with soft-nosed slugs close at

sustain its life. Make it, in effect, the biggest farm on earth. The idea is not to farm it in the literal sense: rather to watch and safeguard the critical links in the food web and minimise destructive human impacts on them. Through the Australian Fisheries Management Authority, the fishing industry agrees to keep its yearly catch within the presently understood biological limits.

To maintain this delicate balance, the life-cycle and food web of the Gulf and its prawns must be clearly understood. To do that, Loneragan and Bunn are trying to work out exactly how the baby prawns subsist. Oddly, no one knows what they eat: they have an internal "food mill" that mashes up their diet beyond recognition. The researchers have taken a smart approach: instead of studying the food, they

The crisis in the oceans is accentuated by what is happening on land: critical shortages of good arable land and fresh water are starting to emerge in the most populous regions as human numbers head for 8.5 billion by 2025. At the same time there has been a disturbing drop in yield progress in the key food crops, wheat and rice. British scientist Ian Carruthers states baldly that the tropics will be incapable of producing enough food from land or sea to sustain its 4 billion inhabitants by that time.

"The implications of this are enormous," says Canada's Alex McCalla, director of agriculture and natural resources with the World Bank. "If the additional 3 billion urban dwellers are to be fed by trade, exports of grain will have to increase four times. 'This is physically, biologically and

Observers like Tribe hope the conference will strike a marked contrast with the talkfests at the Rio Earth Summit and Cairo Population Conference. This is not an abstract issue for portentous rhetoric and national posturing: it is a life-and-death affair for hundreds of millions, with vast ramifications for world political and economic stability and the threat of war, he says. It is the pivotal issue of the 21st century.

Paradoxically, food is the key to checking the exponential growth in human populations. It is the flame that ignites growth in living standards and generates the wealth necessary to reverse destruction of the environment. It is the cornerstone of world security. With ample food and declining poverty, populations cease to grow as people move from rural to urban lifestyles.

The tranquil waters of the Gulf of Carpentaria seem a million miles away from the cutting edge of the global crisis. But the techniques being hammered out by Loneragan, Bunn and their colleagues make it the frontline in the battle for recovery. Nobody in the world has yet developed a truly sustainable large wild fishery. Of all nations, only Australia and Norway come close, though most now recognise the urgent need.

EVERY tonne of prawns trawled from the night-dark depths of Carpentaria

.38 loaded with soft-nosed slugs close at hand.

Crocs are an occupational hazard for CSIRO marine scientists — but one they have to risk to help head off a bigger crisis: 2 billion starving humans by early next century.

The Gulf of Carpentaria ripples azure beneath a winter sun. In the bays and inlets that fringe Groote Eylandt, secret among the seagrass meadows, tiny prawns are feeding — the seed corn of a harvest worth a quarter of a billion dollars to Australia.

But the minute crustacea that Griffith University's Stuart Bunn and Dom Kellaway are sorting so meticulously aboard the same boat have a greater significance. They are the pioneer stock in the world's first great experiment in ocean ranching, a bid to reverse the cycle of decimation and destruction in the seas.

The baby prawns have a startling and dramatic life story: hatched 70km out in the Gulf from an egg, the pinhead-sized larvae make their way inshore, rising to ride the flood tide and sinking to evade the ebb. In the process, billions fall prey to predators.

Once in the safety of the fecund shallows the survivors settle, gaining size and strength until they are ready to begin the perilous trek out into deep water to spawn. The mangrove creeks and seagrass beds that fringe the shoreline are their nursery: take it away and the entire fishery and food web of Carpentaria will collapse. The total tiger prawn population of the Gulf is sustained by a scant 1000km square of seagrass — an area half the size of Port Philip Bay.

And, bit by bit, the nursery areas are being destroyed — by cyclones, dredging, development, pollution, man-made changes in river flows, eroded soil from the land that blocks the sunlight that the grasses need for photosynthesis. It is evidence of the overwhelming human impact on the planet from which even an area so remote and apparently pristine as Carpentaria is no longer immune.

If the seagrasses and mangroves fail, so will the succulent tiger prawns, banana prawns, grooved and greasyback prawns — and all the fish and fishermen who depend on them, Loneragan says.

"There is no single big threat. It's the tyranny of thousands of small decisions being taken constantly by many different people which affect seagrass beds or mangroves," says Bunn. "They all add up. That's what is threatening our coastline."

The only way to avert such a tragedy is to manage the Gulf of Carpentaria as if it were an immense outback station, husbanding

The researchers have taken a smart approach: instead of studying the food, they search for isotopes of the basic nutritional elements — carbon, nitrogen, sulphur — tracing their movement down the creeks, into mud, mangroves and seagrasses, into the algae that bloom on them, and finally into the prawns. This way they can construct a total picture of the nutrient web.

Apart from the risk of being eaten alive by a roving saltwater crocodile, it is basic, slogging science, aimed at building an understanding of a phenomenally complex and delicate bio-system — and saving us from ruining it.

It is information the world desperately needs. A decade ago the Earth's oceans seemed inexhaustible but in the past five years evidence has been amassing that this has been yet another vast human miscalculation.

Fishery after fishery has collapsed. Today, 70 per cent of global commercial fisheries are in trouble. Nine of the world's 17 main fishing areas face serious decline, including the Gulf of Thailand, the waters of South-East Asia, the North Sea, the Mediterranean, the Grand Banks and the Baltic. In spite of a trebling of the global fishing fleet from 1.2 million to 3.5 million boats since 1990, and great leaps in technology that make the fish easier to find and net, the total catch has stagnated. The seas are showing signs of exhaustion.

EARLIER this year, 50 of the world's resources ministers met in Rome to call for urgent action to address the crisis in the oceans. In particular they advocated global efforts to eliminate overfishing, to rebuild fish stocks, protect and restore the marine environment and reduce waste.

"There are no panaceas," warns Meryl Williams, the Australian-born director-general of the International Centre for Living Aquatic Resources Management, based in The Philippines. "We have to all intents and purposes reached the limits. We can no longer just keep looking for new stocks to fish. We have run out of that as an option for development." Instead, she says, the world must turn to aquaculture, to ocean ranching, to new ways of managing and restoring damaged marine ecosystems, to more conservative harvesting techniques.

It is a tall order. By 2010, says Ismail Serageldin, chairman of the Consultative Group on International Agricultural Research, the world must find another 16 million tonnes of fish a year — especially in the most heavily populated regions where it is the main animal-protein source in the

exports of grain will have to increase four times. This is, physically, biologically and economically, a huge task."

To feed the growing population, global food output must grow at least 2 per cent a year — and even then malnutrition will worsen. If developed countries have to shoulder the load of feeding the tropics,

> ***The history of fishing is one of rape and pillage. Bugger up one species, then move on to the next***

their food output must rise by up to 4 per cent per annum, a target many consider impossible.

"The frightening part of this story to me is that while the challenge is critical and immediate, funds to support agricultural development and productivity improvement are being reduced," McCalla says. "Twenty years from now there will be 2 billion more people to feed. To not recognise the challenge and increase efforts is bad enough — but it is much worse to allow existing research capacity to erode."

McCalla echoes warnings sounded by Australia's Derek Tribe, chairman of the Crawford Fund for International Agricultural Research — worldwide, the machinery for achieving food increases is running down. Governments and donors are pulling money and resources out of the essential research needed to keep pace with demand. National and international research programs are being terminated, scientists sacked. Governments, Tribe says, are doing the exact opposite of what commonsense dictates.

The emerging crisis in world food production will be centre-stage at an international conference in Washington this week — the most significant event since the World Food Congress in Rome in 1966 where the foundations for the green revolution were laid. Here the International Food Policy Research Institute, under its dynamic chief, Per Pinstrup-Andersen, will attempt to carve out a global vision for food, agriculture

EVERY tonne of prawns trawled from the night-dark depths of Carpentaria crashes down on the vessel's deck amid 10 tonnes of other fish, sharks, rays, corals and even turtles. Most of them are dumped back in the ocean, dead. To catch 25,000 tonnes of prawns we have to kill nearly a quarter of a million tonnes of fish — and all of it goes to waste. Every prawn you eat has cost a fish to catch.

Worldwide it is estimated that 27 million tonnes of dead fish are dumped at sea or spoiled in the marketing chain each year — more than a quarter of the global catch and enough to overcome much of the present world protein hunger. Most of the fish killed are undersized — with devastating consequences for the future breeding stock — or of varieties with a low market value that do not justify the freezer space on board a trawler.

Dave Brewer is evaluating a range of smart trawls, scoured from Norway, the US or developed locally, which allow unwanted fish and turtles — known as bycatch — to escape while trapping the prawns. Trials are due to take place in the Gulf this October and on commercial boats early in 1996. Research has already proved the net devices exclude turtles and sharks — the challenge is to avoid catching smaller fish.

Their work is coupled with a major CSIRO investigation into the effects of fishing on ocean life — especially on the corals, sponges, reefs and other features of the bottom that affect fish populations.

The bycatch reduction work, the effects of fishing study and Loneragan's research into food webs are components of a master plan to bring about a literal sea change in the nature of fishing — the first in more than 5000 years. A genuine "blue revolution".

Its aim is to move fishing from a hunter-exploiter outlook to a conservation-farming philosophy, says senior CSIRO fisheries researcher, Steve Blaber.

"The good farmer looks after the land. He doesn't cut down the trees, use up all the nutrients, turn his farm into a desert. The analogy applies equally to the sea," he says. "If you destroy the things the fish depend on, you create a marine desert.

"The history of fishing is one of rape and pillage. Bugger up one species, then move on to the next. We now know that is not sustainable. There has to be a better way."

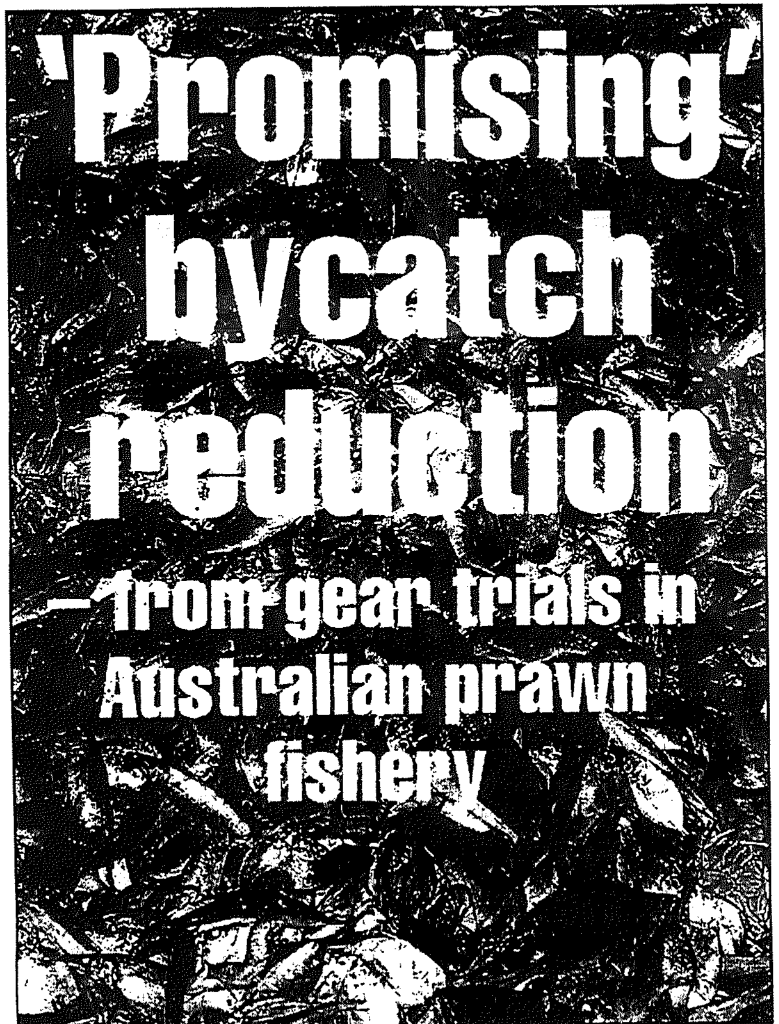
In one of his visionary books written in the 60s, science-fiction doyen Arthur C. Clarke foresaw Australians as the pioneers of sustainable farming of the oceans. In the Gulf of Carpentaria and along the Great Barrier Reef that dream is already being translated into reality.

Julian Cribb is The Australian's science

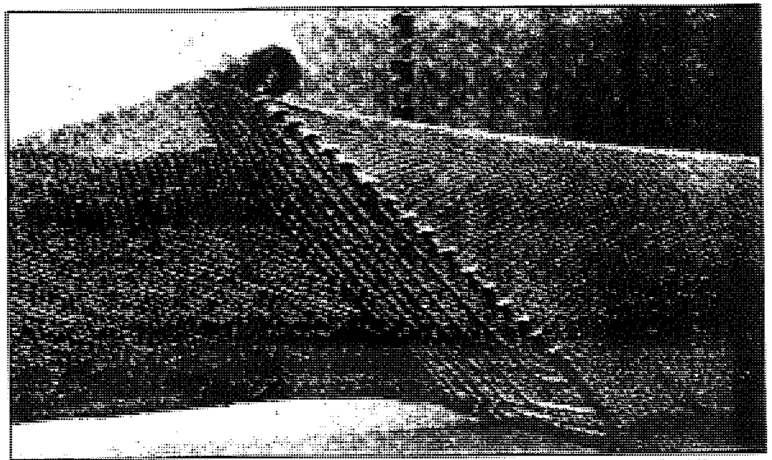
50 FISHERIES RESEARCH Fishing News International — November 1996

'Promising' bycatch reduction

— from gear trials in Australian prawn fishery



A typical mix of prawn and bycatch caught by a trawler operating on Australia's northern prawn fishery.



A 'supershooter' bycatch reduction device attached to a trawl in the flume tank at the Australian Maritime College in Beaconsfield, Tasmania. Bar spacing is 100 mm and the grid is angled approximately 45 degrees from the vertical to help exclude large animals through an opening in the bottom of the codend.

BIOLOGISTS in Australia have completed three research cruises in the country's $150 million northern prawn fishery (NPF) test a range of bycatch reduction devices (BRDs), one of which delivered bycatch reduction rates of up to 70 per cent.

The three year, $5 million project, partly funded by the Commonwealth Government and the fishing industry, has brought together biologists from the country's educational, research and government organisations.

With trials over, the biologists will refine and re-test the devices before carrying out commercial trials on trawlers working in the fishery.

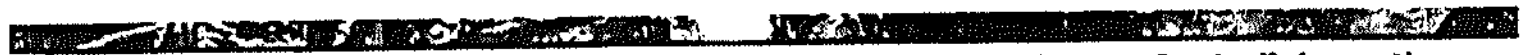
"By the end of the project, a range of devices for the fishery will have been

Steve Eayrs, fisheries technologist at the Australian Maritime College, is one of team of biologists working on bycatch reduction in Australia's northern prawn fishery.

In February 1995 a further eight bycatch reduction devices were trialed over a four week period, including the nordmore grid and the supershooter, which were used to exclude large animals from the trawl. "The nordmore grid was constructed from 12 mm aluminium rod with a bar spacing of 100 mm. The grid was angled at 55 degrees from the vertical," says Steve Eayrs.

"The supershooter bar spacing was 100 mm and the grid was angled approximately 45 degrees from the vertical.

"The supershooter was also fitted with a 'hummer' device behind the grid to 'stimulate' fish to swim away from the codend and through escape openings either side of the codend



A typical mix of prawn and bycatch caught by a trawler operating on Australia's northern prawn fishery.

Bumble Bee deal

UNICORD of Bangkok, Thailand, has sold the Bumble Bee tuna business for around $200 million.

New owner of the brand and San Diego-based seafood business is Questor Partners Fund of Michigan, USA.

Star-Kist (part of H J Heinz) is buying the Bumble Bee plants at Mayaguez, Puerto Rico; Coloroda, USA; and Manta, Ecuador.

Now, Star-Kist will co-pack for the Bumble Bee label for the new owner.

RGI in merger

RESOURCE Group International – fishing magnate Kjell Rokke's Oslo-based company – is merging with Norway's industrial conglomerate Aker Group.

A new company with a turnover of NOK28 million a year and 19,000 employees will be formed when the agreement goes ahead.

Aker RGI will have divisions for fishing, mechanical industries (shipbuilding) and cement production and oil and gas.

Kjell Rokke and partner Bjorn Rune Gjelsten took control of Aker by buying 40 per cent of the stock. Kjell Rokke will control 35 per cent of the shares after the merger.

Timor Sea border deal

AUSTRALIA and Indonesia have reached an agreement to resolve a long-standing dispute over maritime borders and fishing rights in the Timor Sea.

The dispute, which involved rights to an area running from Christmas Island and Java to the Gulf of Carpentaria, originated in 1982 when both countries unilaterally declared overlapping 200 mile zones.

[illegible]

Boundaries would be established between Christmas Island and Java, the western extension of the seabed boundary between Australia from the point just north of the Australian Territory of Ashmore and Cartier Islands and between Australia and Indonesia.

Peter Rogers, executive director of the West Australian Department of Fisheries, says the previously disputed area is already developed and fished by both Australian and Indonesian boats [illegible] some [illegible].

He predicted that the direct impact of the agreement on the Australian and Indonesian fleets would be limited [illegible].

[illegible]

He commends Western Australia, the Northern Territory and Indonesia are doing joint collaborative research work into stock management, which five years ago would have been unheard of."

Probe into CFP

THE Dutch Federation of Fishery Associations has asked the consultancy company DHV to study the basis of the European fishery policy.

It wants to know if the science on which the policy is based is reliable.

A large part the investigation will comprise a study of literature since total allowable catches and quotas were introduced. Officials of the National Institute for Fishery Research and Dutch fishermen will be interviewed.

Anglers catch more flats

STOCKS of some flatfish in New South Wales, Australia, may be under greater pressure from recreational than commercial fisherman, according to a study being carried out by the NSW Department of Fisheries.

According to newspaper reports, the research due to be published this month estimates that recreational fisherman catch 60 tonnes of yellowfish bream each year – more than the commercial catch.

cry.

"By the end of the project, a range of devices for the fishery will have been developed and trialed, each with particular advantages for excluding different types of bycatch while maintaining catches of prawns," Steve Eayrs, fisheries technologist at the Australian Maritime College based in Tasmania, tells *FNI*.

"The northern prawn fishery is essentially two sub-fisheries, one targeting banana prawns during the first few weeks of the fishing season and a second targeting tiger prawns during the remainder.

"The banana prawns form dense schools and are caught in short tows of 10 minutes or less using high opening trawls. When catch rates of banana prawns decline, fishing effort shifts to the more valuable tiger prawns using low opening trawls, which is most of the bycatch is caught

"Tow duration for tiger prawns varies between two and four hours depending on bycatch density, which includes small fish species of little commercial value, crabs, stingrays, sharks, turtles and sponges."

Australia's northern prawn fishery.

The research cruises took place in November 1993, February 1995 and October 1995 on board the 65 metre fisheries research vessel *Southern Surveyor* using dual rigged 14 fathom Florida Flyer prawn trawls.

During the first research cruise, square mesh codends were tested for reducing small fish bycatch using a dual-rig trawl system.

Comparisons were made between a 4 mm standard diamond mesh codend and both a 45 mm square mesh codend and a 38 mm square mesh codend.

"Results showed that over 20 percent of fish bycatch could be excluded through the 45 mm square mesh, but only 5 percent for the 38 mm mesh," says Steve Eayrs.

"For some species such as whiting, exclusion rates exceeded 50 percent with the smaller square mesh and nearly 70 percent with the larger mesh. "There was some loss of tiger prawns through both mesh sizes, but they were mainly juvenile prawns of low commercial value."

stimulate fish to swim away from the codend and through escape openings either side of the codend.

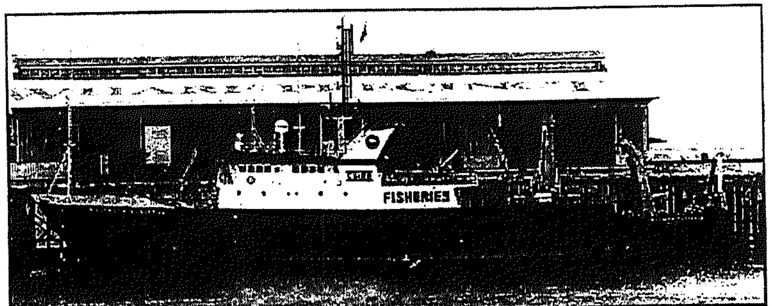
"Different square mesh windows consisting of a netting panel of 150 mm meshes were also tested.

"Prawn retention rates ranged from 55 per cent for the nordmore grid to 130 per cent for the fisheye."

The final research cruise was also of four weeks duration and was completed in October, 1995. Five BRDs were tested including the one developed by the Northern Territory and Queensland Departments of Primary Industry and Fisheries. "This BRD featured a flexible wire grid encased in plastic and large animals and other bycatch were excluded through the top of the codend," says Steve Eayrs.

"A small escape window placed ahead of the guiding funnel also assisted exclusion rates of small fish.

"The nordmore grid and supershooter were also tested in combination with either a fisheye or square mesh window. Tow duration was two hours for all BRDS to more closely reflect commercial practice."



The Australian government's 65 metre research department fisheries research vessel *Southern Surveyor* has been using dual rigged 14 fathom Florida Flyer prawn trawls during her three northern prawn fishery research trips.

5. Newsletters to industry and the general public:

MARINE LIFE

Information from the CSIRO Division of Fisheries

REDUCING UNWANTED BYCATCH IN THE NPF

A JOINT STUDY BY CSIRO DIVISION OF FISHERIES, THE AUSTRALIAN MARITIME COLLEGE AND THE NORTHERN TERRITORY DEPARTMENT OF PRIMARY INDUSTRIES AND FISHERIES

NEW BYCATCH PROJECT

In 1993 a FRDC project began aimed at trialing fishing gear that will reduce the amount of unwanted bycatch while catching the same numbers of the target species (e.g. prawns or commercial fish).

This study is being jointly carried out by the CSIRO Division of Fisheries, the Australian Maritime College (AMC) and the Northern Territory Department of Primary Industries and Fisheries.

THE BYCATCH PROBLEM

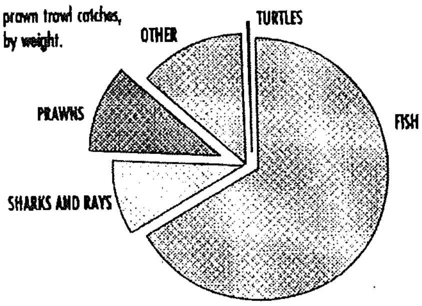
Catches in most north Australian prawn fisheries are dominated by unwanted bycatch.

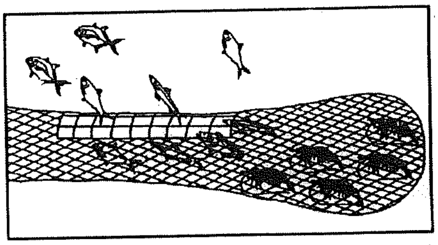
Fish trawling also catches large amounts of unwanted species, as well as damaging the sea bottom habitat that may be vital for the fishery in the long term.

POTENTIAL BENEFITS

- lower catch sorting times
- less damage (and therefore higher value) to valuable export products
- less criticism of the industry from environmental and recreational fishing lobbies
- reduced predation pressure on prawns by increasing the stocks of alternative prey (small fish) for the major prawn predators, like large fish and sharks
- maintenance of the ecosystem that supported the original fishery.

Breakdown of NPF prawn trawl catches, by weight.





GEAR TRIALS

All gear types are first tested as models in the AMC flume tank, full scale gear is then sea trialed on an AMC trawler (FTV *Bluefin*) before biological trials are then made on a research vessel (FRV *Southern Surveyor*). Successful gears will be tested finally on commercial trawlers.

RESULTS SO FAR

So far it has been shown that

- Square mesh codends can reduce bycatch by up to 30% while maintaining catches of commercial prawns
- Survival of fish escaping from square mesh codends is likely to be high
- Semi-demersal fish trawls greatly reduce the damage to the sea bed habitat while not reducing catches of the target species.

FUTURE TRIALS

Several bycatch reducing devices will be tested to see which gives the best results for northern Australian trawl fisheries.

These will include square mesh panels, inclined grids, radial escape sections, fish eyes and other devices shown to be successful in other Australian and overseas trawl fisheries.

The continued support and co-operation of industry is vital for achieving the best results in this project. Please forward any feedback to Dave Brewer or Nick Rawlinson at CSIRO (reverse charges) (07) 286 8222 or fax (07) 286 2582; or Rick Buckworth at NT Fisheries (089) 897 648, fax (089) 813 420

PO BOX 120 CLEVELAND 4163 DIVISION OF FISHERIES 233 MIDDLE ST CLEVELAND

MARINELIFE

REDUCING UNWANTED BYCATCH IN THE NPF

In 1993, Australian marine scientists began a project to determine whether modified nets, fitted with Bycatch Reduction Devices (BRDs), could reduce the number of unwanted species (bycatch) caught during commercial trawling operations in the Northern Prawn Fishery (NPF).

Scientists from the CSIRO Division of Fisheries, the Australian Maritime College (AMC) and the Northern Territory Fisheries Division are now more than half-way through the three-year study funded by the Fisheries Research and Development Corporation (FRDC).

THE BYCATCH PROBLEM

Prawn trawl catches are dominated by up to 90 percent unwanted bycatch, including as many as 50 species in each trawl ranging in size from small fish to 80-kilogram sharks.

In 1994, a survey of about 40 boat skippers in the Northern Prawn Fishery confirmed that they would like to reduce bycatch as long as prawn catches are maintained.

POTENTIAL BENEFITS OF BRDS

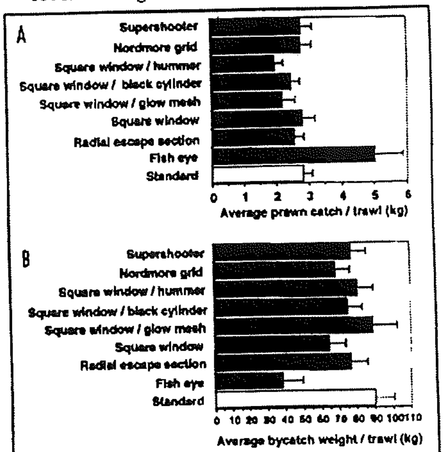
- A reduction in the capture of unwanted species minimises detrimental effects on the marine ecosystem.
- BRDs exclude large unwanted species such as rays, sharks and turtles which damage and therefore devalue the catch.
- Less bycatch in the codend allows the trawl net opening to be maximised and so prawn catching ability is increased. (The codend is the bag at the end of the trawl net where the catch collects.)
- A reduction in bycatch would reduce the amount of time required to sort unwanted species from the rest of the catch.

BRD TRIALS

All BRDs are first tested as models in the AMC flume tank in Launceston, Tasmania. Full-scale gear is then sea-trialled on the AMC training vessel, FTV *Bluefin*, before biological trials are conducted by the CSIRO research vessel, FRV *Southern Surveyor*, in the Northern Prawn Fishery, which spans the northern coastlines of three states: Queensland, the Northern Territory and Western Australia.

Results so far:

- Two BRDs – the Fish eye and the Square mesh window – have maintained prawn catches while reducing the amount of bycatch by 30-50 percent.
- Another BRD, the Nordmore Grid, has effectively excluded large unwanted species from the net.
- Square mesh codends have reduced bycatch by up to 30 percent, while maintaining catches of prawns.
- Survival rates of fish escaping from square mesh codends is high.



These graphs show differences in catches of (A) prawns and (B) fish bycatch between eight BRDs and the standard prawn trawl codend. Several of these devices show high potential for future use in Australia's Northern Prawn Fishery.

FUTURE TRIALS

Further scientific trials to retest and refine the most promising BRDs will be conducted in the Northern Prawn Fishery in October 1995.

Selected BRDs will then be tested on several NPF trawlers early in 1996 to assess their potential under commercial fishing conditions.

The continued support and co-operation of industry is vital for achieving the best results in this project. Please forward any feedback to Dave Brewer or Nick Rawlinson at CSIRO (reverse charges) (07) 286 8222 or fax (07) 286 2582; Steve Eayrs at AMC (003) 354 424 or fax (003) 834 766 or David Romm at NT Fisheries (089) 997 648, fax (089) 813 420.

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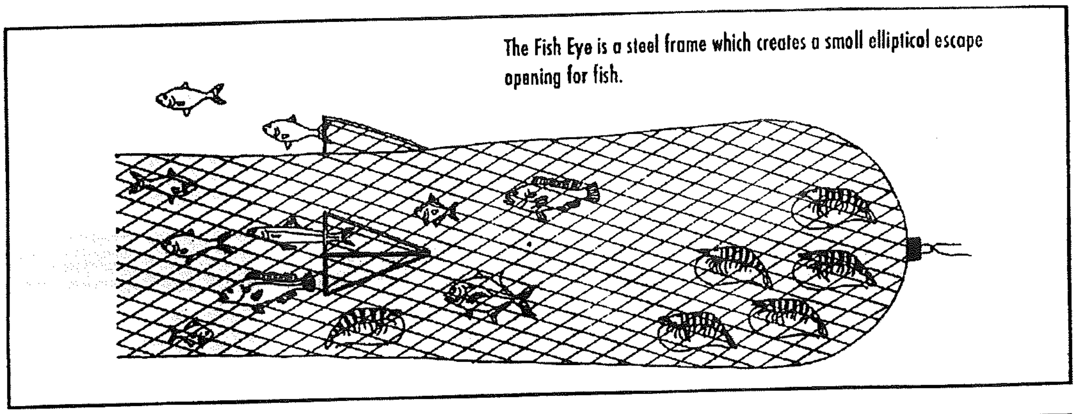
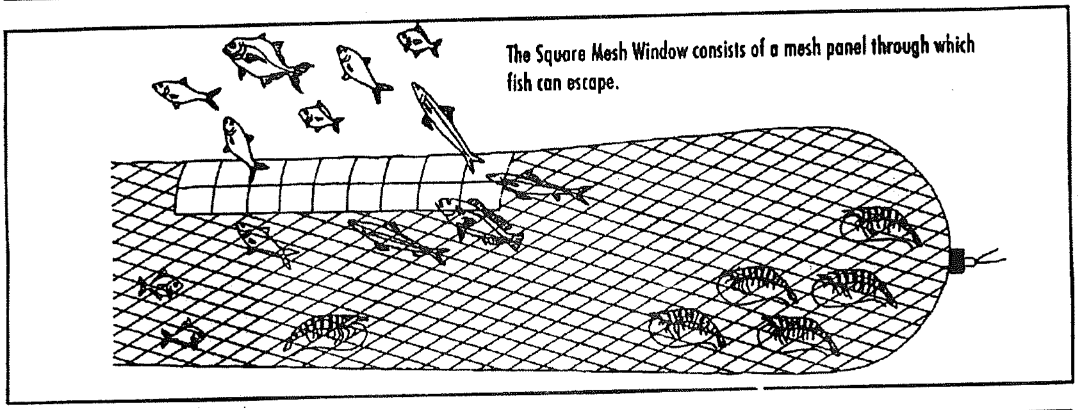
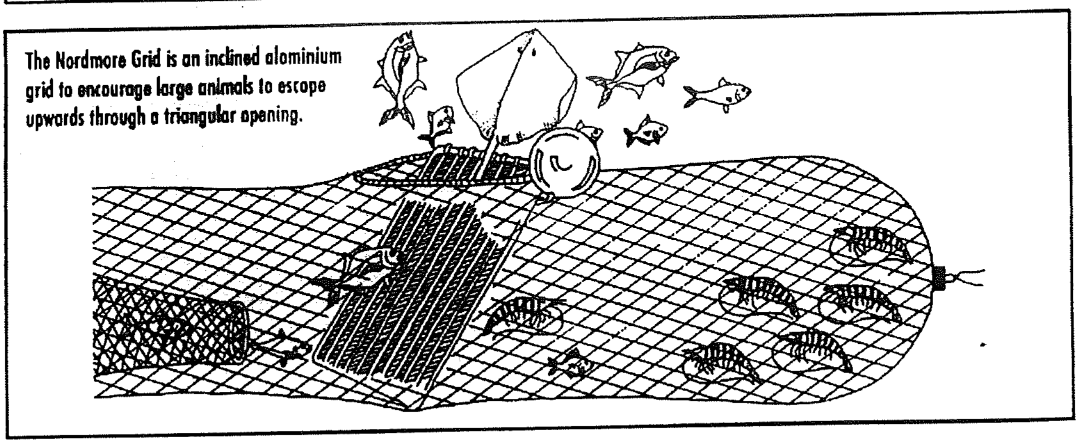


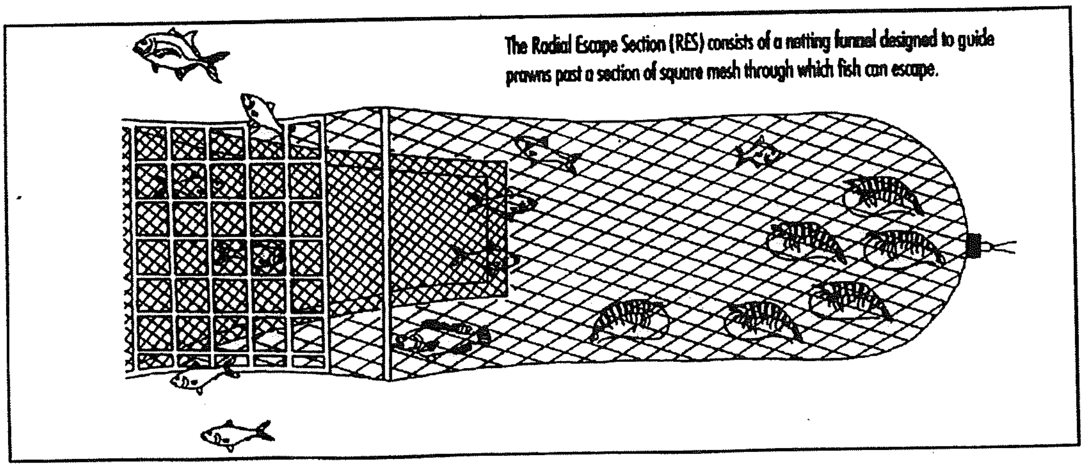
The Fish Eye is a steel frame which creates a small elliptical escape opening for fish.



The Square Mesh Window consists of a mesh panel through which fish can escape.



The Nordmore Grid is an inclined alominium grid to encourage large animals to escape upwards through a triangular opening.



The Radial Escape Section (RES) consists of a netting funnel designed to guide prawns past a section of square mesh through which fish can escape.

Perhaps the greatest potential for small fish reduction from prawn trawls comes from square mesh windows. On their own they have been shown to reduce small fish catches by over 25 percent in the Gulf of Carpentaria and by 70 percent in northern New South Wales. Commercial trials over the next few years will aim to confirm that square-mesh windows can greatly reduce fish catches while maintaining prawn catches.

Future Research

Over the next three years the Queensland Department of Primary Industries, Australian Maritime College and CSIRO will undertake FRDC funded trials of BRDs on commercial trawlers in Australia's tropical prawn trawl fisheries. This will improve their performance and familiarise fishers with the advantages of using these devices. A second new FRDC funded project will focus on describing the bycatch populations and their long term sustainablity under the current fishing pressures. This project will also compare different methods for monitoring bycatch populations in the NPF.

Benefits to Industry of Bycatch Reduction Devices (BRDs)

Main beneficiaries of BRDs are fishing operators in tropical and sub-tropical demersal prawn and fin-fish fisheries.

The capture and destruction of unwanted bycatch is universal throughout Australian tropical and sub-tropical seabed trawl fisheries and is a subject of widespread concern. The benefits of research in the development of BRDs are therefore wide reaching. They include:

- more effective ways of retaining only target species;
- increased survival of juveniles of commercial species (prawns and fish);
- increased survival of bycatch and seabed dwelling animals resulting in maintenance of species diversity;
- decrease in commercial trawl bycatch resulting in a) less damage to target species (eg prawns) resulting in a higher proportion of export quality product. b) shorter sorting time, c) reduction of large numbers of small, floating dead fish and therefore criticism of the fishing industry from tourist and conservation groups.

CSIRO AUSTRALIA   Northern Territory Government   Australian Maritime College

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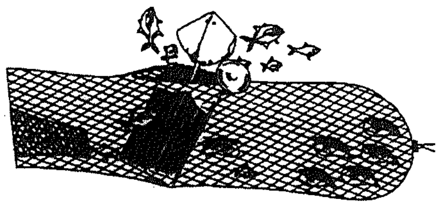
Bycatch Reduction Devices for use in Prawn Trawling

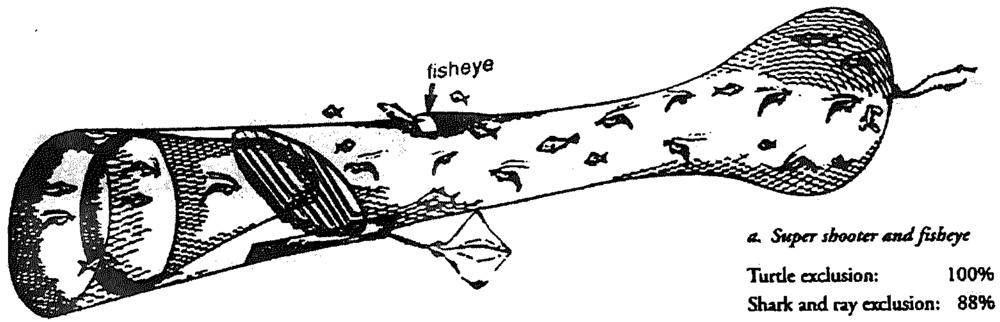


Results of Fisheries Research and Development Council (FRDC) funded research on Bycatch Reduction Devices (BRDs) are promising. The three year research project which began in 1993 was conducted by CSIRO Division of Fisheries, the Australian Maritime College (AMC), and Northern Territory Department of Primary Industry and Fisheries.

These results are timely for Australia's tropical prawn fisheries given the recent US ban on prawns imported from countries that do not enforce the use of Turtle Exclusion Devices (TEDs). There is also pressure on the industry following a submission by the Australian Nature Conservation Agency (ANCA) that trawling for prawns is a key threatening process to turtles and two fish species.

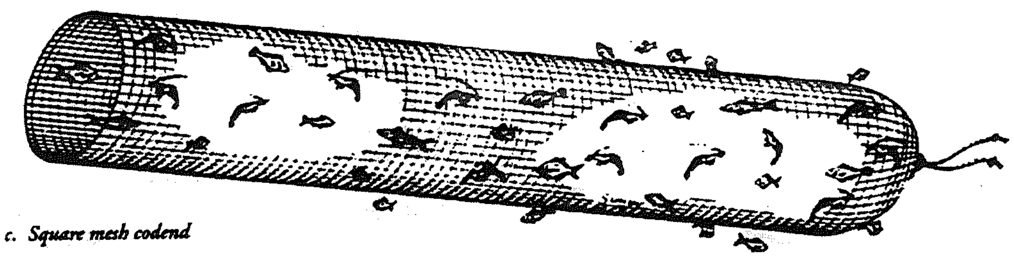
On the basis of current scientific evidence, CSIRO does not assess trawling as a key threatening process for turtles. However, it is a source of mortality that is contributing to declines in some turtle populations. Therefore, according the "precautionary principle", mortalities due to trawling should be minimised along with other measures to reduce turtle mortality in general.

Promising Bycatch Reduction Devices



a. Super shooter and fisheye

Turtle exclusion:	100%
Shark and ray exclusion:	88%
Fish exclusion:	16%
Prawns lost:	2%



c. Square mesh codend

Fish exclusion:	22%
Commercial sized prawn loss:	2%
Non-commercial sized prawn loss:	58-98%

Turtle Excluder Device (TED) Successfully Trialed

Trials have shown that the Supershooter - an oval shaped inclined grid - virtually eliminates turtle catches and most other large animals (rays, small sharks, turtles) but doesn't lose commercially valuable prawns.

Reducing Fish Bycatch

The Supershooter can be used in combination with other BRDs to further reduce catches of unwanted small fish. For example, a Supershooter with a fish eye device has already been shown to reduce over 16 percent of the catch of small fish, and this figure is expected to increase after further refinement of these BRDs following trials on commercial trawlers which begin in September.

Square-mesh codends can reduce catches of small fish by more than 20 percent and 45 mm square-mesh codends caught 98 percent of the commercial sized tiger prawns that entered the trawl. More than half the prawns that were smaller than commercial size escaped from 45 mm square mesh codends - most to live another day. The percentage of small prawns that escaped varied between 58 and 98 percent depending on the species of prawn.

Appendix D: Cruise Reports

1. SS7/93 DARWIN TO CAIRNS
27 OCTOBER - 29 NOVEMBER 1993
FRV *SOUTHERN SURVEYOR*

Itinerary

Leg 1	Departed Darwin:	1800 h Wednesday, 27 October 1993
	Arrived Weipa:	0800 h Friday, 12 November 1993
Leg 2	Departed Weipa:	1800 h Friday, 12 November 1993
	Arrived Cairns:	1900 h Sunday, 28 November 1993

Cruise objectives

Leg 1

1 To investigate the efficiency of "environmentally friendly trawls" by trawling in areas with bottom structure, using both a demersal Angels high-rise net and an environmentally friendly net.

2 To investigate fish habitats by characterising the benthic flora and fauna at each site, using a 3 m Church dredge.

3 To record the bottom structure and fish behaviour visually with a video camera mounted on the EFN.

4 To collect samples of *Lutjanus malabaricus* and *L. sebae* for population genetics studies.

5 To trawl at randomly selected sites in the Gulf of Carpentaria with a Frank and Bryce net in order to survey the abundance of commercial species of lutjanids and lethrinids.

Leg 2

1 To continue random trawls in areas with bottom structure, using both a demersal Engels high-rise net and an environmentally friendly net.

2 To document the benthic community at the trawl sites in order to compare the relative impact of each fish-trawl net on the bottom structure.

3 To videotape the EFN at various heights above the bottom to show how it affects the bottom structure.

4 To collect samples of *Lutjanus malabaricus* and *L. sebae* for population genetics studies.

5 To collect specimens for the I. S. R. Munro Fish Collection in Hobart.

6 To compare commercial 1.75" knotted diamond-mesh codends and codends of various sizes of knotless square-mesh using twin Florida Flyer 14 fathom prawn trawl nets.

Area of Operation

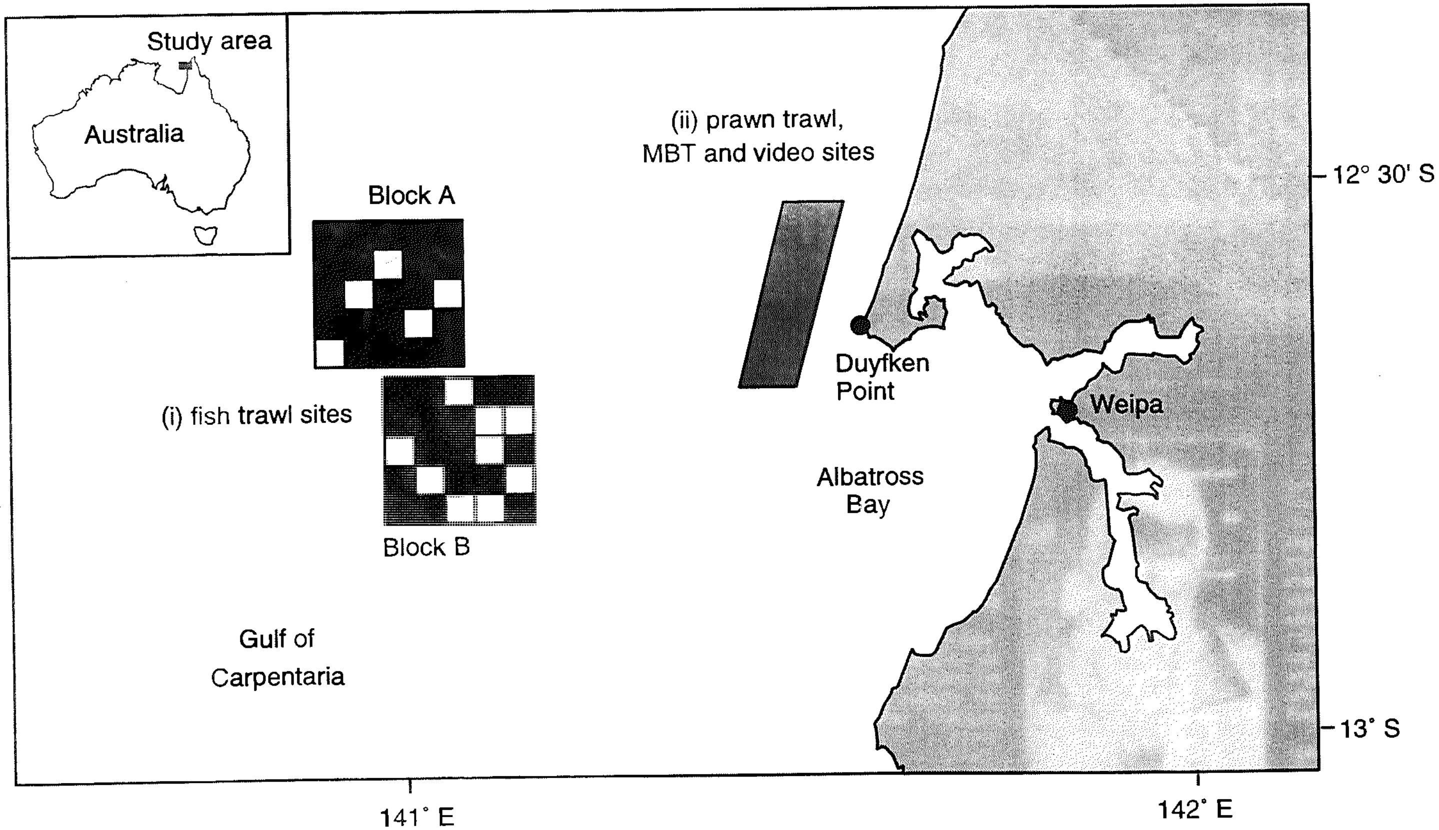
Leg 1

The western Arafura Sea at approximately 10° 20'S and 134° 00'E and west of Duyfken Point at 141° 30'E between 12° 24' and 12° 38'E on a north-south trawl path for the prawn bycatch reduction trials (see Figure 17). The commercial fish biomass survey with the Frank and Bryce net was restricted to the northern half of the GOC as in the previous cruise, SS193 (see Figure 18).

Leg 2

The EFN trials continued in two 10 x 10 nm blocks centred at L/L for block A and L/L for block B. The prawn bycatch reduction trials continued in the same north-south pattern off Duyfken Point as in Leg 1 (see Figure 17)

Figure 17. Locations of the study area for (i) the semi-pelagic fish trawl trials showing Blocks A and B and ii) prawning ground used for the prawn trawl bycatch reduction trials, the multi-level beam trawl trials and underwater video during the research cruise in October 1993.



while prawn net video taping and leiognathid collections were located on the east coast north of and in Shelburne Bay (Figure 19).

Results

Leg 1

1. The EFN work at the Arafura Sea location was abandoned after the EFN was completely destroyed during the first trawl. EFN work resumed several days later at the Weipa site (block A) after 2 Frank and Bryce nets were modified to fish as semi-pelagic trawls.
2. Dredge samples of bottom flora and fauna were obtained at the EFN sites with the 3m Church dredge until it was badly bent on station 74 and could no longer be used.
3. The commercial fishes biomass survey was completed at 40 Frank and Bryce trawl stations over three days with good catches of *L. malabaricus.*
4. Multi-level Beam Trawl (MBT) work was completed over 5 nights with 54 trawls.
5. Paired Florida Flyer prawn nets were calibrated during the last night of Leg 1, with net configuration of attachments to the trawl boards and skid altered each shot in order to prevent digging into mud. Prawn catches from each net were even. This work continued on the first night of Leg 2.
6. The footrope of the EFN was filmed from the wings of two trawls (stations 145, 146) and some useful images were obtained.
7. Tissue samples were taken from *L. malabaricus* and *L. sebae* catches throughout Leg 1.
8. Unusual or rare fish were retained for the fish collection in Hobart
9. Queensland Museum staff collected 75 species of sponge from 21 fish trawls. Little was obtained from the dredge which did not appear to represent the larger benthos (sponges, gorgonia etc) evident in the trawl nets.

Leg 2

1. The EFN trials continued with the modified Frank and Bryce nets with the second 10 x 10 nm block (B) adjacent to the first (A).
2. The benthic community was not sampled due to the damaged dredge, but any benthos (algae, sponges, gorgonia) on the footrope and in the trawl net was recorded as an indicator of bottom structure.
3. Video recordings of the Frank and Bryce EFN was successfully carried out with battery operated lights to improve visibility at depths around 45 m. Some images were obtained inside the net and fish and ray behaviour inside the codend was observed.
4. Whole fish and tissue samples of *L. malabaricus* and *L. sebae* were obtained during the fish (EFN) trawls.
5. Gordon Yearsley continued collecting specimens for the I. S. R. Munro fish collection as well as for a number of other requests both within and outside CSIRO Fisheries.
6. Comparisons were made between 1.75" and 1.5" square-mesh and standard 1.75" diamond-mesh codends on 14 fathom Florida Flyer prawn nets.

Cruise Narrative

Leg 1

Southern Surveyor departed Darwin on time at 1800 h on 27 October 1993. At a cruise debriefing meeting soon after departure, Leg 1 objectives were explained, shifts allocated and first time participants informed of ship safety and day to day house-keeping procedures. The Master, Mike Stanton, advised of a Muster and Fire drill the next day at 1300 h; this drill was successfully completed as anticipated. During the 24 h steam to the first EFN site in the Arafura sea, the fish laboratory was prepared for normal work and the *Southern Surveyor* 's new SUN Oracle database system tested. Numerous software problems were revealed during data entry trials, with Jeff Cordell resolving most of these by phone to Peter Campbell in Hobart.

Southern Surveyor arrived at the first station at 1800 h on 28 October. During deployment of the first EFN trawl, the winches failed for 20 minutes, but the trawl was completed normally. However, on retrieval, the EFN was found to be completely destroyed with sections of netting missing. After assessing the damage as irreparable, all EFN work was postponed and *Southern Surveyor* headed for the first fish biomass survey stations east of the Wessel Islands, about a 15 hour steam.

The biomass survey progressed smoothly, with commercial species occurring regularly, especially in the north west and north east stations. Station 21 in the south central study area (see Figure 18), surprisingly yielded 4 *Lutjanus. sebae*, 4 *L. malabaricus* and 8 *Diagramma pictum* in an area considered devoid of commercial species from previous biomass surveys.

The fish biomass survey was completed at 1700 h on 3 November. A trawl was carried out with the Frank and Bryce net which had no bottom gear and additional weights on the footrope to simulate the EFN. This proved successful with polishing towards the bottom of the chain holding the weights. This confirmed the feasibility of using the Frank and Bryce nets as EFN's at 0.4 and 0.8 metres off the bottom and the ground gear counting as the 0.0 m setting simulating hard on the bottom fishing. It should be noted however, that unlike the original "Julie Ann" EFN which kept all bridle and sweep wires off the bottom, the Frank and Bryce EFN simulation only kept the net off the bottom while bridles and sweeps maintained contact with the bottom.

Southern Surveyor proceeded to the prawn site approximately 5 nm west of Duyfken Point for the MBT work. The MBT worked well in the depths selected for prawn work, ~20 m with seven trawls on the first night, but the MBT sled broke on the first trawl of the second night. This had been attempted in deeper water (~30 m) to save steaming time from the deeper fish-trawl sites. The *Southern Surveyor* engineers re-assembled the MBT with nuts and bolts as no aluminium welding was available onboard and three nights later, MBT work resumed for a further four nights. This provided a total of 52 MBT trawls, the last three were an experiment with the trawl verandah set on the top of the bottom net to check the extent to which this reduced the prawn and bycatch catch in the upper two nets. The effect of this verandah height reduction (equivalent to the position of the headline of a prawn net) was substantial reduction in the prawn catch of the top two nets.

EFN work continued in block A and B with the three net settings of 0.0, 0.4 and 0.8 m off the bottom. This was daytime work, but it continued into the night for three nights when the MBT sled broke. In general, the 0.4 and 0.8 m EFN settings provided clean fish catches compared to the 0.0m settings which provided larger bags of mixed fish, sponges, rock and gorgonia.

Two Queensland Museum staff members collected sponges from the fish trawl during this leg. They obtained 75 different species of sponges, including examples of large mushroom sponges thought to be extinct in the GOC. Various Crustacea and fish specimens were retained as well as a range of invertebrates (gorgonia) for the museum's "marine reptiles" display.

Nick Elliott accumulated tissues for population genetic studies whenever appropriate catches of *L. malabaricus* and *L. sebae* were made.

Some inconsistencies in taring the microweigh scales were evident and it was relocated to a different bench to reduce the effects of ship vibration, but this was not effective. The unit was left for calibration in Weipa at the end of Leg 1.

A video camera was fitted to the EFN for two daytime trawls on the last day. After the first video fish trawl, some adjustments were required to the angle of the camera relative to the net footrope.

The last night was dedicated to calibrating the prawn nets so that they would catch prawns uniformly to allow the treatment comparisons to be carried out during the second leg. Standard diamond-mesh codends were used for both nets at this stage. At first, the trawl boards were digging into the muddy substrate and required adjustments even though the prawn catches were almost identical in both nets. This work was not finalised and was to continue over the first night of Leg 2. The square-mesh codend material for the trials had arrived in Weipa and this would be used to build the 1.75" and 1.5" square-mesh codends.

Figure 18. The sequence of stations sampled during the fish biomass survey (Frank and Bryce trawls) and the Queensland Museum sponge collecting trawl site in Torres Strait on leg one of the October 1993 cruise.

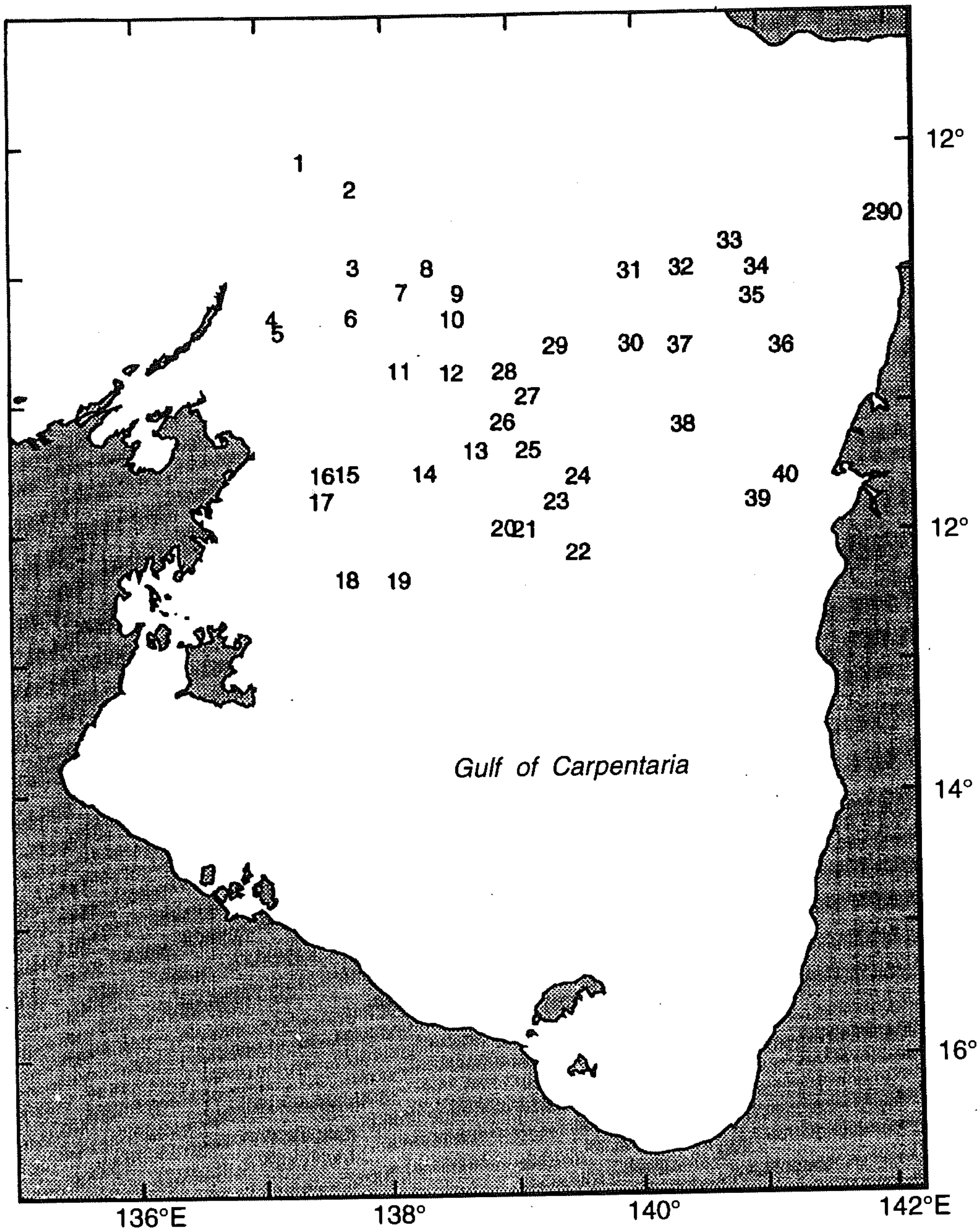
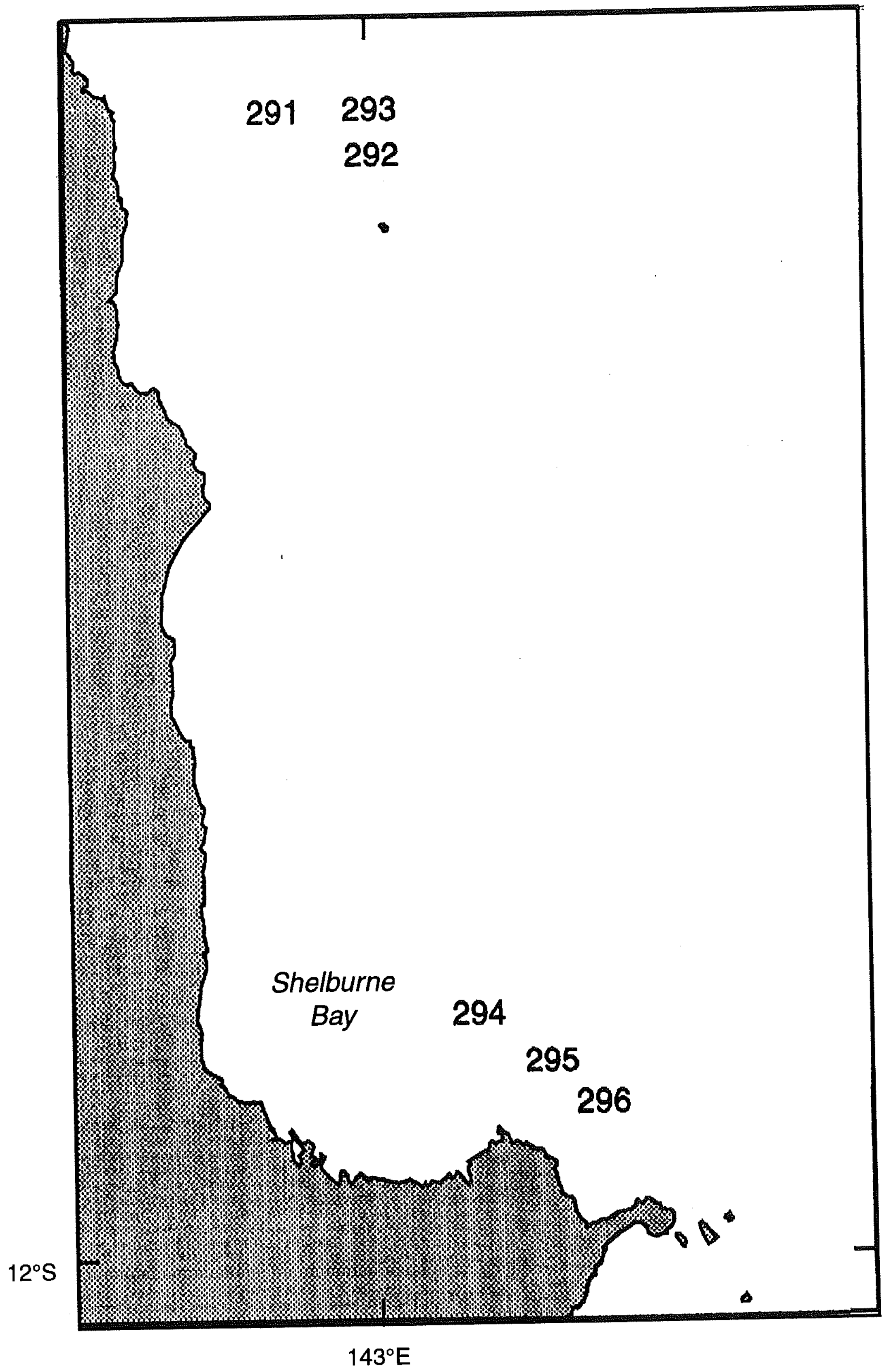


Figure 19. Sites sampled on the east coast for (i) video data and (ii) leiognathids during the October 1993 cruise.



Leg 2

The square-mesh codend netting was collected from the CSIRO Marine Laboratories field station and after the exchange of scientific personnel on the 12 November, *Southern Surveyor* left Weipa at 1800 h and headed for the prawn bycatch study site approximately 5 nm west of Duyfken Point. Prawn net calibrations continued throughout the night to ensure the two nets still caught similar numbers of prawns even after the 16 mm mesh codend cover was sewn on to the treatment net. Once all these calibrations were finalised, the port net was fitted with the 1.75" square-mesh codend and its codend cover. Square vs. diamond-mesh codend comparisons commenced on the second night (13 November) and continued for 12 nights, 7 nights with the 1.75" square-mesh for 43 trawls and 5 nights with the 1.5" square-mesh for 40 trawls. On 10 of the 12 nights, data on physical damage were collected on a selection of various shaped fishes that had passed through the diamond and square-mesh codends. This assessment proved time consuming, and to enable trawling to continue, two people from the second shift assessed damage while normal catch processing continued. David Brewer and Margaret Farmer persisted in this task, well into alternate shifts for the first two nights that this was attempted. The square-mesh codend gilled many more fishes than the diamond-mesh codend and eventually the square-mesh codend had to be cleaned of gilled fish after every second trawl. This was necessary as the catch retained by the square-mesh cover dropped noticeably after more than two or three trawls if the gilled fish were not cleared from the codend.

Little sorting of the fish component (bycatch) of these trawls was possible and an unexpected high number of subsamples were frozen for species composition in Cleveland.

During the day, EFN fish trawls continued in blocks A and B (Figure 17) with video cameras attached to the nets at all three net settings, 0.0, 0.4 and 0.8 m off the bottom.

On the morning of 25 November, *Southern Surveyor* left Duyfken Point to steam to the Orford Ness area (11°S, 143° 05'E) on the east coast for daytime video work on the dual rig prawn nets. The water was too turbid off Duyfken to allow this and so the work was relocated to known clearer waters. During the steam, a short trawl with the Frank and Bryce net was deployed in Endeavour Strait to collect sponges for Queensland Museum (stations 290, Figure 18).

Most of the day on 26 November was occupied with deploying the AMC pan-and-tilt video remote controlled video camera, which pointed at 90° to the towing direction to allow views of the prawn net opening. The pan-and-tilt camera was tethered and so allowed real time images to be viewed at the joystick controls. Deploying the camera proved difficult as it was fouled in the starboard net bridle wires. Late in the day, the camera was dragged with its clear lens cover facing downwards and the cover was irretrievably scratched. No useful images were obtained from this exercise, but some valuable information obtained on modifications required for future *Southern Surveyor* work with this equipment. The pan-and-tilt camera had successfully worked off smaller vessels; the problem on this cruise appeared to be the physical location of the towing point, which was not far enough away from the prawn net bridles.

During the steam to Cairns, two prawn trawls were carried out to obtain samples of leiognathids for Jonathan Staunton Smith in Shelburne Bay. During the two days steaming to Cairns, about 30 boxes of prawn bycatch subsamples were sorted and processed, leaving about 200 boxes to be processed in Cleveland.

During the second leg, the Microweigh scales were not used at all as they locked-up during calibration in Weipa, both on the *Southern Surveyor* and on the wharf. The SUN Sparc station was prone to crashing daily, with the problem tracked to the EK500 data logging. Lyndsay MacDonald toiled with the SUN problems and data entry from the fish laboratory was able to continue uninterrupted for most of the leg. All the biological data were copied to a cassette tape for down loading to the Cleveland SUN Sparc station.

During the steam through the GBR, the Trimble GPS system failed completely and eventually Lyndsay traced the fault to a short circuit due to water entering the masthead amplifier in the antenna. This could not be repaired and the new Trimble NAV TRACK GPS previously installed during Leg 1 had to be engaged to supply data to the Furuno track plotter.

Southern Surveyor berthed in Cairns at 1900 h on Sunday 28 November 1993. All scientific samples and equipment was consigned to Cleveland by 1100 h on 29 November.

Summary

The first field work of the FRDC funded trawl bycatch reduction project was top priority for this cruise. Two square-mesh sizes were compared with standard diamond-mesh codends and the influence of net headline height off the bottom was investigated with the Multilevel Beam Trawl. Physical damage to trawled bycatch was also assessed. The EFN net comparisons in the Gulf of Carpentaria were the second stage of an assessment of the "environmentally friendly net" recommended for the Northern Trawl Fishery. The Tropical Fish Ecology group now has valuable practical information about the operation of the type of net envisaged for the fishery.

The fish biomass survey is the fourth data set CSIRO has provided for use in stock assessment in the Gulf of Carpentaria.

Tissue samples from *L. malabaricus*, *L. sebae* and other species were obtained for population genetic studies in the Hobart genetics laboratory.

The fish collection in Hobart obtained large numbers of specimens, including valuable additions to the sharks and ray collection.

Reporting of results

The results will be analysed and reported in the scientific literature where appropriate. The fish biomass survey data will be used to help set total allowable fish-trawl catches for the Gulf of Carpentaria.

Personnel

(Note: unless otherwise stated, all personnel are staff of the CSIRO Division of Fisheries or students based at CSIRO Cleveland.)

Leg 1

Mr John Salini (Cruise leader)
Mr David Brewer (second shift leader)
Mr Jonathan Staunton Smith
Mr Jeff Cordell
Mr Clive Liron
Dr Nick Elliott
Mr Steve Cook (Q Museum)
Mr John Kennedy (Q Museum)
Mr Steve Eayrs (AMC)
Mr Marcus Strauss (AMC)
Mr Richard Mounsey (NT Fisheries)
Mr Graham Baulch (NT Fisheries)

Leg 2

Mr John Salini (Cruise Leader)
Mr David Brewer (second shift leader)
Mr Steve Eayrs (AMC)
Mr Marcus Strauss (AMC)
Mr Neville Gill (NT Fisheries)
Ms Stephanie Boubaris (NT Fisheries)
Dr Yougan Wang
Mr Carlos Souris
Mr Gordon Yearsley
Ms Pat Graham
Ms Margaret Farmer
Mr Lyndsay MacDonald

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Cruise Leader

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Distribution

- Normal circulation
- Cruise participants

Table 16. Stations occupied by *Southern Surveyor* during Cruise SS7/93.

DEPTH: depth in metres; F/B: Frank & Bryce trawl set at 0.0, 0.4 or 0.8 m off the bottom, BIOM: biomass survey stations; MBT: Multi-level Beam Trawl; FF: Florida Flyer trawl with 1.75" and 1.5" square-mesh codends, set at 0.0, 0.4 or 0.8 m off the bottom; START: start time in decimal hours; SLATMIN: start latitude; SLONMIN: start longitude; ELATMIN: end latitude; ELONMIN: end longitude.

STN	DATE	DEPTH	GEAR	START	SLATMIN	SLONMIN	ELATMIN	ELONMIN
1	29-OCT-93	46	F/B_BIOM	15.33	10° 06.8'	137° 21.2'	10° 07.6'	137° 22.6'
2	29-OCT-93	47	F/B_BIOM	18.41	10° 19.7'	137° 45.0'	10° 20.9'	137° 45.9'
3	29-OCT-93	49	F/B_BIOM	22.08	10° 55.9'	137° 45.9'	10° 57.0'	137° 41.9'
4	30-OCT-93	47	F/B_BIOM	02.33	11° 19.7'	137° 07.0'	11° 08.0'	137° 21.1'
5	30-OCT-93	47	F/B_BIOM	04.00	11° 25.9'	137° 09.7'	11° 06.8'	137° 08.0'
6	30-OCT-93	49	F/B_BIOM	08.75	11° 19.3'	137° 44.7'	11° 08.3'	137° 45.3'
7	30-OCT-93	50	F/B_BIOM	11.75	11° 07.6'	138° 08.9'	11° 06.7'	138° 10.1'
8	30-OCT-93	51	F/B_BIOM	14.16	10° 56.7'	138° 21.1'	10° 58.2'	138° 22.1'
9	30-OCT-93	51	F/B_BIOM	16.41	11° 08.5'	138° 35.5'	11° 11.0'	138° 31.8'
10	30-OCT-93	50	F/B_BIOM	18.13	11° 20.4'	138° 32.5'	11° 23.1'	138° 32.0'
11	30-OCT-93	50	F/B_BIOM	21.71	11° 44.0'	138° 70.5'	11° 44.4'	138° 10.0'
12	31-OCT-93	52	F/B_BIOM	00.33	11° 45.3'	138° 32.0'	11° 47.0'	138° 32.1'
13	31-OCT-93	54	F/B_BIOM	04.17	12° 21.6'	138° 43.3'	12° 03.1'	138° 42.4'
14	31-OCT-93	50	F/B_BIOM	07.00	12° 32.0'	138° 18.7'	12° 30.4'	138° 17.2'
15	31-OCT-93	48	F/B_BIOM	11.28	12° 31.7'	137° 42.1'	12° 30.1'	137° 42.1'
16	31-OCT-93	47	F/B_BIOM	13.16	12° 32.1'	137° 29.8'	12° 34.9'	137° 29.6'
17	31-OCT-93	46	F/B_BIOM	14.63	12° 44.2'	137° 29.6'	12° 46.3'	137° 29.5'
18	31-OCT-93	48	F/B_BIOM	18.41	13° 20.6'	137° 41.3'	13° 23.2'	137° 41.1'
19	31-OCT-93	52	F/B_BIOM	21.53	13° 21.1'	138° 06.0'	13° 21.2'	138° 07.6'
20	01-NOV-93	55	F/B_BIOM	02.75	12° 57.5'	139° 56.6'	12° 57.5'	138° 58.6'
21	01-NOV-93	56	F/B_BIOM	04.25	12° 57.9'	139° 06.6'	12° 58.4'	139° 10.1'
22	01-NOV-93	58	F/B_BIOM	07.08	13° 09.1'	139° 32.1'	13° 07.4'	139° 31.8'
23	01-NOV-93	57	F/B_BIOM	09.92	12° 45.3'	139° 21.6'	12° 44.9'	139° 23.3'
24	01-NOV-93	57	F/B_BIOM	11.91	12° 33.7'	139° 32.5'	12° 32.6'	139° 31.3'
25	01-NOV-93	55	F/B_BIOM	14.75	12° 21.2'	139° 08.9'	12° 19.5'	139° 08.4'
26	01-NOV-93	52	F/B_BIOM	16.91	12° 08.3'	138° 56.3'	12° 06.9'	138° 56.6'
27	01-NOV-93	54	F/B_BIOM	19.11	11° 56.6'	139° 08.4'	11° 55.6'	139° 07.2'
28	01-NOV-93	52	F/B_BIOM	21.20	11° 44.9'	138° 57.7'	11° 44.5'	138° 59.1'
29	02-NOV-93	47	F/B_BIOM	00.33	11° 33.3'	139° 21.9'	11° 33.4'	139° 23.8'
30	02-NOV-93	57	F/B_BIOM	04.08	11° 32.8'	139° 58.2'	11° 34.4'	139° 58.3'
31	02-NOV-93	58	F/B_BIOM	08.00	10° 59.0'	139° 58.2'	11° 00.3'	139° 59.1'

32	02-NOV-93	54	F/B_BIOM	11.83	10° 58.0'	140° 23.3'	10° 58.4'	140° 24.5'
33	02-NOV-93	42	F/B_BIOM	14.83	10° 46.0'	140° 46.7'	10° 46.9'	140° 45.4'
34	02-NOV-93	39	F/B_BIOM	18.55	10° 58.2'	140° 59.4'	11° 00.1'	140° 58.2'
35	02-NOV-93	42	F/B_BIOM	20.83	11° 11.4'	140° 56.9'	11° 12.0'	140° 55.3'
36	03-NOV-93	38	F/B_BIOM	00.42	11° 34.3'	141° 10.6'	11° 34.0'	141° 08.9'
37	02-NOV-93	59	F/B_BIOM	05.33	11° 33.7'	140° 21.9'	11° 33.5'	140° 20.4'
38	03-NOV-93	60	F/B_BIOM	09.67	12° 10.4'	140° 23.2'	12° 10.7'	140° 24.8'
39	03-NOV-93	47	F/B_BIOM	14.42	12° 45.8'	140° 58.8'	12° 44.0'	140° 59.3'
40	03-NOV-93	42	F/B_BIOM	16.56	12° 34.6'	141° 12.3'	12° 35.1'	141° 14.9'
41	03-NOV-93	16	MBT	22.58	12° 34.5'	141° 30.1'	12° 33.8'	141° 30.0'
42	03-NOV-93	19	MBT	23.22	12° 33.3'	141° 29.8'	12° 34.8'	141° 29.7'
43	03-NOV-93	19	MBT	23.90	12° 35.3'	141° 29.7'	12° 36.6'	141° 29.9'
44	03-NOV-93	18	MBT	00.67	12° 37.2'	141° 29.8'	12° 38.3'	141° 29.9'
45	04-NOV-93	16	MBT	01.35	12° 38.1'	141° 29.7'	12° 36.1'	141° 29.6'
46	04-NOV-93	16	MBT	02.50	12° 34.3'	141° 29.5'	12° 32.4'	141° 29.7'
47	04-NOV-93	19	MBT	03.50	12° 33.3'	141° 30.3'	12° 29.4'	141° 30.2'
48	04-NOV-93	21	MBT	04.67	12° 28.5'	141° 29.8'	12° 29.8'	141° 30.2'
49	04-NOV-93	50	F/B_0.4	08.08	12° 30.1'	141° 02.2'	12° 28.6'	141° 02.3'
50	04-NOV-93	53	F/B_0.4	10.42	12° 28.4'	141° 00.6'	12° 26.5'	141° 00.6'
51	04-NOV-93	50	F/B_0.4	8.083	12° 30.1'	141° 02.2'	12° 28.6'	141° 02.3'
52	04-NOV-93	53	F/B_0.4	14.33	12° 28.4'	141° 00.6'	12° 26.5'	141° 00.6'
53	04-NOV-93	57	F/B_0.4	16.28	12° 25.2'	140° 56.5'	12° 24.6'	140° 56.5'
54	04-NOV-93	33	MBT	20.42	12° 31.0'	141° 25.3'	12° 31.8'	141° 25.2'
55	05-NOV-93	57	F/B_0.4	00.42	12° 25.0'	140° 54.0'	12° 26.6'	140° 54.0'
56	05-NOV-93	55	F/B_0.4	02.33	12° 23.9'	140° 58.8'	12° 22.8'	140° 57.2'
57	05-NOV-93	52	F/B_0.4	06.83	12° 27.4'	141° 02.3'	12° 25.2'	141° 02.4'
58	05-NOV-93	51	F/B_0.8	08.58	12° 31.1'	141° 02.4'	12° 29.1'	141° 02.3'
59	05-NOV-93	53	F/B_0.8	10.66	12° 28.7'	141° 00.8'	12° 27.1'	141° 00.7'
60	05-NOV-93	55	F/B_0.8	13.41	12° 31.3'	140° 58.9'	12° 29.5'	140° 58.4'
61	05-NOV-93	57	F/B_0.8	14.66	12° 29.1'	140° 56.7'	12° 27.2'	140° 56.8'
62	05-NOV-93	57	F/B_0.8	17.00	12° 25.2'	140° 56.5'	12° 23.7'	140° 56.7'
63	05-NOV-93	57	F/B_0.8	18.18	12° 23.0'	140° 54.3'	12° 21.7'	140° 54.3'
64	05-NOV-93	56	F/B_0.8	22.08	12° 23.7'	140° 58.0'	12° 21.8'	140° 58.0'
65	06-NOV-93	51	F/B_0.8	01.25	12° 23.7'	141° 02.5'	12° 21.8'	141° 02.1'
66	06-NOV-93	52	F/B_0.8	3.666	12° 28.3'	141° 00.8'	12° 29.7'	141° 00.8'
67	06-NOV-93	51	F/B_0.0	07.00	12° 27.4'	141° 02.6'	12° 29.7'	141° 02.6'
68	06-NOV-93	53	F/B_0.0	10.25	12° 28.4'	141° 00.8'	12° 26.8'	141° 00.9'
69	06-NOV-93	55	F/B_0.0	13.33	12° 31.6'	140° 56.6'	12° 29.8'	140° 56.7'
70	06-NOV-93	57	F/B_0.0	14.25	12° 29.0'	140° 57.1'	12° 27.2'	140° 57.3'
71	06-NOV-93	57	F/B_0.0	16.83	12° 25.6'	140° 56.6'	12° 24.3'	140° 56.8'
72	06-NOV-93	58	F/B_0.0	20.58	12° 23.1'	140° 54.6'	12° 21.5'	140° 54.6'
73	06-NOV-93	55	F/B_0.0	23.38	12° 23.3'	140° 58.0'	12° 21.6'	140° 58.0'
74	07-NOV-93	52	F/B_0.0	01.25	12° 22.9'	141° 02.5'	12° 21.1'	141° 02.7'
75	07-NOV-93	56	F/B_0.0	04.00	12° 30.6'	140° 56.6'	12° 28.7'	140° 56.8'
76	07-NOV-93	43	F/B_0.0	09.33	12° 29.4'	141° 02.3'	12° 28.1'	141° 02.1'
77	07-NOV-93	43	ABORT	09.33	12° 40.2'	141° 03.1'	12° 39.0'	141° 03.1'
78	07-NOV-93	49	F/B_0.0	10.67	12° 38.8'	141° 00.9'	12° 37.2'	141° 01.0'
79	07-NOV-93	47	F/B_0.0	12.75	12° 37.5'	141° 03.1'	12° 35.7'	141° 02.8'
80	07-NOV-93	47	F/B_0.0	14.16	12° 35.7'	141° 03.2'	12° 34.0'	141° 03.2'
81	07-NOV-93	46	F/B_0.0	16.33	12° 35.3'	141° 05.0'	12° 33.8'	141° 05.1'
82	07-NOV-93	19	MBT	20.35	12° 34.1'	141° 29.1'	12° 35.6'	141° 29.5'
83	07-NOV-93	18	MBT	21.17	12° 35.7'	141° 30.0'	12° 34.6'	141° 29.9'
84	07-NOV-93	17	MBT	22.12	12° 33.5'	141° 30.5'	12° 32.4'	141° 30.5'
85	07-NOV-93	17	MBT	22.92	12° 32.5'	141° 30.8'	12° 33.9'	141° 30.7'
86	08-NOV-93	16	MBT	00.10	12° 35.1'	141° 30.6'	12° 36.2'	141° 30.5'

87	08-NOV-93	15	MBT	01.33	12° 36.5'	141° 30.3'	12° 35.5'	141° 30.3'
88	08-NOV-93	17	MBT	02.13	12° 34.4'	141° 30.2'	12° 32.9'	141° 30.4'
89	08-NOV-93	18	MBT	02.83	12° 32.5'	141° 30.5'	12° 31.1'	141° 31.0'
90	08-NOV-93	17	MBT	03.75	12° 31.2'	141° 31.2'	12° 32.0'	141° 31.0'
91	08-NOV-93	17	MBT	04.50	12° 32.4'	141° 30.8'	12° 33.3'	141° 30.5'
92	08-NOV-93	42	F/B_0.8	08.33	12° 41.8'	141° 03.0'	12° 39.5'	141° 03.0'
93	08-NOV-93	47	F/B_0.8	10.16	12° 39.3'	141° 09.0'	12° 36.9'	141° 01.0'
94	08-NOV-93	47	F/B_0.8	12.67	12° 37.8'	141° 02.8'	12° 35.9'	141° 02.8'
95	08-NOV-93	47	F/B_0.8	14.16	12° 35.5'	141° 03.1'	12° 33.7'	141° 03.1'
96	08-NOV-93	46	F/B_0.8	16.20	12° 35.1'	141° 05.1'	12° 33.5'	141° 05.0'
97	08-NOV-93	16	MBT	19.47	12° 34.3'	141° 30.8'	12° 35.7'	141° 30.8'
98	08-NOV-93	15	MBT	20.32	12° 35.7'	141° 31.0'	12° 34.4'	141° 31.0'
99	08-NOV-93	15	MBT	21.02	12° 34.2'	141° 31.0'	12° 32.8'	141° 31.0'
100	08-NOV-93	18	MBT	22.10	12° 31.9'	141° 31.2'	12° 33.3'	141° 31.5'
101	08-NOV-93	14	MBT	23.07	12° 34.4'	141° 31.3'	12° 35.9'	141° 31.3'
102	09-NOV-93	15	MBT	00.33	12° 36.7'	141° 30.6'	12° 35.3'	141° 30.6'
103	09-NOV-93	16	MBT	01.17	12° 34.7'	141° 30.7'	12° 33.4'	141° 30.6'
104	09-NOV-93	17	MBT	01.92	12° 32.7'	141° 30.7'	12° 31.3'	141° 30.9'
105	09-NOV-93	18	MBT	02.67	12° 31.3'	141° 31.0'	12° 32.5'	141° 31.0'
106	09-NOV-93	16	MBT	03.42	12° 32.9'	141° 30.9'	12° 34.3'	141° 30.8'
107	09-NOV-93	15	MBT	04.17	12° 34.6'	141° 30.8'	12° 35.6'	141° 30.6'
108	09-NOV-93	43	F/B_0.4	08.17	12° 40.9'	141° 03.3'	12° 38.8'	141° 03.4'
109	09-NOV-93	47	F/B_0.4	10.16	12° 37.1'	141° 01.1'	12° 37.5'	141° 01.2'
110	09-NOV-93	47	F/B_0.4	12.83	12° 37.1'	141° 03.4'	12° 35.1'	141° 03.4'
111	09-NOV-93	47	F/B_0.4	14.16	12° 35.7'	141° 03.2'	12° 33.7'	141° 03.3'
112	09-NOV-93	46	F/B_0.4	16.30	12° 35.1'	141° 05.0'	12° 33.3'	141° 05.2'
113	09-NOV-93	18	MBT	19.42	12° 31.1'	141° 31.0'	12° 32.4'	141° 33.4'
114	09-NOV-93	16	MBT	20.00	12° 32.8'	141° 34.7'	12° 34.3'	141° 31.1'
115	09-NOV-93	14	MBT	20.75	12° 34.6'	141° 31.2'	12° 35.7'	141° 31.2'
116	09-NOV-93	14	MBT	21.33	12° 35.8'	141° 31.1'	12° 34.5'	141° 31.1'
117	09-NOV-93	14	MBT	22.00	12° 34.2'	141° 31.2'	12° 32.7'	141° 31.3'
118	09-NOV-93	17	MBT	23.07	12° 31.7'	141° 31.1'	12° 33.2'	141° 31.0'
119	10-NOV-93	15	MBT	00.33	12° 34.6'	141° 30.9'	12° 36.8'	141° 30.6'
120	10-NOV-93	16	MBT	01.08	12° 35.9'	141° 30.4'	12° 34.4'	141° 30.4'
121	10-NOV-93	17	MBT	01.75	12° 34.0'	141° 30.4'	12° 32.7'	141° 30.7'
122	10-NOV-93	17	MBT	02.42	12° 32.4'	141° 30.8'	12° 31.1'	141° 31.2'
123	10-NOV-93	17	MBT	03.25	12° 31.2'	141° 31.2'	12° 32.4'	141° 31.0'
124	10-NOV-93	16	MBT	04.00	12° 32.9'	141° 30.9'	12° 34.1'	141° 30.6'
125	10-NOV-93	16	MBT	04.67	12° 34.5'	141° 30.5'	12° 35.6'	141° 30.4'
126	10-NOV-93	50	F/B_0.4	08.33	12° 29.5'	141° 02.6'	12° 27.4'	141° 02.8'
127	10-NOV-93	50	F/B_0.4	09.67	12° 28.6'	141° 02.3'	12° 27.4'	141° 02.5'
128	10-NOV-93	53	F/B_0.4	10.83	12° 28.4'	141° 00.6'	12° 26.3'	141° 00.6'
129	10-NOV-93	53	FB.4VIDEO	11.75	12° 27.3'	141° 00.4'	12° 29.3'	141° 00.4'
130	10-NOV-93	55	F/B_0.4	13.25	12° 31.1'	140° 58.6'	12° 29.3'	140° 58.8'
131	10-NOV-93	55	F/B_0.4	14.33	12° 28.5'	140° 56.9'	12° 26.9'	140° 57.0'
132	10-NOV-93	56	F/B_0.4	16.20	12° 25.8'	140° 56.0'	12° 23.9'	140° 56.3'
133	10-NOV-93	18	MBT	20.08	12° 32.2'	141° 30.7'	12° 33.6'	141° 29.1'
134	10-NOV-93	16	MBT	20.80	12° 34.1'	141° 30.6'	12° 35.4'	141° 30.7'
135	10-NOV-93	15	MBT	21.47	12° 35.9'	141° 30.7'	12° 37.1'	141° 30.6'
136	10-NOV-93	14	MBT	22.17	12° 37.2'	141° 30.8'	12° 35.7'	141° 30.8'
137	10-NOV-93	15	MBT	22.92	12° 35.1'	141° 30.9'	12° 33.5'	141° 30.9'
138	11-NOV-93	17	MBT	00.50	12° 32.6'	141° 31.1'	12° 33.9'	141° 30.9'
139	11-NOV-93	16	MBT	01.17	12° 34.5'	141° 30.8'	12° 35.6'	141° 30.6'
140	11-NOV-93	16	MBT	01.92	12° 35.6'	141° 30.6'	12° 34.1'	141° 30.7'
141	11-NOV-93	17	MBT	02.92	12° 33.4'	141° 30.7'	12° 32.2'	141° 31.0'

142	11-NOV-93	16	MBT	03.67	12° 32.1'	141° 31.1'	12° 33.2'	141° 31.0'
143	11-NOV-93	16	MBT	04.33	12° 33.3'	141° 31.2'	12° 34.9'	141° 30.6'
144	11-NOV-93	42	F/B_0.0	08.08	12° 41.3'	141° 03.0'	12° 39.3'	141° 03.2'
145	11-NOV-93	53	F/B0VIDEO	10.00	12° 29.5'	141° 00.8'	12° 28.4'	141° 00.9'
146	11-NOV-93	53	F/B0VIDEO	10.83	12° 27.2'	141° 00.5'	12° 25.2'	141° 00.7'
147	13-NOV-93	55	F/B_0.0	08.83	12° 29.0'	141° 59.1'	12° 27.4'	141° 59.4'
148	13-NOV-93	55	F/B_0.0	10.27	12° 26.9'	141° 58.0'	12° 25.4'	141° 58.1'
149	13-NOV-93	53	F/B_0.0	13.16	12° 27.8'	141° 00.9'	12° 26.3'	141° 01.0'
150	13-NOV-93	54	F/B_0.0	14.23	12° 25.7'	141° 01.2'	12° 23.8'	141° 01.1'
151	13-NOV-93	53	F/B_0.0	16.33	12° 23.9'	141° 01.1'	12° 22.0'	141° 01.2'
152	13-NOV-93	18	FF_1.75	20.91	12° 28.6'	141° 31.6'	12° 27.3'	141° 32.7'
153	13-NOV-93	18	FF_1.75	22.08	12° 25.8'	141° 34.2'	12° 27.0'	141° 32.4'
154	13-NOV-93	18	FF_1.75	23.58	12° 29.5'	141° 31.0'	12° 27.6'	141° 32.0'
155	14-NOV-93	16	FF_1.75	01.17	12° 26.2'	141° 33.4'	12° 27.5'	141° 32.9'
156	14-NOV-93	16	FF_1.75	02.28	12° 28.2'	141° 32.3'	12° 29.6'	141° 31.7'
157	14-NOV-93	18	FF_1.75	03.70	12° 28.5'	141° 31.6'	12° 27.1'	141° 32.5'
158	14-NOV-93	54	F/B_0.4	09.25	12° 29.8'	140° 59.6'	12° 27.8'	140° 59.6'
159	14-NOV-93	55	F/B_0.4	10.42	12° 27.2'	140° 58.5'	12° 25.4'	140° 58.9'
160	14-NOV-93	53	F/B_0.4	13.41	12° 27.7'	141° 00.9'	12° 26.1'	141° 01.1'
161	14-NOV-93	54	F/B_0.4	14.58	12° 24.7'	141° 01.0'	12° 22.9'	141° 01.1'
162	14-NOV-93	54	F/B_0.4	16.08	12° 23.0'	141° 01.0'	12° 21.3'	141° 01.1'
163	14-NOV-93	17	FF_1.75	20.56	12° 27.4'	141° 32.3'	12° 28.7'	141° 31.5'
164	14-NOV-93	18	FF_1.75	23.33	12° 28.9'	141° 31.3'	12° 27.4'	141° 32.5'
165	15-NOV-93	17	FF_1.75	01.42	12° 25.9'	141° 32.9'	12° 27.1'	141° 32.3'
166	15-NOV-93	18	FF_1.75	03.08	12° 28.7'	141° 31.6'	12° 26.7'	141° 32.6'
167	15-NOV-93	18	FF_1.75	04.17	12° 25.6'	141° 32.9'	12° 26.8'	141° 32.3'
168	15-NOV-93	55	F/B_0.8	08.42	12° 28.4'	140° 59.1'	12° 26.9'	140° 59.1'
169	15-NOV-93	55	F/B_0.8	10.25	12° 27.4'	140° 58.2'	12° 25.9'	140° 59.0'
170	15-NOV-93	53	F/B_0.8	14.00	12° 27.0'	141° 01.1'	12° 26.2'	141° 01.1'
171	15-NOV-93	55	F/B_0.8	15.00	12° 25.8'	141° 00.7'	12° 24.2'	141° 00.7'
172	15-NOV-93	54	F/B_0.8	16.20	12° 23.4'	141° 01.1'	12° 21.7'	141° 01.2'
173	15-NOV-93	18	FF_1.75	21.08	12° 28.0'	141° 31.7'	12° 26.4'	141° 32.5'
174	15-NOV-93	17	FF_1.75	22.93	12° 26.4'	141° 32.3'	12° 27.9'	141° 31.8'
175	16-NOV-93	17	FF_1.75	1.166	12° 26.7'	141° 32.3'	12° 27.8'	141° 34.0'
176	16-NOV-93	18	FF_1.75	02.50	14° 28.6'	141° 31.7'	12° 26.4'	141° 32.7'
177	16-NOV-93	17	FF_1.75	03.58	12° 25.7'	141° 33.0'	12° 26.7'	141° 32.6'
178	16-NOV-93	18	FF_1.75	04.42	12° 27.4'	141° 32.3'	12° 28.3'	141° 31.6'
179	16-NOV-93	41	F/B_0.8	08.33	12° 39.1'	141° 07.1'	12° 37.5'	141° 07.2'
180	16-NOV-93	44	F/B_0.8	10.00	12° 37.3'	141° 04.8'	12° 35.3'	141° 04.8'
181	16-NOV-93	48	F/B_0.8	12.58	12° 35.4'	141° 01.4'	12° 34.1'	141° 01.2'
182	16-NOV-93	50	F/B_0.8	14.16	12° 33.6'	141° 01.4'	12° 31.8'	141° 01.5'
183	16-NOV-93	49	F/B_0.8	16.08	12° 32.8'	141° 03.3'	12° 31.1'	141° 03.3'
184	16-NOV-93	18	FF_1.75	20.10	12° 28.4'	141° 31.2'	12° 30.1'	141° 31.0'
185	16-NOV-93	19	FF_1.75	21.58	12° 29.9'	141° 31.0'	12° 28.7'	141° 31.8'
186	16-NOV-93	17	FF_1.75	23.00	12° 27.0'	141° 32.5'	12° 28.4'	141° 31.9'
187	17-NOV-93	18	FF_1.75	00.58	12° 30.1'	141° 30.7'	12° 28.6'	141° 31.4'
188	17-NOV-93	18	FF_1.75	04.50	12° 29.1'	141° 31.4'	12° 27.3'	141° 32.0'
189	17-NOV-93	44	F/B_0.0	08.50	12° 39.3'	141° 07.0'	12° 37.5'	141° 07.0'
190	17-NOV-93	45	F/B_0.0	10.16	12° 38.0'	141° 04.7'	12° 36.5'	141° 04.7'
191	17-NOV-93	49	F/B_0.0	12.91	12° 35.5'	141° 00.9'	12° 34.2'	141° 01.0'
192	17-NOV-93	50	F/B_0.0	14.16	12° 34.0'	141° 00.9'	12° 32.4'	141° 01.0'
193	17-NOV-93	48	F/B_0.0	16.16	12° 33.6'	141° 03.1'	12° 31.9'	141° 03.3'
194	17-NOV-93	18	FF_1.75	19.92	12° 27.1'	141° 32.5'	12° 28.8'	141° 31.9'
195	17-NOV-93	19	FF_1.75	21.66	12° 30.1'	141° 30.9'	12° 28.7'	141° 31.6'
196	17-NOV-93	18	FF_1.75	22.92	12° 26.7'	141° 32.5'	12° 28.1'	141° 31.8'

197	18-NOV-93	18	FF_1.75	00.72	12° 28.4'	141° 31.4'	12° 26.8'	141° 32.2'
198	18-NOV-93	17	FF_1.75	01.80	12° 26.0'	141° 32.4'	12° 27.5'	141° 32.1'
199	18-NOV-93	17	FF_1.75	02.75	12° 28.5'	141° 31.8'	12° 29.6'	141° 31.7'
200	18-NOV-93	17	FF_1.75	03.83	12° 29.1'	141° 31.5'	12° 26.8'	141° 32.5'
201	18-NOV-93	18	FF_1.75	04.75	12° 25.7'	141° 32.7'	12° 26.8'	141° 32.5'
202	18-NOV-93	44	F/B_0.4	09.00	12° 39.0'	141° 07.0'	12° 37.2'	141° 07.0'
203	18-NOV-93	45	F/B_0.4	10.16	12° 37.4'	141° 04.8'	12° 35.7'	141° 04.8'
204	18-NOV-93	48	F/B_0.4	12.58	12° 35.6'	141° 00.7'	12° 34.2'	141° 00.7'
205	18-NOV-93	50	F/B_0.4	14.08	12° 33.5'	141° 00.8'	12° 31.8'	141° 00.9'
206	18-NOV-93	50	F/B_0.4	16.16	12° 33.1'	141° 02.5'	12° 31.5'	141° 03.2'
207	18-NOV-93	20	FF_1.75	20.16	12° 29.9'	141° 30.7'	12° 28.9'	141° 31.4'
208	18-NOV-93	19	FF_1.75	22.16	12° 28.3'	141° 31.7'	12° 30.0'	141° 31.1'
209	18-NOV-93	19	FF_1.75	23.41	12° 29.6'	141° 31.5'	12° 27.2'	141° 32.6'
210	19-NOV-93	18	FF_1.75	01.42	12° 28.3'	141° 31.7'	12° 29.6'	141° 31.2'
211	19-NOV-93	18	FF_1.75	02.33	12° 29.7'	141° 31.2'	12° 27.8'	141° 31.8'
212	19-NOV-93	16	FF_1.75	03.42	12° 26.4'	141° 32.6'	12° 27.5'	141° 31.9'
213	19-NOV-93	18	FF_1.75	04.42	12° 28.7'	141° 31.4'	12° 26.7'	141° 32.0'
214	19-NOV-93	54	F/B_0.4	08.67	12° 30.8'	141° 00.5'	12° 28.6'	141° 00.6'
215	19-NOV-93	58	F/B_0.4	10.33	12° 29.4'	140° 54.3'	12° 27.5'	140° 54.4'
216	19-NOV-93	58	F/B_0.4	12.91	12° 27.4'	140° 54.7'	12° 25.5'	140° 54.5'
217	19-NOV-93	57	F/B_0.4	14.17	12° 23.4'	140° 56.5'	12° 21.4'	140° 56.6'
218	19-NOV-93	53	F/B_0.4	16.16	12° 25.5'	141° 01.6'	12° 24.0'	141° 01.8'
219	19-NOV-93	19	FF_1.75	20.00	12° 26.6'	141° 32.1'	12° 28.2'	141° 31.4'
220	19-NOV-93	19	FF_1.75	21.42	12° 29.0'	141° 31.0'	12° 27.6'	141° 31.9'
221	19-NOV-93	18	FF_1.75	23.16	12° 26.7'	141° 32.2'	12° 28.3'	141° 31.7'
222	20-NOV-93	17	FF_1.75	01.83	12° 25.9'	141° 32.9'	12° 24.3'	141° 33.1'
223	20-NOV-93	17	FF_1.75	02.83	12° 24.7'	141° 33.1'	12° 25.9'	141° 32.8'
224	20-NOV-93	17	FF_1.75	04.00	12° 27.7'	141° 32.5'	12° 29.0'	141° 32.0'
225	20-NOV-93	53	F/B_0.8	08.67	12° 31.2'	141° 00.3'	12° 29.5'	141° 00.3'
226	20-NOV-93	50	F/B_0.8	10.75	12° 27.8'	140° 54.6'	12° 25.8'	140° 54.7'
227	20-NOV-93	57	F/B_0.8	12.58	12° 27.4'	140° 55.0'	12° 25.6'	140° 55.0'
228	20-NOV-93	57	F/B_0.8	14.08	12° 23.2'	140° 56.0'	12° 21.1'	140° 56.0'
229	20-NOV-93	53	F/B_0.8	16.16	12° 24.9'	141° 02.0'	12° 22.2'	141° 02.2'
230	20-NOV-93	19	FF_1.5	20.33	12° 31.8'	141° 30.9'	12° 33.7'	141° 30.9'
231	20-NOV-93	15	FF_1.5	21.91	12° 35.2'	141° 31.0'	12° 33.8'	141° 31.0'
232	20-NOV-93	17	FF_1.5	23.41	12° 31.7'	141° 31.1'	12° 30.1'	141° 31.4'
233	21-NOV-93	18	FF_1.5	00.92	12° 27.9'	141° 31.9'	12° 29.6'	141° 31.3'
234	21-NOV-93	19	FF_1.5	01.83	12° 30.1'	141° 30.8'	12° 28.5'	141° 30.8'
235	21-NOV-93	17	FF_1.5	02.92	12° 27.4'	141° 32.3'	12° 28.3'	141° 31.7'
236	21-NOV-93	18	FF_1.5	03.83	12° 28.9'	141° 31.4'	12° 27.2'	141° 32.0'
237	21-NOV-93	53	F/B_0.0	08.75	12° 31.5'	141° 00.9'	12° 29.4'	141° 01.2'
238	21-NOV-93	57	F/B_0.0	11.41	12° 28.7'	140° 54.7'	12° 27.2'	140° 54.1'
239	21-NOV-93	58	F/B_0.0	13.16	12° 27.6'	140° 54.6'	12° 25.4'	140° 55.3'
240	21-NOV-93	57	F/B_0.0	14.50	12° 23.2'	140° 56.6'	12° 21.4'	140° 57.2'
241	21-NOV-93	52	F/B_0.0	16.33	12° 25.8'	141° 02.2'	12° 23.7'	141° 02.5'
242	21-NOV-93	19	FF_1.5	20.33	12° 27.4'	141° 31.8'	12° 25.9'	141° 32.8'
243	21-NOV-93	18	FF_1.5	21.91	12° 26.7'	141° 32.5'	12° 28.5'	141° 31.9'
244	21-NOV-93	18	FF_1.5	23.16	12° 31.3'	141° 30.9'	12° 33.0'	141° 30.7'
245	22-NOV-93	15	FF_1.5	00.25	12° 34.8'	141° 30.9'	12° 33.3'	141° 31.0'
246	22-NOV-93	17	FF_1.5	01.33	12° 31.7'	141° 31.1'	12° 30.2'	141° 31.5'
247	22-NOV-93	17	FF_1.5	02.25	12° 29.4'	141° 31.9'	12° 30.8'	141° 31.4'
248	22-NOV-93	16	FF_1.5	03.17	12° 32.1'	141° 31.2'	12° 33.4'	141° 31.1'
249	22-NOV-93	18	FF_1.5	04.17	12° 33.6'	141° 31.0'	12° 31.6'	141° 31.0'
250	22-NOV-93	42	F/B_0.0	08.33	12° 40.9'	141° 08.6'	12° 38.8'	141° 08.6'
251	22-NOV-93	46	F/B_0.0	10.16	12° 41.8'	141° 00.9'	12° 40.0'	141° 00.8'

252	22-NOV-93	44	F/B_0.0	12.58	12° 39.6'	141° 05.1'	12° 38.0'	141° 05.2'
253	22-NOV-93	42	F/B_0.0	14.16	12° 37.1'	141° 08.9'	12° 35.3'	141° 08.9'
254	22-NOV-93	44	F/B_0.0	16.08	12° 33.6'	141° 07.0'	12° 31.7'	141° 07.1'
255	22-NOV-93	16	FF_1.5	19.91	12° 32.9'	141° 31.2'	12° 35.3'	141° 31.2'
256	22-NOV-93	16	FF_1.5	21.83	12° 35.7'	141° 30.7'	12° 32.9'	141° 30.6'
257	22-NOV-93	17	FF_1.5	23.50	12° 32.1'	141° 31.1'	12° 33.7'	141° 31.0'
258	23-NOV-93	15	FF_1.5	01.08	12° 35.9'	141° 30.5'	12° 34.1'	141° 30.9'
259	23-NOV-93	17	FF_1.5	02.17	12° 32.0'	141° 30.9'	12° 30.1'	141° 31.2'
260	23-NOV-93	18	FF_1.5	03.17	12° 28.8'	141° 31.6'	12° 27.2'	141° 32.2'
261	23-NOV-93	18	FF_1.5	04.08	12° 26.6'	141° 32.7'	12° 28.0'	141° 32.1'
262	23-NOV-93	42	F/B_0.8	08.20	12° 41.5'	141° 09.2'	12° 40.0'	141° 09.4'
263	23-NOV-93	42	F/B_0.8	10.16	12° 41.2'	141° 01.4'	12° 39.3'	141° 01.7'
264	23-NOV-93	46	F/B_0.8	12.91	12° 39.5'	141° 04.9'	12° 37.6'	141° 05.0'
265	23-NOV-93	42	F/B_0.8	14.50	12° 36.6'	141° 09.0'	12° 34.7'	141° 09.1'
266	23-NOV-93	45	F/B_0.8	16.41	12° 33.3'	141° 06.8'	12° 31.3'	141° 07.1'
267	23-NOV-93	17	FF_1.5	19.75	12° 33.9'	141° 30.6'	12° 32.4'	141° 31.0'
268	23-NOV-93	18	FF_1.5	21.08	12° 29.0'	141° 31.7'	12° 27.4'	141° 32.4'
269	23-NOV-93	18	FF_1.5	22.08	12° 26.6'	141° 32.7'	12° 27.9'	141° 32.2'
270	23-NOV-93	17	FF_1.5	23.08	12° 29.7'	141° 31.6'	12° 31.4'	141° 31.2'
271	24-NOV-93	16	FF_1.5	00.17	12° 33.6'	141° 30.9'	12° 35.3'	141° 31.0'
272	24-NOV-93	15	FF_1.5	01.17	12° 35.8'	141° 30.7'	12° 34.3'	141° 30.7'
273	24-NOV-93	17	FF_1.5	02.42	12° 32.1'	141° 31.0'	12° 30.6'	141° 31.2'
274	24-NOV-93	17	FF_1.5	03.33	12° 29.3'	141° 31.7'	12° 27.8'	141° 32.4'
275	24-NOV-93	17	FF_1.5	04.42	12° 27.5'	141° 32.4'	12° 29.1'	141° 31.6'
276	24-NOV-93	42	F/B_0.4	08.67	12° 38.6'	141° 09.5'	12° 36.7'	141° 09.6'
277	24-NOV-93	50	F/B_0.4	10.41	12° 40.7'	141° 06.0'	12° 38.1'	141° 01.1'
278	24-NOV-93	45	F/B_0.4	12.67	12° 39.4'	141° 04.7'	12° 37.6'	141° 04.7'
279	24-NOV-93	43	F/B_0.4	14.16	12° 37.4'	141° 08.7'	12° 35.9'	141° 08.7'
280	24-NOV-93	37	F/B_0.4	16.33	12° 33.0'	141° 07.0'	12° 33.0'	141° 07.0'
281	24-NOV-93	16	FF_1.5	20.00	12° 33.8'	141° 30.7'	nd	nd
282	24-NOV-93	18	FF_1.5	21.58	12° 29.6'	141° 31.5'	12° 28.1'	141° 32.3'
283	24-NOV-93	18	FF_1.5	22.83	12° 28.8'	141° 32.5'	12° 29.2'	141° 31.8'
284	25-NOV-93	18	FF_1.5	00.00	12° 30.1'	141° 31.3'	12° 31.6'	141° 31.0'
285	25-NOV-93	18	FF_1.5	01.00	12° 32.5'	141° 30.7'	12° 30.5'	141° 30.9'
286	25-NOV-93	18	FF_1.5	02.00	12° 28.7'	141° 31.6'	12° 26.7'	141° 32.2'
287	25-NOV-93	17	FF_1.5	02.92	12° 26.0'	141° 32.8'	12° 27.5'	141° 32.0'
288	25-NOV-93	18	FF_1.5	03.83	12° 29.5'	141° 31.4'	12° 31.2'	141° 31.6'
289	25-NOV-93	18	FF_1.5	04.75	12° 31.6'	141° 30.8'	12° 29.9'	141° 31.2'
290	25-NOV-93	12	F/B_0.0	17.50	10° 34.0'	141° 59.0'	10° 34.0'	142° 00.0'
291	26-NOV-93	19	FF	12.00	10° 52.5'	142° 55.6'	10° 52.5'	142° 57.5'
292	26-NOV-93	20	FFCAM	12.92	10° 52.8'	142° 58.6'	10° 52.8'	142° 55.9'
293	26-NOV-93	20	FFCAM	15.57	10° 52.4'	142° 57.9'	nd	nd
294	26-NOV-93	30	FF	23.83	11° 52.4'	143° 12.3'	11° 50.5'	143° 10.7'
295	27-NOV-93	30	FF	00.58	11° 50.8'	143° 11.1'	11° 52.2'	143° 12.3'
296	27-NOV-93	32	FF	02.33	11° 52.4'	143° 12.4'	11° 50.7'	143° 10.8'

2. SS295 WEIPA - WEIPA
13 FEBRUARY - 9 MARCH 1995
FRV *SOUTHERN SURVEYOR*

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Itinerary

Leg 1	Departed Weipa:	2000 h Monday, 13 February 1995
	Arrived Weipa:	0800 h Monday, 27 February 1995
Leg 2	Departed Weipa:	1800 h Monday, 27 February 1995
	Arrived Weipa:	1150 h Thursday, 9 March 1995

CRUISE OBJECTIVES

1. To test various prawn net modifications for their effectiveness in reducing the catch of non-target species in the tiger prawn fishery off Weipa without significant loss of commercial prawns.
2. To obtain daytime video images of these devices and their effects on fish behaviour in the net during trawling
3. To test the catchability of fishes using reduced sweeps in a semi-pelagic fish trawl.
4. To test the effect of a verandah panel set at different levels of the MB T on reducing bycatch and maintaining prawn catches.
5. To collect whole specimens for the Hobart Fish Taxonomy Group's Handbook of Commercial Fishes (Ross Daley)
6. To collect representative specimens of cephalopods for QDPI Fisheries in the sample areas (Julie Robins).
7. To collect museum specimens of sponges and invertebrates for Queensland Museum (Steve Cook) and AIMS (Rob McCauley).
8. To opportunistically collect genetic samples of *Thenus* spp. (University of Queensland), and scombrid/sillaginid species (QDPI Fisheries).
9. To deploy and retrieve an acoustic recorder package near the prawn trawl sites to record biological and trawler acoustic signals (AIMS, Rob McCauley).

AREA OF OPERATION

West of Weipa, Gulf of Carpentaria between 12°S - 13°S, and 140° 50'E and 141° 35'E (see Figure 9).

Results

1 Eight Bycatch Reduction Devices (BRDs) and a control or standard prawn net codend were tested over 21 nights and 153 paired trawls. The five most successful BRDs were compared more intensively during the last seven nights.

2 Video images of fish behaviour in both the prawn net BRDs and the fish-trawl net fitted with the BRDs were obtained during leg 1 when weather conditions were favourable. No video recordings of the EFN trawls were possible during leg 2.

3 Ten days of EFN fish trawls, 43 trawls, were completed on the fish grounds about 25 nm west of Duyfken Point with 2 stations lost due to returning a journalist to Weipa and 5 stations were lost due to cyclone 'Warren'.

4 The Multi-level Beam Trawl (MBT) work was not completed after the second, and irretrievable collapse of the MBT during the second night of operation. Only four trawls were completed and the remaining time allocated to it was profitably used to increase the number of BRD paired trawls.

5. Ross Daley was able to collect 130 fish specimens for the Hobart Fish Taxonomy Group.

6. Representative specimens of cephalopods were retained for QDPI Fisheries from inshore prawn grounds and offshore fish-trawl grounds. Julie Robins also tagged 11 turtles during prawn trawling on leg 1.

7. Most sponges and invertebrates were collected during leg 1 due to their availability. Rob McCauley collected 176 samples (leg 1) and Steve Cook collected 20 specimens not recorded from his previous cruises.

8. Whole specimens of three species of *Thenus* were collected for Ted Burton (University of Queensland). Frames of at least three species of scombrid and whole specimens of sillaginids were collected during both legs for QDPI Fisheries.

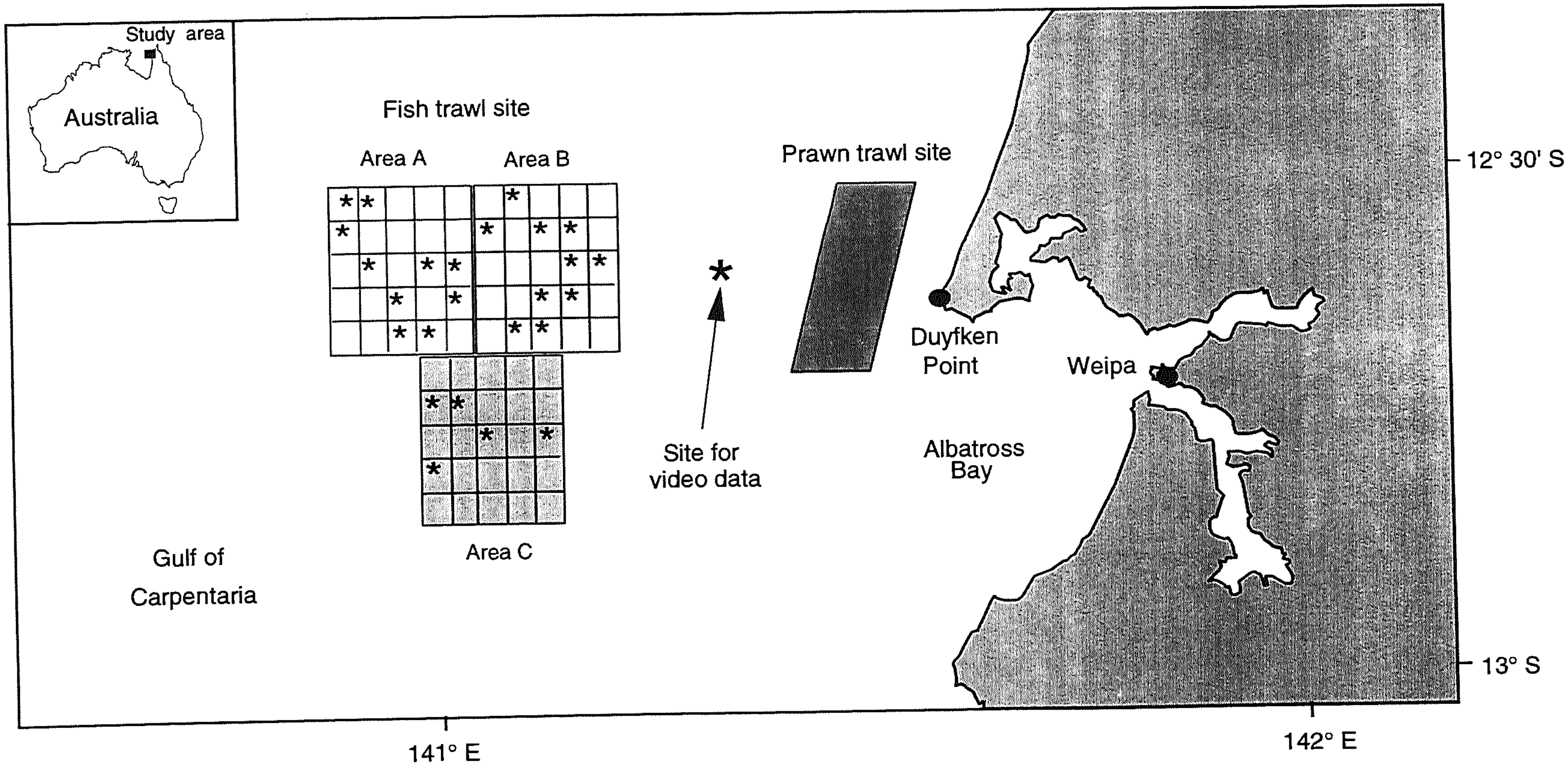
9. The AIMS acoustic recorder was deployed and retrieved twice during the first leg. Once near the inshore prawn grounds for four days and once near the offshore fish-trawl grounds for three days. Successful recordings were obtained from both deployments.

Cruise Narrative

Southern Surveyor departed Weipa at 2000 h on 13 February 1995. At a cruise debriefing soon after departure, Leg 1 objectives were explained, shifts allocated and first time participants informed of ship safety and day to day house-keeping procedures. The Master, Bruce Wallis, advised of a Muster and Fire drill the next day at 1300 h; this drill was successfully completed. After arriving at the prawn trawl grounds five nautical miles west of Duyfken Point, the paired Florida Flyer prawn trawl nets were tested for even catching ability using normal codends (diamond-mesh). The first trawl was successfully deployed at 05:50 h the next morning with both nets recording similar catches, 220 k in the port side net and 226 k in the starboard side net. The rest of the daytime was then occupied with testing of the codend Bycatch Reduction Devices (BRDs) to be used during the next night of sampling. During the day, the Australian Institute of Marine Science acoustic recorder was deployed close to the prawn trawl site to record trawler generated noise and fish sounds. The acoustic housing was recovered four days later; a preliminary check of the tape recording revealed that the *Southern Surveyor* noise swamped all other sounds. A second deployment in deeper water near the EFN trawl site recorded successfully for three days. The pattern of trawling during a complete day involved night prawn trawling in approximately 20 m depth west of Duyfken Point and day time trawling in clearer (30 - 40 m depth) water further west. Towards the end of the first leg and all through the second leg, day time fish trawling with the EFN was situated about 25 nm west of Duyfken Point (see Figure 20 for grids sampled).

The Communications Group in Hobart arranged for Simon Grose, a journalist from the Canberra Times, to spend a day on board *Southern Surveyor* from the first day of leg 2. This involved one scientific crew (Clive Liron) remaining ashore for that day and exchanging with the journalist via the CSIRO chartered fish trawler F.V. *Clipper Bird* near the shipping channel. At the same time, the ships crew was reinforced with the arrival of AB Ross Hay replacing AB Colin Haebick. Work continued smoothly until trawling was halted for 36 hours from 0800 h on Sunday 5 March, due to cyclone 'Warren'. The sampling was terminated one day early due to increasing winds and the related danger to the crew and difficulty in deploying gear.

Figure 20. Locations of the study areas during the SS295 cruise (i) semi-pelagic fish trawl study -Areas A, B and C and (ii) Prawn trawl bycatch reduction study. Daytime video taping of prawn bycatch reduction devices was located between the two sites for optimum light penetration and weater clarity. Area C was superimposed over Areas A and B.
*= 2 nm grids sampled with the semi-pelagic fish trawl using long and medium length sweeps.



Night time sampling

All night time prawn trawling was carried out in approximately 20 m depth along a north–south path centred 5 nm west of Duyfken Point. Tuesday night, 14 February, marked the beginning of the BRD comparison trawls. The sampling design for BRD paired comparisons was changed from the original method proposed in the cruise plan. Instead of using the same pair of codends (one control and one of eight BRDs) in consecutive trawls over two nights, each trawl was a different combination of all nine gear types, such that each gear type was paired against each of the other types once. This required 36 trawls to complete one round of all possible pairings. Within each round, each BRD was equally used on both port and starboard sides. After this first round, any BRD that was obviously inferior with regard to prawn retention and bycatch reduction were eliminated from the next round of comparisons. However, the results were not clear enough to eliminate any BRD and a second round of 36 paired comparison trawls was started. Catches of prawns in these nets were low initially but gradually numbers increased and efforts were made to avoid locations with high banana prawn (*Penaeus merguiensis*) abundances as these were of no interest to the aims of the project. Most trawls contained more than enough tiger prawns to allow comparisons of the bycatch reduction and tiger prawn retention abilities of the various BRDs.

On completion of the second round of prawn trawls (giving a total of 72 paired trawls), two BRDs were eliminated from the third round, the square-mesh window with glow netting and the square-mesh window with hummer. The six other BRDs, plus the control were paired for 21 trawls over four nights, after which the Super Shooter grid was eliminated. This allowed a 15 trawl comparison as the fourth and final round of the five most efficient BRDs, before the allocated time for the MBT.

During this time, many trawls were rendered invalid because of gear failure and sharks bites in the codends. The 21 paired trawls for round three required 36 trawls before completion. To overcome some of these wasted trawls, codends were successfully protected from shark bites with a second codend "skirt".

Round four was completed Friday morning, 3 March, in time to allow for the allocated seven nights of MBT trawls half way through leg 2. Before sampling began, the MBT folded at right angles near one sled during it's second trial deployment. Sea conditions were rough and unfavourable for towing the MBT, but after consultation with the Chief Engineer, Ian McAllister, repairs were made which shortened the beam by about 0.7 m. This was achieved in about four hours under difficult sea conditions and occasional driving rain. Ian McAllister and John Hinchliffe are firmly recognised for their efforts here. After several precautionary trial deployments, four MBT trawls were completed by dawn Saturday 4 March.

On the first trawl the next night, the MBT once again folded at right angles just at the end of the reinforcing welded on earlier. This time the damage was assessed as terminal and the ship's crew prepared to resume prawn trawling with the paired Florida Flyers for more BRD comparisons.

The prawn trawling gear was ready after five hours and two trawls were completed in round 5 of the 15 paired comparison trawls. Sea conditions continued to deteriorate during this time and the tropical low causing the conditions had strengthened into cyclone 'Warren', category 1 about 100 nm south of our position. As a result of these conditions, all trawling activity ceased from 0800 h on Sunday, 5 March. Cyclone 'Warren' intensified to category 2 at 2000h and crossed the mainland coast south west of Mornington Island at around 0300 h on Monday 6 March. *Southern Surveyor* continued along an east–west track at reduced speed while waiting for conditions to abate. Winds persisted at 25-40 knots with occasional squalls above 50 knots. Trawling recommenced at 2000 h Monday 6 March with round five of the BRD paired trawls. During hauling of the fourth trawl of the evening, the main five ton swivel from the warp to the bridle gave way as it entered the winch drum. The bridle, boards and nets were lost overboard in an extremely dangerous situation with the wires sliding back to the main block in a few seconds. Fortunately, nobody was in the vicinity which is the normal safety situation during deployment and hauling of trawl gear. The position was marked on the GPS plotter to guide retrieval of the gear. Once again Ian McAllister and John Hinchliffe constructed a large, heavy duty grappling device to be dragged from the towed body winch. The trawl gear was hooked on the first pass. Substantial damage was incurred on the net, wires and Nordmøre grid device and the rest of the night was spent sorting and repairing the prawn trawl gear. The ship's crew worked diligently towards returning the prawn gear to a workable stage, despite these difficulties.

New nets were assembled the next night, Tuesday 7 March, because of the extensive damage to the previous nets and the first trial trawl was finally shot away after midnight. Round five was started again and three more of the 15 planned trawls were completed. This left nine trawls to complete on the last two nights of the cruise. At this stage, live ripe *P. semisulcatus* females were kept when possible for return to Cleveland (B. J. Hill). Only two prawn trawls were completed on the next night due to the heavy seas and their effect on net deployment. The new bridles were not exactly the same length and this caused the boards to tangle as the nets were shot away. This created dangerous conditions for the crew when trying to sort out the tangled gear. Winds increased during the night and the Master and Fishing Masters stopped trawling at dawn. *Southern Surveyor* sailed for Weipa one day early at about 0800 h.

Daytime sampling

On the first day, Lyndsay MacDonald booted the SUN Oracle database software to enable direct data entry from the fish laboratory as on previous cruises. Some problems were encountered. The species reference database was an old incomplete version and the data entry was reduced to manual recording for the first day. Data entry proceeded well once these problems were overcome, until the second leg when the SUN failed for a day and a half. Again data was manually recorded and eventually re-entered onto Oracle when Jeff Cordell successfully re-established operations on the SUN.

Prawn nets were tested on the first day for uniformity of catch between port and starboard nets using standard (control) nets. When catches were similar in both nets (220.8 k port and 226.7 k starboard), the first BRDs to be used at night were tested in daylight to ensure they functioned properly. The second day, Wednesday 15 February, was used as the first of seven days of video taping of all the BRDs. These BRD video trawls were carried out in ~35 m water which was less turbid than the 20 m depth night-time trawling. Some excellent tapes of fish behaviour in the various devices was obtained from the codend mounted cameras despite difficulties with the cameras and their housings.

Two more days were spent video taping the Super Shooter BRD fitted to the fish-trawl net (McKenna Wing Trawl) in an attempt to record large animals (rays, sharks or turtles) being excluded from the net by the Super Shooter grid device. Some useful recordings were obtained but most of these attempts failed due to poor visibility. Conditions became more overcast during the last day of leg 1 and video taping became less productive due to reduced light penetration at these depths. Prior to this, conditions at sea had been uncharacteristically calm and sunny much of the time with only occasional rain.

The EFN fish trawl was tested using long (40 m sweep plus 50 m bridle = 90 m), medium (30 m sweep plus 20 m bridle = 50 m) and no sweeps (bridle = 20 m) on Friday 25 February. Unfortunately, the no sweeps treatment would not stabilise off the bottom (as detected by Scanmar) without time consuming modifications and consequently was eliminated from the experiment. Hence the EFN comparisons were reduced to long versus medium sweeps. Three 10 x 10 nm areas were planned with each trawl grid chosen at random from 25, 2 x 2 nm grids (see Figure 20). One gear type was used per day with the same five grids sampled by both long and medium sweeps gear and then a second set of five grids was selected and the sampling repeated over the next two days. Hence, there were four days sampling in each of three areas.

Area A was half completed at the end of leg 1 and completed on the second day of leg 2. The first day of leg 2 saw only the first three grids sampled with the EFN long sweeps as *Southern Surveyor* had to drop off Simon Grose, a journalist with the Canberra Times, and collect Clive Liron and AB Ross Hay, a replacement crew for AB Colin Haebick. Three days sampling was completed in Area B before cyclone 'Warren' caused a halt in trawling from 0800 h Sunday 5 March until 2000 hr Monday 6 March. Area B was completed on Tuesday, 7 March with sea conditions still moderate to rough.

Area C was selected to overlap two fifths of Area A and three fifths of Area B and the five grids to be completed in the two days remaining were chosen to exclude any grids already sampled in Areas A and B. This was done to concentrate the remaining EFN trawls adjacent to grids which had previously recorded commercial species of fish. Four of these grids produced commercial species with the third grid producing 123 *L. erythropterus*. The second day of trawling on Area C was not completed as *Southern Surveyor* returned to Weipa one day early due to deteriorating sea conditions. The sea conditions were affecting the behaviour of the EFN (inferred from the Scanmar data and substrate retained in the net) which is designed to ride 0.5 m above the bottom.

All the biological data were copied to a cassette tape for down loading to the Cleveland SUN Sparc station.

Summary

The Bycatch Reduction in Prawn Trawls project tested eight devices (Nordmøre grid, Super Shooter, square-mesh with black cylinder, square-mesh window, square-mesh with glow mesh, square-mesh with hummer, fisheye, radial escape section). The five most successful BRDs were compared more intensively during the last seven nights. Clear video images of fish behaviour in codends and escaping from the various devices were obtained for the first time. The EFN net comparisons in the Gulf of Carpentaria were the final stage of an assessment of the new "environmentally friendly net" recommended for the Northern Trawl Fishery. The Tropical Fish Ecology project now has valuable catch and video information about the operation of the type of net envisaged for the fishery.

Samples of scombrids and whole cephalopods were obtained for QDPI Fisheries. Tissue samples from *L. malabaricus*, *L. sebae* and other species were obtained for population genetic studies in the Hobart genetics laboratory.

The fish collection for the Seafood Handbook (Hobart) obtained 130 genetic specimens, as well as whole frozen and preserved fish including valuable additions to the ray collection.

Queensland Museum and AIMS collected invertebrates and sponges as well as two valuable acoustic recordings of trawler noise and background fish sounds.

Reporting of results

The results will be analysed and reported in the scientific literature where appropriate. All the collected data resides on the Oracle database at the CSIRO Marine Laboratories in Cleveland.

Personnel

(Note: unless otherwise stated, all personnel are staff of the CSIRO Division of Fisheries or students based at CSIRO Cleveland.)

Scientific Crew

Leg 1

Mr John Salini (Cruise & shift leader)
Mr David Brewer (second shift leader)
Mr Nick Rawlinson
Mr Ted Wassenberg
Mr Steve Eayrs (AMC)
Mr Marcus Strauss (AMC sponsored volunteer)
Mr John MacCartie (NT Fisheries)
Mr Lyndsay MacDonald
Ms Julie Robins (QDPI)
Ms Emma Hopkins (student volunteer)
Mr Michael O'Neill (student volunteer)
Mr Robert McCauley (AIMS)

Leg 2

Mr John Salini (Cruise & shift leader)
Mr David Brewer (second shift leader)
Mr Nick Rawlinson
Mr Clive Liron
Mr Steve Eayrs (AMC)
Mr Rik Buckworth (NT Fisheries)
Mr Neville Gill (NT Fisheries)
Mr Jeff Cordell
Mr Ross Daley
Ms Liz Cameron
Ms Fiona Manson
Mr Steve Cook (Q Museum)
Mr Lyndsay MacDonald

Ship's Crew

Bruce Wallis	Master, (Leg 1)
Ian Taylor	Master, (Leg 2)
Ian McAllister	Chief Engineer
Rick Miller	First Engineer
John Hinchliffe	Electrical Engineer
Tony Hearne	Bosun
Alan Brownlie	A. B.
Colin Haebick	A. B. (Leg 1)
Phil Lee	A. B.
John Spinks	A. B.
Len Darling	A. B.
Lou Jacomos	A. B.
Drew Meincke	Greaser
Noel Anderson	Chief Steward
Alan Smith	Chief Cook
Don Collins	Second Cook
Ross Hay	A. B. (Leg 2)

Acknowledgments

We thank the Masters, Bruce Wallis (Leg 1) and Ian Taylor (Leg 2); the Fishing Masters, Roger Pepper and John Boyes and the crew of *Southern Surveyor* for their skills during the cruise. The crew's cooperation by sailing short-handed on the first day of Leg 2 is especially appreciated. Steve Eayrs, Marcus Strauss (AMC), John MacCartie and Neville Gill (NT Fisheries) contributed many extra hours of duty setting-up and testing the BRDs (prawn trawling) and the EFN as well as managing the video taping from both the fish and prawn nets.

Cruise Leader

John Salini

Chief, CSIRO Division of Fisheries

P. C. Young

Contacts

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This report may not be cited without reference to the author(s).

Distribution

- Normal circulation,
- Cruise participants

Table 17. Stations occupied by *Southern Surveyor* during Cruise SS295.

Time: start time in decimal hours; F-Flyers: Florida Flyer prawn trawl, daytime trawls included a video camera; Fish/Video: Frank & Bryce fish trawl with video camera; EFNLong: Environmentally Friendly fish-trawl Net with Long (90 m) sweeps; EFNMedium: Environmentally Friendly fish-trawl Net with Medium (50 m) length sweeps; MBT: Multi-level Beam Trawl; StartLat: start latitude; StartLong: start longitude; EndLat: end latitutde; EndLong: end longitude; Depth: depth in metres

Stn	Time	Date	Gear	Depth	StartLat	StartLong	EndLat	EndLong
1	5.83	14-Feb-95	F_Flyers	28	12°29.9'	141°29.0'	12°28.8'	141°29.6'
2	10.42	14-Feb-95	F_Flyers	22	12°35.1'	141°28.5'	12°34.0'	141°28.8'
3	14.67	14-Feb-95	F_Flyers	24	12°28.2'	141°29.4'	12°30.3'	141°29.5'
4	18.75	14-Feb-95	F_Flyers	23	12°29.1'	141°29.0'	12°28.0'	141°29.3'
5	21.83	14-Feb-95	F_Flyers	22	12°33.0'	141°21.7'	12°34.9'	141°28.8'
6	0.33	15-Feb-95	F_Flyers	21	12°29.1'	141°29.6'	12°27.6'	141°30.2'
7	1.83	15-Feb-95	F_Flyers	20	12°2.6.2'	141°30.5'	12°27.6'	141°30.4'
8	4.58	15-Feb-95	F_Flyers	23	12°30.0'	141°29.4'	12°28.4'	141°29.6'
9	6.25	15-Feb-95	F_Flyers	22	12°27.2'	141°29.9'	12°28.9'	141°30.1'
10	10.25	15-Feb-95	F_Flyers	40	12°30.3'	141°18.4'	12°28.6'	141°18.2'
12	14.17	14-Feb-95	F_Flyers	40	12°32.3'	141°17.7'	12°34.8'	141°18.0'
13	17.67	15-Feb-95	F_Flyers	38	12°29.8'	141°19.3'	12°28.5'	141°19.4'
14	20.92	15-Feb-95	F_Flyers	22	12°27.0'	141°29.4'	12°28.5'	141°29.4'
15	23.33	15-Feb-95	F_Flyers	22	12°28.3'	141°29.6'	12°26.7'	141°29.8'
16	1.33	16-Feb-95	F_Flyers	20	12°27.2'	141°29.9'	12°28.7'	141°29.9'
17	2.75	16-Feb-95	F_Flyers	21	12°31.4'	141°29.8'	12°32.0'	141°29.7'
18	3.92	16-Feb-95	F_Flyers	20	12°35.5'	141°39.3'	12°35.3'	141°29.0'
19	8.33	16-Feb-95	F_Flyers	34	12°32.4'	141°21.4'	12°31.1'	141°21.3'
20	9.92	16-Feb-95	F_Flyers	35	12°29.9'	141°20.9'	12°32.8'	141°21.0'
21	12.75	16-Feb-95	F_Flyers	33	12°36.6'	141°21.6'	12°35.1'	141°21.5'
22	14.17	16-Feb-95	F_Flyers	34	12°32.5'	141°21.1'	12°31.2'	141°21.1'
23	15.42	16-Feb-95	F_Flyers	36	12°30.1'	141°21.2'	12°32.2'	141°21.5'
24	19.83	16-Feb-95	F_Flyers	21	12°28.0'	141°29.3'	12°26.4'	141°29.6'
25	22.83	16-Feb-95	F_Flyers	23	12°31.5'	141°28.7'	12°33.0'	141°29.3'
26	0.17	17-Feb-95	F_Flyers	22	12°31.9'	141°29.0'	12°30.3'	141°29.2'
27	1.42	17-Feb-95	F_Flyers	22	12°27.4'	141°29.6'	12°25.7'	141°30.0'
28	3.00	17-Feb-95	F_Flyers	20	12°28.6'	141°30.5'	12°30.0'	141°30.4'
29	4.25	17-Feb-95	F_Flyers	20	12°31.1'	141°29.9'	12°29.3'	141°30.0'
30	5.42	17-Feb-95	F_Flyers	22	12°27.5'	141°30.0'	12°29.3'	141°30.2
31	13.58	17-Feb-95	F_Flyers	34	12°36.4'	141°21.6'	12°34.8'	141°21.6'
32	14.83	17-Feb-95	F_Flyers	34	12°32.1'	141°21.5'	12°30.6'	141°21.5'
33	16.00	17-Feb-95	F_Flyers	35	12°30.8'	141°21.1'	12°32.5'	141°20.9'
34	17.17	17-Feb-95	F_Flyers	34	12°34.4'	141°20.9'	12°33.2	141°21.2
35	19.83	17-Feb-95	F_Flyers	21	12°31.6'	141°29.7'	12°30.6'	141°29.9'
36	20.92	17-Feb-95	F_Flyers	21	12°28.8'	141°30.1'	12°27.5'	141°30.2
37	22.42	17-Feb-95	F_Flyers	21	12°28.1'	141°30.1'	12°29.7'	141°30.0'
38	23.67	17-Feb-95	F_Flyers	20	12°31.4'	141°29.6'	12°29.7'	141°29.8'
39	0.67	18-Feb-95	F_Flyers	20	12°28.1'	141°29.9'	12°26.1'	141°30.2
40	2.00	18-Feb-95	F_Flyers	21	12°26.0'	141°30.3'	12°27.8'	141°30.1'
41	4.92	18-Feb-95	F_Flyers	21	12°30.3'	141°30.0'	12°31.6'	141°30.0'
42	5.92	18-Feb-95	F_Flyers	22	12°31.1'	141°29.4'	12°29.5'	141°29.5'
43	9.17	18-Feb-95	F_Flyers	39	12°29.0'	141°18.4'	12°27.9'	141°18.3'
44	12.17	18-Feb-95	F_Flyers	39	12°31.4'	141°17.7'	12°30.3'	141°17.6'
45	13.92	18-Feb-95	F_Flyers	39	12°28.0'	141°17.7'	12°30.0'	141°17.6'
46	15.00	18-Feb-95	F_Flyers	34	12°35.8'	141°21.1'	12°34.6'	141°21.9'

47	16.00	18-Feb-95	F_Flyers	34	12°35.8'	141°21.1'	12°34.5'	141°21.9'
48	19.67	18-Feb-95	F_Flyers	26	12°32.5'	141° 27.9'	12°31.5'	141°28.5'
49	21.67	18-Feb-95	F_Flyers	23	12°30.4'	141°29.3'	12°27.2	141°29.8'
50	22.67	18-Feb-95	F_Flyers	23	12°27.5'	141°29.2	12°29.1'	141°12.9'
51	23.67	18-Feb-95	F_Flyers	24	12°31.3'	141°28.4'	12°33.1'	141°12.8'
52	1.33	19-Feb-95	F_Flyers	23	12°29.8'	141°28.7'	12°28.5'	141°29.9'
53	2.50	19-Feb-95	F_Flyers	20	12°28.1'	141°30.2'	12°29.6'	141°30.2'
54	3.42	19-Feb-95	F_Flyers	20	12°30.2'	141°30.1'	12°29.1'	141°30.2'
55	4.42	19-Feb-95	F_Flyers	21	12°27.1'	141°30.4'	12°25.3'	141°30.5'
56	5.67	19-Feb-95	F_Flyers	22	12°26.6'	141°30.1'	12°28.3'	141°29.8'
57	9.08	19-Feb-95	F_Flyers	34	12°35.3'	141°21.1'	12°33.8'	141°21.0'
58	10.75	19-Feb-95	F_Flyers	35	12°30.9'	141°20.9'	12°32.8'	141°20.8'
59	12.42	19-Feb-95	F_Flyers	33	12°36.6'	141°21.2'	12°35.2'	141°21.0'
60	14.17	19-Feb-95	F_Flyers	34	12°34.2'	141°20.6'	12°32.7'	141°21.0'
61	16.00	19-Feb-95	F_Flyers	34	12°34.2'	141°20.6'	12°36.2'	141°20.5'
62	17.50	19-Feb-95	F_Flyers	33	12°36.2'	141°20.5'	12°34.0'	141°20.6'
63	19.92	19-Feb-95	F_Flyers	25	12°33.0'	141°27.9'	12°31.8'	141°28.6'
64	21.08	19-Feb-95	F_Flyers	23	12°29.7'	141°29.1'	12°28.4'	141°29.4'
65	22.25	19-Feb-95	F_Flyers	22	12°26.1'	141°29.7'	12°24.8'	141°30.0'
66	23.42	19-Feb-95	F_Flyers	21	12°26.7'	141°30.0'	12°28.7'	141°29.8'
67	1.50	20-Feb-95	F_Flyers	22	12°30.0'	141°29.7'	12°28.3'	141°30.0'
68	2.67	20-Feb-95	F_Flyers	21	12°27.2'	141°30.0'	12°29.2'	141°29.8'
69	3.75	20-Feb-95	F_Flyers	22	12°31.5'	141°29.4'	12°31.1'	141°28.9'
70	9.00	20-Feb-95	F_Flyers	24	12°29.7'	141°28.9'	12°28.7'	141°29.5'
71	10.67	20-Feb-95	F_Flyers	22	12°31.9'	141°29.4'	12°33.8'	141°29.0'
72	13.17	20-Feb-95	F_Flyers	24	12°30.7'	141°28.4'	12°29.5'	141°29.1'
73	15.83	20-Feb-95	F_Flyers	23	12°30.1'	141°28.9'	12°27.8'	141°29.7'
74	17.25	20-Feb-95	F_Flyers	23	12°27.2'	141°29.8'	12°29.3'	141°29.6'
75	19.67	20-Feb-95	F_Flyers	24	12°30.2'	141°29.1'	12°32.0'	141°29.0'
76	20.75	20-Feb-95	F_Flyers	23	12°33.8'	141°28.8'	12°32.5'	141°29.1'
77	22.75	20-Feb-95	F_Flyers	23	12°28.9'	141°29.5'	12°31.0'	141°29.4'
78	23.67	20-Feb-95	F_Flyers	21	12°32.8'	141°29.4'	12°34.4'	141°29.3'
79	1.42	21-Feb-95	F_Flyers	22	12°32.1'	141°28.9'	12°30.5'	141°29.0'
80	2.42	21-Feb-95	F_Flyers	24	12°28.8'	141°28.9'	12°27.0'	141°28.9'
81	3.33	21-Feb-95	F_Flyers	24	12°26.2'	141°29.0'	12°28.0'	141°28.9'
82	4.33	21-Feb-95	F_Flyers	24	12°29.7'	141°29.0'	12°31.5'	141°29.0'
83	5.25	21-Feb-95	F_Flyers	22	12°33.3'	141°29.0'	12°35.1'	141°29.0'
84	9.33	21-Feb-95	F_Flyers	38	12°28.5'	141°19.7'	12°27.0'	141°19.8'
85	11.50	21-Feb-95	F_Flyers	36	12°31.9'	141°20.1'	12°30.6'	141°20.8'
86	13.50	21-Feb-95	F_Flyers	36	12°29.3'	141°20.9'	12°27.7'	141°21.2'
87	15.13	21-Feb-95	F_Flyers	35	12°28.7'	141°21.1'	12°30.0'	141°21.1'
88	16.67	21-Feb-95	F_Flyers	36	12°29.5'	141°20.9'	12°28.0'	141°21.3'
89	19.50	21-Feb-95	F_Flyers	22	12°31.2'	141°29.3'	12°32.9'	141°29.2'
90	20.58	21-Feb-95	F_Flyers	22	12°34.5'	141°29.5'	12°32.8'	141°29.4'
91	21.58	21-Feb-95	F_Flyers	22	12°31.8'	141°29.5'	12°34.0'	141°29.4'
92	22.67	21-Feb-95	F_Flyers	22	12°34.9'	141°29.3'	12°33.4'	141°29.3'
93	23.67	21-Feb-95	F_Flyers	22	12°32.2'	141°29.1'	12°33.8'	141°29.2'
94	1.00	22-Feb-95	F_Flyers	20	12°34.9'	141°29.2'	12°32.8'	141°29.4'
95	2.50	22-Feb-95	F_Flyers	22	12°32.3'	141°29.2'	12°34.5'	141°29.2'
96	3.75	22-Feb-95	F_Flyers	21	12°34.9'	141°29.1'	12°33.0'	141°29.0'
97	4.92	22-Feb-95	F_Flyers	24	12°32.6'	141°28.6'	12°34.9'	141°28.6'
98	14.83	22-Feb-95	Fish/Video	29	12°33.3'	141°23.9'	12°31.6'	141°23.8'
99	16.50	22-Feb-95	Fish/Video	32	12°29.9'	141°23.5'	12°32.6'	141°23.5'

100	21.50	22-Feb-95	F_Flyers	22	12°32.4'	141°29.2'	12°30.9'	141°29.1'
101	21.50	22-Feb-95	F_Flyers	24	12°30.4'	141°28.6'	12°32.1'	141°28.9'
102	22.42	22-Feb-95	F_Flyers	22	12°32.6'	141°29.1'	12°34.5'	141°29.1'
103	23.50	02-Feb-95	F_Flyers	20	12°32.6'	141°29.1'	12°33.7'	141°29.4'
104	0.50	23-Feb-95	F_Flyers	22	12°31.7'	141°29.4'	12°30.2'	141°29.3'
105	1.50	23-Feb-95	F_Flyers	23	12°28.4'	141°29.4'	12°26.8'	141°29.3'
106	2.58	23-Feb-95	F_Flyers	23	12°28.1'	141°29.3'	12°29.9'	141°29.1'
107	3.58	23-Feb-95	F_Flyers	23	12°31.6'	141°29.2'	12°33.6'	141°28.8'
108	4.58	23-Feb-95	F_Flyers	23	12°32.8'	141°29.0'	12°31.3'	141°29.1'
109	5.50	23-Feb-95	F_Flyers	23	12°29.9'	141°29.3'	12°28.2'	141°29.3'
110	9.17	23-Feb-95	Fish/Video	38	12°29.6'	141°19.7'	12°27.7'	141°19.6'
111	10.67	23-Feb-95	Fish/Video	39	12°27.6'	141°18.1'	12°29.5'	141°17.8'
112	13.83	23-Feb-95	Fish/Video	34	12°23.4'	141°23.1'	12°25.2'	141°23.5'
113	15.17	23-Feb-95	Fish/Video	34	12°24.5'	141°23.7'	12°25.6'	141°23.3'
114	19.58	23-Feb-95	F_Flyers	25	12°25.1'	141°28.5'	12°26.3'	141°28.6'
115	20.67	23-Feb-95	F_Flyers	24	12°29.1'	141°28.8'	12°30.4'	141°28.7'
116	21.75	23-Feb-95	F_Flyers	23	12°32.5'	141°28.8'	12°34.0'	141°28.6'
117	22.75	23-Feb-95	F_Flyers	22	12°33.2'	141°28.8'	12°31.4'	141°29.0'
118	23.83	23-Feb-95	F_Flyers	23	12°29.2'	141°29.3'	12°27.9'	141°29.3'
119	0.75	24-Feb-95	F_Flyers	23	12°31.8'	141°28.9'	12°29.6'	141°29.3'
120	1.67	23-Feb-95	F_Flyers	23	12°31.8'	141°29.3'	12°33.8'	141°28.7'
121	2.50	24-Feb-95	F_Flyers	20	12°34.6'	141°29.0'	12°33.0'	141°29.2'
122	4.25	24-Feb-95	F_Flyers	24	12°33.7'	141°28.4'	12°35.5'	141°28.6'
123	5.20	24-Feb-95	F_Flyers	19	12°35.6'	141°29.4'	12°33.8'	141°29.5'
124	19.67	24-Feb-95	F_Flyers	20	12°31.1'	141°29.8'	12°32.7'	141°29.8'
125	20.75	24-Feb-95	F_Flyers	18	12°33.8'	141°29.9'	12°35.4'	141°29.7'
126	21.83	24-Feb-95	F_Flyers	19	12°35.0'	141°29.2'	12°33.4'	141°29.2'
127	22.75	24-Feb-95	F_Flyers	22	12°32..8'	141°29.2'	12°	141°
128	23.90	24-Feb-95	F_Flyers	21	12°36.0'	141°28.6'	12°34.3'	141°28.7'
129	0.92	25-Feb-95	F_Flyers	23	12°32.6'	141°28.7'	12°30.8'	141°28.9'
130	2.08	25-Feb-95	F_Flyers	24	12°28.1'	141°29.1'	12°26.5'	141°29.0'
131	3.58	25-Feb-95	F_Flyers	24	12°29.2'	141°28.9'	12°31.1'	141°28.7'
132	4.58	25-Feb-95	F_Flyers	22	12°33.1'	141°28.9'	12°34.9'	141°28.8'
133	5.50	25-Feb-95	F_Flyers	20	12°35.2'	141°29.2'	12°33.8'	141°29.3'
134	9.63	25-Feb-95	EFNLong	55	12°31.1'	140°58.5'	12°30.3'	140°57.0'
135	11.00	25-Feb-95	EFNLong	57	12°27.7'	140°56.7'	12°26.0'	140°55.0'
136	13.17	25-Feb-95	EFNLong	52	12°27.6'	141°2.4'	12°25.9'	141°2.4'
137	14.83	25-Feb-95	EFNLong	53	12°27.0'	141°1.0'	12°28.6'	141°1.0'
138	16.75	25-Feb-95	EFNLong	56	12°22.3'	140°54.3'	12°20.8'	140°53.7'
139	21.00	25-Feb-95	F_Flyers	25	12°28.0'	141°28.1'	12°29.4'	141°28.7'
140	22.17	25-Feb-95	F_Flyers	21	12°31.8'	141°29.5'	12°32.9'	141°29.4'
141	23.17	25-Feb-95	F_Flyers	22	12°32.5'	141°29.2'	12°30.5'	141°29.1'
142	0.20	26-Feb-95	F_Flyers	23	12°29.3'	141°29.3'	12°31.0'	141°29.2'
143	1.17	26-Feb-95	F_Flyers	21	12°32.8'	141°29.4'	12°32.8'	141°29.4'
144	2.25	26-Feb-95	F_Flyers	19	12°34.8'	141°29.6'	12°32.7'	141°29.9'
145	3.25	26-Feb-95	F_Flyers	21	12°32.7'	141°29.7'	12°34.7'	141°29.4'
146	4.17	26-Feb-95	F_Flyers	21	12°35.2'	141°28.8'	12°33.5'	141°24.0'
147	5.20	26-Feb-95	F_Flyers	23	12°31.3'	141°29.4'	12°29.6'	141°29.4'
148	9.17	26-Feb-95	EFNMedium	52	12°30.2'	141°1.4'	12°28.4'	141°1.2'
149	10.83	26-Feb-95	EFNMedium	57	12°27.2'	140°56.8'	12°25.1'	140°56.1'
150	13.08	26-Feb-95	EFNMedium	52	12°27.9'	141°1.9'	12°28.0'	140°59.7'
151	14.75	26-Feb-95	EFNMedium	54	12°27.1'	140°59.9'	12°25.6'	140°59.5'
152	16.58	26-Feb-95	EFNMedium	57	12°24.0'	140°54.7'	12°25.9'	140°55.7'

153	21.00	25-Feb-95	F_Flyers	21	12°31.1'	141°29.5'	12°32.5'	141°29.6'
154	21.92	26-Feb-95	F_Flyers	18	12°34.4'	141°29.6'	12°35.9'	141°29.3'
155	23.67	26-Feb-95	F_Flyers	19	12°35.1'	141°29.3'	12°33.4'	141°29.7'
156	0.67	27-Feb-95	F_Flyers	21	12°31.4'	141°29.6'	12°29.1'	141°29.9'
157	1.75	27-Feb-95	F_Flyers	22	12°27.3'	141°29.7'	12°25.6'	141°29.8'
158	3.00	27-Feb-95	F_Flyers	22	12°28.0'	141°29.8'	12°29.8'	141°29.8'
159	4.00	27-Feb-95	F_Flyers	21	12°32.3'	141°29.7'	12°34.1'	141°29.6'
160	5.17	27-Feb-95	F_Flyers	19	12°36.5'	141°29.5'	12°25.5'	141°29.5'
161	20.58	27-Feb-95	F_Flyers	19	12°36.1'	141°29.2'	12°34.4'	141°29.4'
162	21.75	27-Feb-95	F_Flyers	21	12°32.2'	141°29.2'	12°30.5'	141°29.6'
163	22.83	27-Feb-95	F_Flyers	22	12°28.4'	141°29.4'	12°26.3'	141°29.5'
164	0.17	28-Feb-95	F_Flyers	22	12°28.1'	141°29.7'	12°29.5'	141°29.7'
165	1.33	28-Feb-95	F_Flyers	22	12°31.4'	141°29.1'	12°33.1'	141°29.1'
166	2.42	28-Feb-95	F_Flyers	21	12°34.9'	141°29.3'	12°36.7'	12°29.4'
167	3.67	28-Feb-95	F_Flyers	18	12°36.6'	141°29.5'	12°34.9'	141°29.6'
168	4.00	28-Feb-95	F_Flyers	21	12°33.3'	141°29.4'	12°31.9'	141°29.3'
169	9.83	28-Feb-95	EFNMedium	49	12°28.6'	141°3.1'	12°26.9'	141°3.2'
170	11.50	28-Feb-95	EFNMedium	55	12°30.4'	140°58.9'	12°29.2'	140°59.1'
171	12.83	28-Feb-95	EFNMedium	56	12°29.8'	140°58.9'	12°32.1'	140°58.7'
172	20.25	28-Feb-95	F_Flyers	18	12°37.4'	141°29.7'	12°35.4'	141°29.7'
173	21.33	28-Feb-95	F_Flyers	18	12°35.4'	141°29.6'	12°37.2'	141°29.4'
174	22.58	28-Feb-95	F_Flyers	17	12°36.4'	141°29.6'	12°34.0'	141°29.8'
175	1.75	01-Mar-95	F_Flyers	25	12°27.3'	141 28.7'	12°25.7'	141°29.1'
176	2.75	01-Mar-95	F_Flyers	25	12°26.4'	141°28.9'	12°28.2'	141°29.0'
177	3.83	01-Mar-95	F_Flyers	24	12°29.9'	141°28.9'	12°31.8'	141°28.8'
178	4.83	01-Mar-95	F_Flyers	24	12°32.5'	141°28.6'	12°30.8'	141°28.5'
179	5.75	01-Mar-95	F_Flyers	26	12°29.5'	141°28.5'	12°27.9'	141°28.8'
180	10.25	01-Mar-95	EFNLong	51	12°29.9'	141°2.3'	12°31.7'	141°2.2'
181	11.67	01-Mar-95	EFNLong	55	12°31.7'	140°58.4'	12°30.7'	140°57.4'
182	13.42	01-Mar-95	EFNLong	55	12°29.3'	140°54.1'	12°28.4'	140°58.3'
183	14.75	01-Mar-95	EFNLong	58	12°25.3'	140°54.3'	12°24.7'	140°53.7'
184	16.25	01-Mar-95	EFNLong	57	12°22.5'	140°55.6'	12°24.2'	140°57.5'
185	20.58	01-Mar-95	F_Flyers	25	12°26.6'	141°28.7'	12°28.2'	141°28.9'
186	21.58	01-Mar-95	F_Flyers	24	12°30.5'	141°28.9'	12°32.0'	141°28.9'
187	22.92	01-Mar-95	F_Flyers	23	12°30.5'	141°28.8'	12°29.0'	141°29.0'
188	0.00	02-Mar-95	F_Flyers	22	12°29.2'	141°29.2'	12°31.3'	141°29.4'
189	1.13	02-Mar-95	F_Flyers	21	12°33.1'	141°29.3'	12°34.9'	141°29.2'
190	2.25	02-Mar-95	F_Flyers	21	12°34.0'	141°28.9'	12°31.9'	141°29.3'
191	2.50	02-Mar-95	F_Flyers	24	12°30.0'	141°29.1'	12°28.6'	141°29.2'
192	4.58	02-Mar-95	F_Flyers	26	12°28.3'	141°28.8'	12°30.1'	141°28.5'
193	5.67	02-Mar-95	F_Flyers	24	12°30.6'	141°28.9'	12°28.9'	141°20.3'
194	9.00	02-Mar-95	EFNLong	42	12°26.3'	141°12.4'	12°24.7'	141°12.2'
195	10.67	02-Mar-95	EFNLong	43	12°29.7'	141°10.4'	12°32.0'	141°10.0'
196	12.75	02-Mar-95	EFNLong	43	12°28.0'	141°8.0'	12°26.6'	141°7.9'
197	14.25	02-Mar-95	EFNLong	52	12°24.9'	141°4.0'	12°23.8'	141°3.2'
198	16.57	02-Mar-95	EFNLong	46	12°22.2'	141°6.1'	12°24.1'	141°7.2'
199	19.83	02-Mar-95	F_Flyers	24	12°27.9'	141°29.3'	12°29.9'	141°28.8'
200	20.92	02-Mar-95	F_Flyers	25	12°31.5'	141°28.6'	12°30.2'	141°28.6'
201	23.47	02-Mar-95	F_Flyers	25	12°28.0'	141°28.9'	12°29.5'	141°28.8'
202	0.42	03-Mar-95	F_Flyers	23	12°31.0'	141°28.8'	12°32.6'	141°28.7'
203	1.58	03-Mar-95	F_Flyers	23	12°32.3'	141°28.9'	12°30.4'	141°29.2'
204	2.58	03-Mar-95	F_Flyers	24	12°29.1'	141°29.2'	12°27.6'	141°29.3'
205	3.58	03-Mar-95	F_Flyers	23	12°27.3'	141°29.1'	12°29.2'	141°29.2'

206	4.58	03-Mar-95	F_Flyers	23	12°31.3’	141°29.2’	12°33.2’	141°29.2’
207	5.5’8	03-Mar-95	F_Flyers	22	12°33.9’	141°28.9’	12°32.7’	141°28.8’
208	10.3’3	03-Mar-95	EFNMedium	43	12°16.4’	141°11.6’	12°28.8’	141°11.3’
209	11.5’8	03-Mar-95	EFNMedium	44	12°28.3’	141°10.0’	12°29.9’	141°11.2’
210	13.5’0	03-Mar-95	EFNMedium	44	12°28.1’	141°7.0’	12°29.1’	141°9.0’
211	15.3’3	03-Mar-95	EFNMedium	48	12°25.9’	141°4.5’	12°24.9’	141°9.0’
212	16.75	03-Mar-95	EFNMedium	44	12°23.5’	141°7.5’	12°25.0’	141°9.1’
213	2.5’0	04-Mar-95	MBT	24	12°29.8’	141°28.9’	12°31.0’	141°28.9’
214	3.4’2	04-Mar-95	MBT	24	12°31.9’	141°28.6’	12°33.8’	141°29.1’
215	4.25	04-Mar-95	MBT	21	12°34.9’	141°29.4’	12°33.8’	141°29.1’
216	5.05	04-Mar-95	MBT	22	12°33.4’	141°29.1’	12°32.4’	141°28.9’
217	8.85	04-Mar-95	EFNMedium	42	12°27.4’	141°11.9’	12°26.8’	141°10.7’
218	10.15	04-Mar-95	EFNMedium	43	12°29.2’	141°10.2’	12°31.5’	141°10.4’
219	12.75	04-Mar-95	EFNMedium	44	12°29.0’	141°7.7’	12°28.0’	141°7.3’
220	14.42	04-Mar-95	EFNMedium	50	12°25.3’	141°3.9’	12°24.5’	141°2.8’
221	16.50	04-Mar-95	EFNMedium	47	12°22.6’	141°5.4’	12°24.2’	141°7.4’
222	19.57	04-Mar-95	MBT	25	12°30.8’	141°28.6’	12°32.3’	141°29.4’
223	3.67	05-Mar-95	F_Flyers	23	12°31.3’	141°29.1’	12°30.0’	141°29.4’
224	4.75	05-Mar-95	F_Flyers	24	12°28.9’	141°29.1’	12°27.7’	141°29.2’
225	20.75	06-Mar-95	F_Flyers	24	12°32.3’	141°29.0’	12°31.3’	141°29.4’
226	22.00	06-Mar-95	F_Flyers	24	12°30.1’	141°29.0’	12°29.0’	141°28.9’
227	23.08	06-Mar-95	F_Flyers	24	12°29.0’	141°28.9’	12°31.3’	141°28.8’
228	0.08	07-Mar-95	F_Flyers	25	12°32.3’	141°28.9’	12°31.2’	141°29.1’
229	10.08	07-Mar-95	EFNLong	41	12°27.2’	141°11.4’	12°26.1’	141°11.6’
230	11.50	07-Mar-95	EFNLong	43	12°26.6’	141°11.6’	12°28.1’	141°13.4’
231	13.92	07-Mar-95	EFNLong	43	12°25.3’	141°8.2’	12°27.4’	141°8.5’
232	15.58	07-Mar-95	EFNLong	47	12°31.9’	141°4.2’	12°32.5’	141°5.9’
233	17.25	07-Mar-95	EFNLong	44	12°30.7’	141°6.6’	12°31.6’	141°8.5’
234	0.17	08-Mar-95	F_Flyers	28	12°26.9’	141°27.6’	12°	141°
235	1.33	08-Mar-95	F_Flyers	24	12°31.2’	141°28.9’	12°33.4’	141°28.9’
236	2.50	08-Mar-95	F_Flyers	21	12°34.5’	141°28.7’	12°33.6’	141°29.0’
237	3.75	08-Mar-95	F_Flyers	22	12°32.4’	141°28.9’	12°31.2’	141°28.9’
238	4.92	08-Mar-95	F_Flyers	23	12°29.8’	141°28.6’	12°28.5’	141°28.6’
239	9.25	08-Mar-95	EFNLong	44	12°27.1’	141°8.1’	12°28.6’	141°9.5’
240	11.33	08-Mar-95	EFNLong	50	12°27.1’	141°3.7’	12°28.9’	141°5.1’
241	13.83	08-Mar-95	EFNLong	54	12°24.8’	140°59.9’	12°26.6’	141°1.4’
242	15.58	08-Mar-95	EFNLong	54	12°24.7’	140°58.2’	12°26.2’	140°59.4’
243	16.83	08-Mar-95	EFNLong	55	12°28.3’	140°58.5’	12°30.1’	140°59.4’
244	21.17	08-Mar-95	F_Flyers	26	12°31.8’	141°28.5’	12°30.4’	141°28.9’
245	4.75	09Mar-95	F_Flyers	24	12°30.7’	141°28.1’	12°31.7’	141°29.2’

3. SS595 Weipa - Weipa
16 JUNE - 23 JUNE 1995
FRV *SOUTHERN SURVEYOR*

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Itinerary
Leg 1 Departed Weipa: 1815 h Friday, 16 June 1995
Arrived Weipa: 1230 h Friday, 23 June 1995

CRUISE OBJECTIVES
1. To monitor *Penaeus semisulcatus* prawn distribution and abundance across the Gulf of Carpentaria in a roughly east-west transect from Weipa to north of Groote Eylandt using 14 fathom Florida Flyer prawn nets.
2. To compare an AusTED codend and a standard diamond-mesh codend for bycatch reduction.
3. To collect frozen *P. semisulcatus* for isotope and genetic analysis of population structure.
4. To collect sediment samples each dawn and dusk before completion and commencement of night time trawling.
5. To collect stratified water samples with the CTD each morning and analyse the samples for primary productivity.
6. To streamline the Oracle data entry from the fish laboratory and resolve other onboard computing problems as they arise.

AREA OF OPERATION
Return transect west of Weipa, across the Gulf of Carpentaria between 12°S - 13° 30'S, and 136° 50'E and 141° 35'E (see Figure 21).

RESULTS
1 The distribution of P. semisulcatus across the GOC was investigated during 39 paired Florida Flyer prawn trawls centred on 6 nm grids as in Figure 21.

2 The AusTED Bycatch Reduction Device and a standard codend were compared over 39 trawls across the GOC.

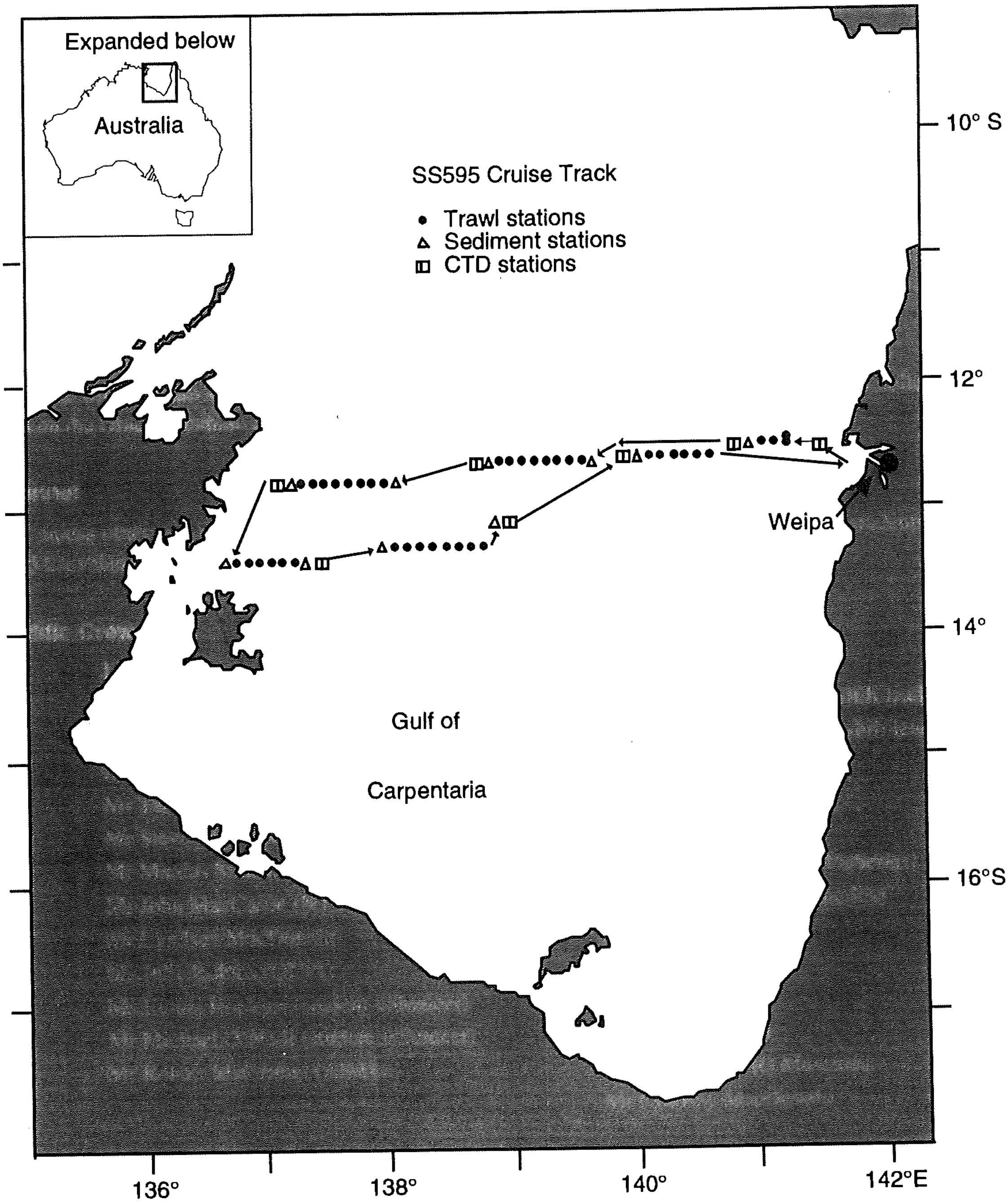
3 Representative samples of *P. semisulcatus* from each night's trawling were kept frozen for genetic and isotope analyses.

4 Sediment samples were collected on each day except the fifth day when the substrate was too soft to trigger the Smith-Mac grab.

5. The CTD was deployed twice each day and water samples collected from selected depths for analysis on board.

6. Data entry from the Fish Laboratory was streamlined and de-bugged during the cruise.
7. Leiognathids were systematically collected to complete sampling for a PhD study (Jonathan Staunton Smith).

Figure 21. Cruise track and sample sites from the June 1995 cruise



CRUISE NARRATIVE

Southern Surveyor departed Weipa at 1815 h on 16 June 1995; this delay was due to the late delivery of the AusTED codends. At a cruise debriefing soon after departure, cruise objectives were explained, shifts allocated and first time participants informed of ship safety and day to day house-keeping procedures. The Master, Ian Taylor, advised of a Muster and Fire drill for all scientific crew to be held the next day at 1700 h; this drill was successfully completed. During the steam out to position 12° 45'S, 141° 33'E, both Florida Flyer prawn nets were fitted with standard mesh codends prior to calibrating the nets in order to obtain even catches on both side (nets) before starting the paired comparisons. Difficulties were encountered deploying the trawl nets but three trial shots were completed during the night with even catches of prawns and bycatch in both nets on the third trawl. This effectively removed the spare night available for trawling in a selected area of high *P. semisulcatus* abundance. Seas were moderate to rough for the first five days due to strong south to south easterly winds with surprisingly cold air temperatures.

Night time sampling

On the second night of the cruise, the AusTED codend replaced the standard codend on the starboard net for the first comparison trawl. The AusTED was changed from one side to the other between trawls according to a Latin Square design with each block consisting of the two possible combinations ie AusTED on starboard side followed by AusTED on the port side. There were only two block types possible, AusTED on port side first or AusTED on the starboard side first and each block was chosen at random. Planning was based on an expected eight trawls per night consisting of four blocks of two trawls each.

During the first night of comparisons, Saturday 17 July, four stations were completed. The first trawl station, cruise station 3, was repeated due to gear problems; this station was abandoned when the starboard (AusTED) codend parted from the net and required about 1.5 hours to repair. The port trawl board on station 5 was retrieved in a "flipped" state and obviously did not ride on the bottom correctly as the catch from that net (port side) consisted almost entirely of rubble. There was no time for repeating the trawl and the next station, 6, was successfully completed before sunrise.

Problems deploying the trawl gear persisted throughout the cruise although all eight stations were trawled on three nights, Sunday 18 July, Monday 19 July and Wednesday 21 July. Despite trawling with the observed currents across the GOC ie in a north-westerly direction, there was a consistently higher catch in the starboard net than in the port net. The statistical design of the codend switching should allow this effect to be isolated and the true comparison of the treatment codend (the AusTED) and the control codend (standard diamond-mesh). Of the 48 planned comparison trawls, 39 were completed. Whole *Penaeus semisulcatus* were kept each night for genetic and isotope analysis after the cruise. When trawl catches could not be sorted and recorded quickly enough, the species composition sub-sample was frozen for processing in Cleveland.

The direct data entry from the terminal in the fish laboratory work very well, especially with Miroslaw available to rectify any software problems. The extra terminal installed by Matt in the fish laboratory proved to be of great value for instantaneous readings of ships position.

Daytime sampling

Sediment samples were taken at the start and end of each evening except on three occasions when the sediment was too soft to trigger the Smith-McIntyre grab (stations 34, 41 and 53). These samples were frozen for particle size analysis at the Cleveland laboratory.

CTD profiling to determine salinity, temperature, light, fluorescence through the water column was done once a day (0900h) for 6 days. The transect across the Gulf and back made it possible to collect information on one shallow (off Duyfken Point) and five deep water (40 m +) stations. Water samples were also collected from 5 depths at these sites for experimental work. The Gulf appeared to be well mixed as indicated by the lack of thermoclines, haloclines or fluorescence maxima, with the exception of one station, station 8,9 where there was a distinct increase in fluorescence at 46-48m.

Primary productivity incubations were done on water samples from each sampling station using the PI light box in the Productivity lab. Water samples from five depths were incubated under 7 different light regimes to determine the effect of light on productivity. In addition on–deck incubations using water from a shallow and a deep water station were done on two days following the same technique as that used on the Franklin cruise in 1988. This will allow a direct comparison of results. On Day 5 water samples were taken using both black and white silicone rubber bands and o-rings in the Niskin bottles. This was done to determine if there is a growth suppression of phytoplankton sampled in Niskin bottles with black rubber o-rings, as suggested by Brian Griffith. Initial results suggest that there is indeed a suppression, however it is not yet known if this is statistically significant.

Water samples were also spiked with nutrients (nitrate, phosphate and silicate) and incubated on deck for 20 hours. Samples were then incubated for primary productivity measurements. In addition samples were spiked with ^{15}N-nitrate and ammonium to determine the uptake rates of nitrogen by phytoplankton.

Samples were also taken daily for pigment analysis and flow cytometry analysis. On Day 5 significant amounts of 'marine snow' were observed in the water collected in the Niskin bottles. Microscopic observations showed that this was predominantly the diatom *Thalassiosira* with a mucous binding the cells together. Other diatom species , *Nitzschia, Navicula* and *Pleurosigma* were also present.

Electronics and Computing: Brisbane to Weipa

Electronics Personnel – Matt Sherlock

Computing Personnel – Miroslaw Ryba

The steaming leg from Brisbane to Weipa prior to commencement of trawling operations for SS595 provided an excellent opportunity for electronics (Matt Sherlock) and computing personnel (Miroslaw Ryba) to prepare and upgrade shipboards systems. The following is a summary of achievements:

SUN Workstation Printer

The existing dot matrix printer connected to the SUN computer used for SSDLS data logging and Oracle was replaced with a new laser printer. Drivers for this printer were loaded onto both the SUN and other Windows based PC's. for later use over the network.

Seabird Thermosalinograph

The original underway thermosalinograph (SDL based) in the chemistry laboratory was replaced on the preceding cruise with a new, more stable and accurate Seabird thermosalinograph. The software module which allows the SSDLS system to communicate with the thermosalinograph was modified and tested during the transit leg to allow the system to be fully operational during the cruise.

Light Measurement Systems

Both the masthead ambient light sensor and CTD light sensor were calibrated against a reference sensor. In addition the interface electronics for both light systems were completely checked and results used to generate new calibration coefficients for the two systems. These sensors were used extensively during the cruise for targeting water samples for biological productivity work.

Other tasks undertaken included testing of a new Ethernet repeater unit for the shipboard network, attempted servicing of the underway fluorometer, testing of a spare G.P.S. antenna, investigation of radar problems in the wheelhouse and discussion of options for future expansion of computing facilities in the fish lab.

Weipa to Weipa

During the cruise, electronics support was provided in running the CTD system, operation and data backup for the vessel logging system and repairs and maintenance of various shipboard systems.

CTD System

The CTD system was used for collection of water samples and characterisation of the water mass in depths to 62 metres. Two casts were carried out each day in quick succession using either the fluorometer or light sensor to determine position in the water column for samples. The altimeter was used to allow the CTD to be positioned within 2 -3 metres of the bottom. On one occasion the CTD rosette touched bottom due to excessive rolling of the vessel. The bottom consisted of soft mud which caused no damage to the unit.

During the cruise temperature and salinity measurements from Niskin bottles were compared with the CTD and found to be in agreement within the limits of measurements. Hence the CTD calibration is very accurate at present.

Capturing bottle samples at different percentages of surface light proved difficult due to roll of the vessel and high turbidity of the water. This turbidity resulted in the attenuation of surface light to less than twenty percent in the first 5 meters making accurate collection of water difficult.

Lower light levels of 5 percent , 10 percent etc were somewhat easier to achieve as it was possible to take the CTD deep to obtain an accurate dark level reading and then come up slowly to the desired point.

Data Logging System

The data logging system performed well with no hangups, a credit to the efforts made on the previous cruise to resolve problems with the Oracle data base and networking. A batch file called FIXCRU still needs to be run before each cruise to globally update the cruise number. The forms really need to be changed to allow the cruise number to be picked up from an easily modified source file as FIXCRU does a recompilation of all forms which is potentially risky.

All the biological data were copied to a cassette tape for down loading to the Cleveland SUN Sparc station.

SUMMARY

The distribution of *Penaeus semisulcatus* was monitored across the GOC with an observed decline in abundance in the central Gulf. The AusTED Bycatch Reduction Device was compared to a standard codend at all trawl stations. A noticeable reduction in bycatch was observed although a bias towards higher catches on the starboard side regardless of codend type, compounded the AusTED's effect. Most sediments samples were successfully obtained except at three stations where the sediment was too soft to trigger the grab.

All the primary productivity work planned for cruise SS595 was successfully completed and analysis of the samples and data is continuing.

REPORTING OF RESULTS

The results will be analysed and reported in the scientific literature where appropriate. All the collected data resides on the Oracle database at the CSIRO Marine Laboratories in Cleveland.

Personnel

(Note: unless otherwise stated, all personnel are staff of the CSIRO Division of Fisheries or students based at CSIRO Cleveland.)

Scientific Crew

John Salini	Cruise Leader/Fish/Prawns/Data
Jonathan Staunton Smith	Fish
Mick Haywood	Prawns
Don Heales	Prawns
Peter Rothlisberg	Primary Productivity
Michele Burford	Primary Productivity

Ron Plaschke (OMS Hbt) CTD	Primary Productivity
Matt Sherlock	Electronics
John Wallace (Hbt OIC)	Fish
John McCartie (NTDPIE)	Gear
Jason McGilvray (QDPI)	Gear
Miroslaw Ryba	Computing

Ship's Crew

Ian Taylor	Master
Roger Pepper	First Mate/Fishing Master
John Boyes	Second Mate/Fishing Master
Ian McAllister	Chief Engineer
Rick Miller	First Engineer
John Hinchliffe	Electrical Engineer
Noel Anderson	Chief Steward
Alan Smith	Chief Cook
Don Collins	Second Cook
Malcolm McDougall	Bosun
Len Darling	A. B. 1
Tony Hearne	A. B. 2
Lou Jacomos	A. B. 3
Drew Meincke	A. B. 4
Graham McDougall	A. B. 5
Tom Stephen	A. B. 6
Chris Williams	A. B. 7

Acknowledgments

We thank the Master, Ian Taylor; the Fishing Masters, Roger Pepper and John Boyes and the crew of *Southern Surveyor* for their skills during the cruise. John MacCartie (NT Fisheries) and Jason McGilvray (QDPI) contributed many extra hours of duty setting-up the standard nets on the first night and the AusTED during the next day (when they should have been off shift).

Cruise Leader

John Salini

Chief, CSIRO Division of Fisheries

P. C. Young

Contacts

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This report may not be cited without reference to the author(s).

Distribution

Normal Circulation

Table 18. Stations occupied by *Southern Surveyor* during Cruise SS595.

Time: start time; Grabs: Smith-McIntyre sediment grab, F-Flyers: Florida Flyer prawn trawl, StartLat: start latitude; StartLong: start longitude; EndLat: end latitutde; EndLong: end longitude; Depth: depth in metres; *: grab failed to trigger due to soft sediment.

Stn	Time	Date	Gear	Depth	StartLat	StartLong	EndLat	EndLong
1	0900	17-Jun-95	CTD	11	12°37.3'	141°32.7'		
2	0955	17-Jun-95	CTD	11	12°35.1'	141°28.5'		
3	1930	17-Jun-95	F_Flyers	47	12°38.6'	141°02.2'	12°52.4'	140°56.5'
3a	2054	17-Jun-95	F_Flyers	46	12°38.3'	141°03.1'	12°39.3'	141°02.4'
4	0125	18-Jun-95	F_Flyers	49	12°38.7'	140°57.7'	12°37.3'	140°57.0'
5	0255	18-Jun-95	F_Flyers	55	12°39.0'	140°52.0'	12°38.1'	140°51.3'
6	0605	18-Jun-95	F_Flyers	60	12°39.0'	140°43.0'	12°27.6'	140°42.4'
7	0830	18-Jun-95	Grabs	60	12°40.9'	140°42.5'		
8	0915	18-Jun-95	CTD	60	12°41.8'	140°38.0'		
9	1000	18-Jun-95	CTD	61	12°41.8'	140°38.0'		
10	1800	18-Jun-95	Grabs	57	12°47.1'	139°33.4'		
11	1840	18-Jun-95	F_Flyers	57	12°44.5'	139°32.5'	12°43.1'	139°32.1'
12	2010	18-Jun-95	F_Flyers	58	12°44.6	139°27.3'	12°43.3'	139°26.3'
13	2155	18-Jun-95	F_Flyers	56	12°43.8'	139°19.9'	12°42.9'	139°18.7'
14	2330	18-Jun-95	F_Flyers	57	12°44.8'	139°15.0'	12°44.0'	139°13.8'
15	0100	19-Jun-95	F_Flyers	55	12°45.6'	139°08.9'	12°44.3'	139°08.4'
16	0250	19-Jun-95	F_Flyers	56	12°45.6'	139°03.0'	12°44.4'	139°02.8'
17	0430	19-Jun-95	F_Flyers	54	12°45.3'	138°57.0'	12°43.8'	138°56.0'
18	0612	19-Jun-95	F_Flyers	54	12°45.5'	138°51.0'	12°43.9'	139°50.7'
19	0810	19-Jun-95	Grabs	53	12°44.3'	138°506'		
20	0900	19-Jun-95	CTD	53	12°43.7'	138°50.2'		
21	0950	19-Jun-95	CTD	53	12°43.0'	138°49.5'		
22	1810	19-Jun-95	Grabs	49	12°53.8'	138°43.1'		
23	1830	19-Jun-95	F_Flyers	49	12°53.3'	138°04.2'	12°51.8'	138°03.7'
24	2015	19-Jun-95	F_Flyers	49	12°52.5'	137°57.2'	12°50.0'	137°56.9'
25	2230	19-Jun-95	F_Flyers	48	12°51.6'	137°51.0'	12°49.9'	137°50.7'
26	0055	20-Jun-95	F_Flyers	48	12°52.8'	137°44.9'	12°1.3'	137°44.0'
27	0215	20-Jun-95	F_Flyers	48	12°51.1'	137°39.1'	12°50.3'	137°37.8'
28	0330	20-Jun-95	F_Flyers	48	12°50.6'	137°33.5'	12°49.8'	137°32.3'
29	0445	20-Jun-95	F_Flyers	46	12°50.8'	137°27.7'	12°50.3'	137°26.4'
30	0610	20-Jun-95	F_Flyers	46	12°51.0'	137°21.0'	12°50.3'	137°19.8'
31	0810	20-Jun-95	Grabs	44	12°52.9'	137°21.6'		
32	0910	20-Jun-95	CTD	45	12°52.9'	137°21.6'		
33	0945	20-Jun-95	CTD	45	12°52.9'	137°21.6'		
34*	1800	20-Jun-95	Grabs	31	13°22.5'	136°50.7'		
35	2110	20-Jun-95	F_Flyers	31	13°20.4'	136°50.2'	13°21.6'	136°49.7'
36	2245	20-Jun-95	F_Flyers	38	13°20.7'	136°56.3'	13°19.7'	136°57.4'
37	0045	21-Jun-95	F_Flyers	43	13°21.2'	137°03.4'	13°19.5'	137°02.9'
38	0300	21-Jun-95	F_Flyers	45	13°21.4'	137°09.6'	13°19.8'	137°09.1'
39	0500	21-Jun-95	F_Flyers	46	13°21.8'	137°15.8'	13°20.5'	137°15.0'
40	0620	21-Jun-95	F_Flyers	45	13°20.7'	137°17.9'	13°19.6'	137°17.5'
41*	0805	21-Jun-95	Grabs	46	13°20.8'	137°20.8'		
42	0900	21-Jun-95	CTD	46	13°20.1'	137°20.0'		
43	0945	21-Jun-95	CTD	46	13°20.1'	137°20.0'		
44	1800	21-Jun-95	Grabs	51	13°14.9'	138°08.5'		
45	1845	21-Jun-95	F_Flyers	51	13°14.9'	138°08.5'	13°14.9'	138°10.0'
46	2025	21-Jun-95	F_Flyers	52	13°15.1'	138°15.1'	13°13.5'	138°15.3'
47	2210	21-Jun-95	F_Flyers	52	13°15.2'	138°21.2'	13°13.5'	138°21.1'

48	2250	21-Jun-95	F_Flyers	52	13°14.8'	138°26.9'	13°13.2'	138°26.9'
49	0125	22-Jun-95	F_Flyers	54	13°15.0'	138°32.6'	13°13.4'	138°32.9'
50	0305	22-Jun-95	F_Flyers	53	13°15.3'	138°38.8'	13°14.0'	138°39.4'
51	0430	22-Jun-95	F_Flyers	54	13°15.2'	138°44.6'	13°14.0'	138°45.3'
52	0600	22-Jun-95	F_Flyers	55	13°15.3'	138°50.6'	13°13.8'	138°51.2'
53*	0800	22-Jun-95	Grabs	57	13°04.3'	139°11.5'		
54	0900	22-Jun-95	CTD	57	13°04.3'	139°11.5'		
55	0945	22-Jun-95	CTD	57	13°04.3'	139°11.5'		
56	1700	22-Jun-95	Grabs	56	12°40.2'	139°55.3'		
57	2015	22-Jun-95	F_Flyers	60	12°37.5'	139°56.4'	12°36.1'	139°57.2'
58	2145	22-Jun-95	F_Flyers	59	12°38.6'	140°00.0'	12°37.3'	140°010'
59	2305	22-Jun-95	F_Flyers	60	12°38.8'	140°05.0'	12°37.5'	140°05.9'
60	0030	23-Jun-95	F_Flyers	60	12°39.1'	140°09.9'	12°37.8'	140°10.5'
61	0210	23-Jun-95	F_Flyers	61	12°39.9'	140°16.5'	12°38.3'	140°17.4'
62	0355	23-Jun-95	F_Flyers	61	12°39.3'	140°22.1'	12°39.6'	140°20.4'

4. SS1095 Weipa - Weipa
10 OCTOBER - 5 NOVEMBER 1995
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ITINERARY

Leg 1	Departed Weipa:	1845 h Tuesday, October 10, 1995
	Arrived Weipa:	1100 h Tuesday, October 24, 1995
Leg 2	Departed Weipa:	1600 h Tuesday, October 24, 1995
	Arrived Weipa:	1000 h Sunday, November 5, 1995

AREA OF OPERATION

West of Weipa, Gulf of Carpentaria between 12°S - 13°S, and 140° 50'E and 141° 35'E (see Figure 20).

CRUISE OBJECTIVES

1. To test various prawn net modifications for their effectiveness in reducing the catch of non-target species in the tiger prawn fishery off Weipa without significant loss of commercial prawns.
2. To obtain daytime video images of these devices and their effects on fish behaviour in the net during trawling
3. To test the catchability of fishes using long (90 m) and no sweeps in a semi-pelagic fish trawl.
4. To collect a variety of saurids for genetic analysis in Hobart.
5. To obtain video images of the Environmentally Friendly Net's (EFN) performance over structured benthos and of fish behaviour in the codend.

Results

1 Five Bycatch Reduction Devices (BRDs) and a control or standard prawn net codend were tested during 26 consecutive nights and 93 paired 120 minute trawls. Four of these BRDs were retained or modified and compared more intensively during the second leg.

2 Video images were obtained of fish behaviour in the BRD codends of the prawn net and the EFN, and of the performance of the EFN over benthic structure.

3 Ten days of EFN fish trawls, 50 trawls, were completed on the fish grounds about 25 nm west of Duyfken Point.

4 Three shark longline sets of up to 40 hooks were successfully completed with about one shark caught on every second hook on the second set.

5. Several boxes of representative bycatch species were frozen for reference specimens.

6. Two afternoons were dedicated to public relations when prawn trawler crews visited Southern Surveyor to inspect the BRDs, underwater video tapes, scanmar and related equipment.

7. Samples of saurids were frozen for the Hobart genetics group.

CRUISE NARRATIVE

Southern Surveyor left Weipa at 1845 h on Tuesday, October 10, 1995. The ship's crew lost able seaman Tony Hearne at the last hour due to a serious illness in his family, leaving the deck crew undermanned on the midday to midnight shift. At a cruise debriefing soon after departure, Leg 1 objectives were explained, shifts allocated and first-time participants informed of ship safety and day to day housekeeping procedures. The Master, Bruce Wallis, advised of a Muster and Fire drill the next day at 1300 h; this drill was successfully completed. After arriving at the prawn trawl grounds five nautical miles west of Duyfken Point, the paired Florida Flyer prawn trawl nets were tested for even-catching ability using normal codends (diamond-mesh). The first trawl was successfully deployed at 2330 h. Trial trawls continued through the day until after nine trawls, the nets recorded similar catches. All night prawn trawls were of 120 minutes duration and continued throughout the entire cruise, with a maximum of four trawls per night. Trawling commenced 30-60 minutes after sunset and generally finished at least 30 minutes before sunrise. The pattern of trawling during a complete day involved night prawn trawling in approximately 20 m west of Duyfken Point and daytime trawling in clearer (30 - 40 m depth) water further west. Towards the end of the first leg and all through the second leg, daytime fish trawling with the EFN (which replaced video trawls of the BRDs) took place about 25 nm west of Duyfken Point (see Figure 20). These EFN trawls were of 30 min duration. This cruise was blessed by idyllic weather conditions with no seasonal storms.

On two afternoons, once each during the first and second legs, Southern Surveyor anchored among nearby commercial prawn trawlers and played host to visiting crew members from the trawlers. The scientific crew arranged displays of the various BRDs and showed interested visitors underwater videos of the BRDs. The cooperation of the ship's crew, in particular the Chief Engineer's tour of the engine room, was clearly appreciated by all the visitors.

During the changeover of scientific personnel in Weipa (October 24), Able Seaman Tony Hearne's replacement, Terry Stinchcome arrived. October 24 also marked an unusual natural event visible only from northern Australia. A partial eclipse of the sun occurred at about 1445 h and was witnessed by many of the cruise participants by projection through binoculars or direct viewing using appropriate solar filters.

Night time sampling

All night prawn trawling was carried out in approximately 20 m along a north-south path centred 5 nm west of Duyfken Point. Wednesday night, October 11, marked the beginning of the BRD comparison trawls. The sampling design for BRD paired comparison trawls consisted of a different combination of all BRDs, such that each BRD was paired once against all others. This required 10 trawls, representing two and a half nights of trawling, to complete one round of all possible pairings. Within each round, each BRD was equally used on both port and starboard sides. Four such rounds were completed during Leg 1. From an assessment of the results at the end of these four rounds, one BRD was removed from further comparisons and the size and position of the square-mesh window was changed, as was the angle of the Nordmøre grid. There was a slight change to the position of the fisheye in both the Super Shooter/Fisheye and the Nordmore/Fisheye BRDs. All these modifications were then used during Leg 2 when a round was completed in six trawls - or one and a half nights. This allowed a maximum of eight rounds over the 12 nights available on Leg 2. A total of six and a half rounds were completed because of occasional invalid trawls which were repeated, and time lost due to gear problems. The codend skirts used during the last two cruises (SS295 and SS595) again prevented any loss of catch as a result of shark bites.

Southern Surveyor sailed for Weipa soon after completion of the last trawl on the morning of Sunday, 5th November and tied up at the Evans Landing wharf at 1000 h.

Daytime sampling

Prawn nets were tested on the first day for catch uniformity between port and starboard nets using standard (control) nets. On the second day, Wednesday 12th October, the first of eleven days of videotaping of all the BRDs commenced. These BRD video trawls were carried out in ~35 m water which was less turbid than the 20 m depth used for night-time trawling. Some excellent tapes of fish behaviour in the various devices was obtained from the codend mounted cameras despite difficulties with the cameras and their housings. Turbidity varied from day to day and in a search for better visibility some trawls were located further south in Albatross Bay. The domestic video camera from NTDPIE proved to be reliable. The AMC high resolution, low light camera suffered from numerous electrical faults that were corrected during the course of the cruise. Matt Sherlock dedicated many hours to trouble-shooting this camera. Fortunately, some good images were obtained eventually.

Both cameras were used on the EFN during the second leg and some excellent video images were obtained of fish behaviour in the codend and of the net's performance in relation to the bottom.

The EFN fish trawl was tested using long and no sweeps. The last day of Leg 1 was dedicated to setting up and testing the EFN. Each day was organised into five, two hour windows, 0800-1000, 1000-1200, 1200-1400, 1400-1600 and 1600-1800 h with one trawl per two hours. Area A (Figure 20, Area A) consisted of 25 grids (2 x 2 nm); five grids were chosen at random every two days. These five grids were then trawled on the first day using long sweeps and in the same sequence the next day using zero sweeps. The set of five grids was chosen to exclude previously sampled grids so that after 10 days, all 25 grids were sampled. Catches of commercial finfish, mainly lutjanids and lethrinids, were patchy as expected, with many grids producing little or no commercial species. However, many good catches of red snappers, mainly Lutjanus erythropterus and L. malabaricus were made and this should allow a meaningful comparison of catch rates with long and zero sweeps.

On the last day of the cruise, shark longlines were set near the night time trawl site. This method may be used on a future research project to capture useful numbers of sharks as part of a study of their relationships with trawl discards. The method proved extremely successful for capturing small carcharhinids and numerous gut samples were obtained by this method. Because of the baited hooks used, there was some concern about whether any sharks with food in their stomachs would be captured. Longlining did not produce only empty stomachs. Baits dyed with methylene blue were used to see to what extent the dye persisted in shark stomachs. The first line was set for three hours to ensure some sharks were captured. Many large and small sharks were hooked but most large sharks fell off the hook on retrieval of the line. The second line set was hauled in after 30 minutes and produced a shark on every second hook! Dyed bait was still identifiable in shark stomachs from the first line set, suggesting the dye persisted for at least two and a half to three hours.

In the afternoon of the last day, local trawler crews visited *Southern Surveyor* to inspect the BRDs and other associated equipment. This proved highly successful with strong interest in all aspects of the BRD research especially the underwater videos of large and small fishes escaping or being excluded from the prawn net codends.

All the biological data were copied to a cassette tape for down loading to the Cleveland SUN Sparc station.

SUMMARY

The Bycatch Reduction in Prawn Trawls project tested five devices over 50 paired trawls during the first leg (Nordmøre grid with fisheye, Super Shooter with fisheye, Nordmøre grid with square-mesh window, fisheye and AusTED2) and three devices over 42 trawls on the second leg (Nordmore with fisheye, Super Shooter with fisheye, Nordmore with square-mesh window). Clear video images of fish behaviour in codends and escaping from the various devices were obtained. The 50 EFN trawls used to compare catches from trawls with long or zero length sweeps were the final stage of an assessment of the new 'environmentally friendly net' recommended for the Northern Trawl Fishery. The Tropical Fish Ecology project now has valuable catch and video information about the operation of the type of net envisaged for the fishery.

Samples of saurids were obtained for population genetic studies in the Hobart genetics laboratory. Longlining was successfully used to demonstrate its effectiveness at obtaining large numbers of sharks over short time intervals.

Reporting of results

The results will be analysed and reported in the scientific literature where appropriate. All the collected data resides on the Oracle database at the CSIRO Marine Laboratories in Cleveland.

PERSONNEL

(Note: unless otherwise stated, all personnel are staff of the CSIRO Division of Fisheries or students based at CSIRO Cleveland.)

Scientific Crew

Leg 1 (Oct 10-24, 1995)

1 John Salini, Cruise Leader
2 Gary Fry
3 Nick Rawlinson
4 Margaret Farmer
5 Ted Wassenberg
6 Matt Sherlock
7 Steve Eayrs (AMC)
8 Brian McDonald (AMC)
9 John MacCartie (NTDPIE)
10 Paul Johnson (NTDPIE)
11 Samantha Miller
12 Anders Cormie (AMC)

Leg 2 (Oct 24 - Nov 5,1995)

1 John Salini, Cruise Leader
2 Gary Fry
3 David Brewer
4 Yougan Wang
5 Jonathan Staunton Smith
6 Jeff Cordell
7 Steve Eayrs (AMC)
8 Brian McDonald (AMC)
9 Neville Gill (NTDPIE)
10 Clive Liron
11 Miroslaw Ryba
12 Anders Cormie (AMC)

Ship's Crew

Bruce Wallis	Master
Roger Pepper	First Mate/Fishing Master
John Boyes	Second Mate/Fishing Master
Ian McAllister	Chief Engineer
Ian Murray	First Engineer
John Hinchliffe	Electrical Engineer
Noel Anderson	Chief Steward
Alan Smith	Chief Cook
Don Collins	Second Cook
Len Darling	Bosun
Alan Brownlie	A. B.
Malcolm McDougall	A. B.
Phil Lee	Greaser
John Walsham	A. B.
Chris Williams	A. B.
Terry Stinchcome	A. B.
Laurie Cregan	A. B.

ACKNOWLEDGMENTS

We thank the Master, Bruce Wallis; the Fishing Masters, Roger Pepper and John Boyes and the crew of Southern Surveyor for their skills and frequent enthusiastic help in the fish laboratory. The crew's cooperation by sailing short-handed on the first Leg is especially appreciated. Steve Eayrs, Brian McDonald and Anders Cormie (AMC), John MacCartie, Paul Johnson and Neville Gill (NT Fisheries) contributed many extra hours of duty setting-up and testing the BRDs (prawn trawling) and the EFN as well as managing the video taping of both the fish and prawn nets.

Cruise Leader

John Salini

Chief, CSIRO Division of Fisheries

P.C. Young

Contacts

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Distribution

- Normal circulation
- Cruise participants

Table 19. Stations occupied by Southern Surveyor during Cruise SS1095.

Time:	start time in decimal hours;
FF:	Florida Flyer prawn trawl, daytime trawls included a video camera;
Fish/Video:	Frank & Bryce fish trawl with video camera;
EFNLong:	Environmentally Friendly fish-trawl Net with Long (90 m) sweeps;
EFNZero:	Environmentally Friendly fish-trawl Net with Zero (0 m) length sweeps;
StartLat:	start latitude;
StartLong:	start longitude;
EndLat:	end latitutde;
EndLong:	end longitude;
Depth:	depth in metres.

Stn	Time	Date	Gear	Depth	StartLat	StartLong	EndLat	EndLong
1	21.1	11-Oct-95	FF	18	12° 34.5’	141° 30.2’	12° 32.5’	141° 30.4’
2	0.75	12-Oct-95	FF	22	12° 24.3’	141° 30’	12° 30’	141° 29.1’
3	3.67	12-Oct-95	FF	22	12° 31.8’	141° 29.3’	12° 24.4’	141° 29.8’
4	10.47	12-Oct-95	FF	31	12° 26’	141° 24.9’	12° 27.7’	141° 26.4’
5	14.70	12-Oct-95	FF	25	12° 32.9’	141° 28.2’	12° 31.1’	141° 28.1’
6	16.08	12-Oct-95	FF	27	12° 30.7’	141° 27.7’	12° 32.3’	141° 28.2’
7	19.00	12-Oct-95	FF	20	12° 33.2’	141° 30’	12° 27.1’	141° 32.1’
8	21.75	12-Oct-95	FF	18	12° 24.3’	141° 33.1’	12° 30.2’	141° 30.9’
9	0.43	13-Oct-95	FF	16.5	12° 32.3’	141° 30.7’	12° 24.5’	141° 33.3’
10	2.72	13-Oct-95	FF	15.3	12° 2[illegible].4’	141° 34’	12° 31.4’	141° 31.3’
11	10.00	13-Oct-95	FF	32	12° 27.6’	141° 24.8’	12° 26.1’	141° 24.5’
12	12.42	13-Oct-95	FF	33	12° 25.4’	141° 24.4’	12° 27’	141° 24.1’
13	14.75	13-Oct-95	FF	31	12° 28.8’	141° 25’	12° 27.2’	141° 25’
14	16.75	13-Oct-95	FF	30.5	12° 30’	141° 25.3’	12° 31.5’	141° 24.7’
15	19.00	13-Oct-95	FF	16.8	12° 33.7’	141° 30.8’	12° 26.9’	141° 30.8’
16	21.77	13-Oct-95	FF	18.2	12° 27.2’6	141° 32.6’’	12° 34.1’	141° 30.8’
17	1.00	14-Oct-95	FF	19	12° 33.5’	141° 29.6’	12° 26.9’	141° 32.3’
18	3.58	14-Oct-95	FF	18	12° 25.3’	141° 33.2’	12° 30.2’	141° 30.8’
19	8.75	14-Oct-95	FF	37.7	12° 25.3’	141° 20’	12° 23.4’	141° 20’
20	10.55	14-Oct-95	FF	36.5	12° 18.6’	141° 20.2’	12° 19.8’	141° 21.6’
21	13.50	14-Oct-95	FF	35	12° 27.6’	141° 22.8’	12° 29.4’	141° 5.1’
22	16.00	14-Oct-95	FF	32	12° 30.2’	141° 23.9’	12° 28.8’	141° 24.4’
23	17.42	14-Oct-95	FF	32	12° 26.1’	141° 25.3’	12° 28.1’	141° 25.3’
24	19.08	14-Oct-95	FF	23	12° 30.8’	141° 29.4’	12° 25.9’	141° 33’
25	21.92	14-Oct-95	FF	18	12° 27.6’	141° 32.2’	12° 33.7’	141° 29.3’
26	0.50	15-Oct-95	FF	16.4	12° 34.9’	141° 29.6’	12° 28’	141° 32.1’
27	3.03	15-Oct-95	FF	15	12° 27.5’	141° 33.4’	12° 32.9’	141° 30.7’
28	9.42	15-Oct-95	FF	14	12° 26.8’	141° 34.3’	12° 28.3’	141° 33.6’
29	13.58	15-Oct-95	FF	16	12° 26.2’	141° 33.8’	12° 24.9’	141° 34.4’
30	15.75	15-Oct-95	FF	17	12° 28.9’	141° 32.3’	12° 30.8’	141° 31.7’
31	18.75	15-Oct-95	FF	17	12° 30.8’	141° 31.9’	12° 24.6’	141° 34.2’
32	21.33	15-Oct-95	FF	17.5	12° 24.5’	141° 33.8’	12° 31.8’	141° 31’
33	0.08	16-Oct-95	FF	17	12° 29.8’	141° 31.6’	12° 23.5’	141° 33.5’
34	2.67	16-Oct-95	FF	19	12° 22.9’	141° 32.9’	12° 28.4’	141° 30.8’
35	9.00	16-Oct-95	FF	39.5	12° 25’	141° 17.4’	12° 24.5’	141° 19.6’
36	11.05	16-Oct-95	FF	40	12° 23.5’	141° 16.3’	12° 23.1’	141° 14.5’
37	13.50	16-Oct-95	FF	35	12° 24.2’	141° 22.9’	12° 25.9’	141° 28.3’
38	16.08	16-Oct-95	FF	27	12° 27.6’	141° 27.8’	12° 31.2’	141° 27.3’
39	18.83	16-Oct-95	FF	19	12° 32.2’	141° 30.4’	12° 26.4’	141° 32.7’
40	21.50	16-Oct-95	FF	19	12° 26.1’	141° 32.3’	12° 32.6’	141° 29.5’
41	0.22	17-Oct-95	FF	17.2	12° 31.3’	141° 31.1’	12° 29.6’	141° 32’

42	3.80	17-Oct-95	FF	15	12° 30.4'	141° 32'	12° 28.6'	141° 32.7'
43	9.42	17-Oct-95	FF	26	12° 47.8'	141° 25.1'	12° 44.1'	141° 25.7'
44	15.00	17-Oct-95	FF	23	12° 47'	141° 27.5'	12° 43.9'	141° 27.9'
45	17.33	17-Oct-95	FF	23	12° 37.7'	141° 27.7'	12° 36.3'	141° 27.7'
46	19.23	17-Oct-95	FF	15.3	12° 30.3'	141° 32.2'	12° 23.8'	141° 34.9'
47	22.00	17-Oct-95	FF	16.3	12° 25.2'	141° 34.2'	12° 32'	141° 31.3'
48	0.50	18-Oct-95	FF	17	12° 33.1'	141° 30.7'	12° 27.1'	141° 32.6'
49	3.17	18-Oct-95	FF	17	12° 25.9'	141° 33.3'	12° 31.5'	141° 30.4'
50	8.50	18-Oct-95	FF	22	12° 34.7'	141° 27.4'	12° 30.7'	141° 27.4'
51	10.83	18-Oct-95	FF	25	12° 35.8'	141° 27.1'	12° 34.6'	141° 23.6'
52	19.70	18-Oct-95	FF	17	12° 27.3'	141° 32.8'	12° 34.1'	141° 30.4'
53	22.17	18-Oct-95	FF	19	12° 35.1'	141° 29.8'	12° 29.2'	141° 29.4'
54	1.10	19-Oct-95	FF	16.2	12° 27'	141° 33.4'	12° 33.3'	141° 30.8'
55	3.53	19-Oct-95	FF	15	12° 32'	141° 31.5'	12° 25'	141° 34.6'
56	8.25	19-Oct-95	FF	36	12° 23.3'	141° 22.2'	12° 26'	141° 21.7'
57	11.17	19-Oct-95	FF	39	12° 21.6'	141° 17.7'	12° 21.6'	141° 14.6'
58	13.75	19-Oct-95	FF	40	12° 25.4'	141° 17.9'	12° 28.9'	141° 18.4'
59	16.33	19-Oct-95	FF	33.2	12° 31.1'	141° 21.3'	12° 27.8'	141° 23.8'
60	18.97	19-Oct-95	FF	20	12° 37.8'	141° 28.6'	12° 44.9'	141° 28.6'
61	21.62	19-Oct-95	FF	19.8	12° 46'	141° 29.1'	12° 39.1'	141° 29.1'
62	0.25	20-Oct-95	FF	17	12° 39.3'	141° 29.4'	12° 45.6'	141° 28.5'
63	2.75	20-Oct-95	FF	19	12° 44.7'	141° 28.9'	12° 37.7'	141° 29'
64	8.93	20-Oct-95	FF	29.5	12° 48.2'	141° 21.1'	12° 47.2'	141° 17.7'
65	11.75	20-Oct-95	FF	37.5	12° 46.3'	141° 14.5'	12° 46.5'	141° 18.1'
66	14.83	20-Oct-95	FF	30	12° 46.6'	141° 23.8'	12° 45'	141° 20.2'
67	17.08	20-Oct-95	FF	34	12° 44.5'	141° 19.1'	12° 45'	141° 22'
68	19.17	20-Oct-95	FF	21	12° 43.4'	141° 27.9'	12° 37.7'	141° 29.5'
69	21.75	20-Oct-95	FF	18	12° 34.5'	141° 30'	12° 28'	141° 32.5'
70	0.45	21-Oct-95	FF	17.3	12° 27.8'	141° 33.7'	12° 34.8'	141° 30.4'
71	3.07	21-Oct-95	FF	18.1	12° 37.9'	141° 29.6'	12° 45.1'	141° 29.4'
72	9.17	21-Oct-95	FF	33	12° 43.8'	141° 19.9'	12° 45.2'	141° 17.3'
73	13.42	21-Oct-95	FF	37	12° 46.6'	141° 16.1'	12° 46.8'	141° 12.7'
74	15.25	21-Oct-95	FF	37	12° 47.1'	141° 15.4'	12° 47.7'	141° 18.8'
75	17.50	21-Oct-95	FF	30	12° 46.7'	141° 22.2'	12° 44.7'	141° 23'
76	18.93	21-Oct-95	FF	18.9	12° 44.8'	141° 28.3'	12° 38.4'	141° 29.8'
77	21.50	21-Oct-95	FF	18.5	12° 35.2'	141° 29.7'	12° 28.1'	141° 32.8'
78	0.00	22-Oct-95	FF	18	12° 26.9'	141° 32.6'	12° 32.7'	141° 30.5'
79	3.00	22-Oct-95	FF	19	12° 31.8'	141° 30.7'	12° 25.3'	141° 33.4'
80	8.13	22-Oct-95	FF	37	12° 29.7'	141° 21.3'	12° 18.6'	141° 24.1'
81	11.00	22-Oct-95	FF	37	12° 19.1'	141° 20.2'	12° 18.6'	141° 24.1'
82	19.25	22-Oct-95	FF	18	12° 24.7'	141° 33.2'	12° 30.8'	141° 30.8'
83	21.92	22-Oct-95	FF	17	12° 30.6'	141° 31.4'	12° 23.6'	141° 33.6'
84	0.40	23-Oct-95	FF	18	12° 24.1'	141° 33.5'	12° 30.3'	141° 32'
85	2.83	23-Oct-95	FF	16	12° 31.1'	141° 31.6'	12° 24.5'	141° 34.4'
86	15.08	23-Oct-95	efn trial	40	12° 25.8'	141° 17.2'	12° 24.3'	141° 7.8'
87	16.42	23-Oct-95	efn trial	39	12° 24.6'	141° 17.8'	12° 27.4'	141° 16.9'
88	22.55	23-Oct-95	FF	16	12° 30.5'	141° 31.7'	12° 24.1'	141° 34.1'
89	1.00	24-Oct-95	FF	18	12° 24.2'	141° 33.3'	12° 29.9'	141° 31.6'
90	3.58	24-Oct-95	FF	18	12° 30.2'	141° 31.8'	12° 23.7'	141° 34.3'
91	19.17	24-Oct-95	FF	17	12° 31'	141° 31.4'	12° 25'	141° 34'
92	21.83	24-Oct-95	FF	15.2	12° 23.9'	141° 34.2'	12° 30'	141° 32'
93	0.67	25-Oct-95	FF	14.4	12° 31.5'	141° 31.7'	12° 24.6'	141° 34.4'
94	3.20	25-Oct-95	FF	16.5	12° 24.4'	141° 33.9'	12° 30.6'	141° 31.9'
95	9.42	25-Oct-95	efn-long	48	12° 28.5'	141° 3.7'	12° 26.7'	141° 2.6'

96	11.00	25-Oct-95	efn-long	0	12° 25.1’	140° 58.1’	12° 26.5’	140° 59.4’
97	12.08	25-Oct-95	efn-long	53	12° 28.7’	141° 0.1’	12° 30.2’	141° 0.7’
98	14.25	25-Oct-95	efn-long	48	12° 32.3’	141° 4.3’	12° 30.9’	141° 5.3’
99	16.50	25-Oct-95	efn-long	46	12° 28.7’	141° 6’	12° 30.8’	141° 7.1’
100	0.00	25-Oct-95	FF	14	12° 31.4’	141° 31.9’	12° 25.3’	141° 34.7’
101	22.50	25-Oct-95	FF	15	12° 25.3’	141° 34.3’	12° 30.8’	141° 31.7’
102	1.17	26-Oct-95	FF	16	12° 32’	141° 31.3’	12° 25’	141° 34.2’
103	3.75	26-Oct-95	FF	16	12° 23.8’	141° 34’	12° 29.5’	141° 31.4’
104	9.75	26-Oct-95	efn-no	54	12° 29.3’	141° 0.2’	12° 27.4’	141° 59.7’
105	11.42	26-Oct-95	efn-no	55	12° 25.6’	140° 58.6’	12° 24.4’	140° 56.6’
106	13.50	26-Oct-95	efn-no	48.5	12° 29.8’	141° 4’	12° 31.8’	141° 4.07’
107	14.87	26-Oct-95	efn-no	47	12° 33.3’	141° 4.5’	12° 31.6’	141° 5’
108	16.17	26-Oct-95	efn-no	46	12° 29.1’	141° 6.3’	12° 27.6’	141° 7.3’
109	19.25	26-Oct-95	FF	17	12° 30.3’	141° 31.8’	12° 25.1’	141° 34.2’
110	21.75	26-Oct-95	FF	15	12° 24.3’	141° 34.1’	12° 30.6’	141° 32.1’
111	0.20	27-Oct-95	FF	0	12° 31.6’	141° 31.4’	12° 24.5’	141° 34.2’
112	2.60	27-Oct-95	FF	14.8	12° 23.7’	141° 34.4’	12° 30.4’	141° 32’
113	9.17	27-Oct-95	efn-no	52	12° 29.8’	141° 1.7’	12° 28.5’	141° 0.8’
114	11.08	27-Oct-95	efn-no	56	12° 27.7’	140° 57.6’	12° 27.9’	140° 59.6’
115	13.17	27-Oct-95	efn-no	54	12° 25.3’	141° 0.6’	12° 27.1’	141° 1’
116	14.70	27-Oct-95	efn-no	47	12° 31.5’	141° 5.9’	12° 33.7’	141° 5.8’
117	16.42	27-Oct-95	efn-no	50	12° 32.8’	141° 2’	aborted	aborted
118	17.08	27-Oct-95	efn-no	50	12° 32.9’	141° 2.5’	12° 32.8’	141° .5’
119	1.08	28-Oct-95	FF	17	12° 31.5’	141° 30.7’	12° 24.2’	141° 33.9’
120	3.67	28-Oct-95	FF	16	12° 24.1’	141° 34’	12° 29.7’	141° 32.1’
121	9.75	28-Oct-95	efn-long	54	12° 29.3’	141° 1’	12° 27.6’	140° 59.5’
122	11.00	28-Oct-95	efn-long	55	12° 27.6’	140° 58.1’	12° 27.4’	141° 0.2’
123	13.83	28-Oct-95	efn-long	53	12° 25.3’	141° 0.4’	12° 26.7’	141° 0.4’
124	14.50	28-Oct-95	efn-long	46	12° 30.9’	141° 6.1’	12° 33.1’	141° 5.8’
125	16.25	28-Oct-95	efn-long	51	12° 33’	141° 1.5’	12° 33.1’	141° 3.4’
126	19.70	28-Oct-95	FF	19	12° 31.4’	141° 31’	12° 26.5’	141° 33.4’
127	22.33	28-Oct-95	FF	16	12° 25.3’	141° 34’	12° 31.9’	141° 31.3’
128	1.13	29-Oct-95	FF	15	12° 32.4’	141° 31.1’	12° 25.3’	141° 34.9’
129	3.63	29-Oct-95	FF	13	12° 24.1’	141° 35.7’	12° 29.5’	141° 32.6’
130	8.92	29-Oct-95	efn-long	50	12° 24.6’	141° 4.5’	12° 26’	141° 4.1’
131	10.58	29-Oct-95	efn-long	54	12° 27’	141° 0.3’	12° 28.3’	140° 58.8’
132	12.92	29-Oct-95	efn-long	56	12° 30.7’	140° 57.7’	12° 30.8’	140° 59.2’
133	14.42	29-Oct-95	efn-long	54	12° 30.7’	141° 0.6’	12° 32.4’	141° 1.6’
134	15.83	29-Oct-95	efn-long	47	12° 32.6’	141° 5.9’	12° 31’	141° 5.9’
135	19.50	29-Oct-95	FF	16	12° 30.3’	141° 32.2’	12° 24.1’	141° 35.6’
136	22.37	29-Oct-95	FF	15	12° 25.7’	141° 34.7’5	12° 32.4’	141° 31’
137	1.58	30-Oct-95	FF	15	12° 31.8’	141° 31.3’	12° 25’	141° 34.3’
138	8.33	30-Oct-95	efn-no	50	12° 24.5’	141° 5.4’	12° 26.4’	141° 4.8’
139	10.75	30-Oct-95	efn-no	54	12° 26.5’	141° 0.6’	12° 29.4’	141° 0.5’
140	12.83	30-Oct-95	efn-no	55	12° 30.5’	141° 57.8’	12° 32.2’	141° 58.3’
141	14.08	30-Oct-95	efn-no	53	12° 31.5’	141° 0.5’	12° 29.4’	141° 0.5’
142	16.00	30-Oct-95	efn-no	46	12° 32’	141° 5.9’	12° 33.7’	141° 5.6’
143	19.25	30-Oct-95	FF	20	12° 33.5’	141° 29.8’	12° 28.3’	141° 32.5’
144	21.92	30-Oct-95	FF	17	12° 27.2’	141° 33.7’	12° 33.7’	141° 30.2’
145	0.47	31-Oct-95	FF	15.5	12° 33.6’	141° 30.9’	12° 26.9’	141° 34.6’
146	3.50	31-Oct-95	FF	13.5	12° 26.3’	141° 34.6’	12° 32.1’	141° 31.4’
147	8.75	31-Oct-95	efn-no	51	12° 32.6’	141° 0.9’	12° 32.3’	140° 59.2’
148	10.17	31-Oct-95	efn-no	55	12° 33.3’	140° 57.2’	12° 31.9’	140° 58.3’
149	12.08	31-Oct-95	efn-no	49	12° 28.9’	141° 3.4’	12° 27.4’	141° 3.1’

150	14.08	31-Oct-95	efn-no	50	12° 27.1'	141° 4.1'	12° 27.3'	141° 5.7'
151	16.20	31-Oct-95	efn-no	46	12° 27'	141° 6'	12° 29.6'	141° 6.5'
152	19.70	31-Oct-95	FF	18	12° 29.9'	141° 31.8'	12° 22.4'	141° 35.1'
153	22.30	31-Oct-95	FF	0	12° 23.4'	141° 34.5'	12°	141'
154	1.00	01-Nov-95	FF	18	12° 31.9'	141° 30.7'	12° 25.7'	141° 32.6'
155	3.50	01-Nov-95	FF	15	12° 25'	141° 34.3'	12° 30.4'	141° 31.2'
156	8.75	01-Nov-95	efn-long	51	12° 32.6'	141° 0.6'	12° 35.2'	141° 0.6'
157	11.00	01-Nov-95	efn-long	53	12° 33.2'	140° 59'	12° 34.3'	140° 58.5'
158	13.00	01-Nov-95	efn-long	50	12° 29.8'	141° 2.9'	12° 27.8'	141° 2.5'
159	14.50	01-Nov-95	efn-long	50	12° 26.5'	141° 4.5'	12° 28.7'	141° 4.5'
160	16.17	01-Nov-95	efn-long	46	12° 27.1'	141° 6.4'	12° 25.7'	141° 6.3'
161	19.42	01-Nov-95	FF	23	12° 32.5'	141° 29.2'	12° 27.4'	141° 33'
162	21.83	01-Nov-95	FF	16	12° 27.1'	141° 33.5'	12° 32.9'	141° 29'
163	0.23	02-Nov-95	FF	24	12° 33.3'	141° 20.5'	12° 27.5'	141° 32.8'
164	2.67	02-Nov-95	FF	20	12° 27.3'	141° 33.8'	12° 33.3'	141° 28.3'
165	8.33	02-Nov-95	efn-long	47	12° 31'	141° 4.6'	12° 29.2'	141° 4.6'
166	10.17	02-Nov-95	efn-long	56	12° 28.4'	140° 57.8'	12° 26.9'	140° 59.2'
167	12.08	02-Nov-95	efn-long	52	12° 26.7'	141° 2.9'	12° 25.3'	141° 2.7'
168	14.17	02-Nov-95	efn-long	53	12° 25.1'	141° 2.7'	12° 24.1'	141° 3.7'
169	16.00	02-Nov-95	efn-long	0	12° 24.4'	141° 6.5'	12° 26.6'	141° 6.3'
170	19.42	02-Nov-95	FF	25	12° 33.9'	141° 27.9'	12° 27.8'	141° 32.8'
171	21.83	02-Nov-95	FF	21	12° 27.5'	141° 32.6'	12° 33.8'	141° 28.2'
172	0.42	03-Nov-95	FF	26	12° 34.4'	141° 27.6'	12° 29.2'	141° 31.5'
173	3.00	03-Nov-95	FF	18	12° 28.2'	141° 32'	12° 33.9'	141° 28'
174	9.00	03-Nov-95	efn-no	46	12° 31.4'	141° 4.9'	12° 28.8'	141° 4.7'
175	10.33	03-Nov-95	efn-no	56	12° 29'	140° 58.5'	12° 26.4'	140° 58.8'
176	13.92	03-Nov-95	efn-no	49	12° 27.8'	141° 2.9'	12° 26'	141° 3.9'
177	14.25	03-Nov-95	efn-no	53	12° 25.6'	141° 2.6'	12° 23.6'	141° 2.6'
178	16.08	03-Nov-95	efn-no	46	12° 24.6'	141° 6.3'	12° 26.4'	141° 6.2'
179	19.00	03-Nov-95	FF	26	12° 33'	141° 28'	12° 27.9'	141° 33'
180	0.50	04-Nov-95	FF	22	12° 34.3'	141° 27.7'	12° 27.7'	141° 32.2'
181	2.92	04-Nov-95	FF	18	12° 27.4'	141° 33'	12° 34.1'	141° 29.7'
182	8.50	04-Nov-95	longline	20	12° 26.6'	141° 30.5'		
183	11.25	04-Nov-95	longline	20	12° 26.4'	141° 30.5'		
184	12.50	04-Nov-95	longline	20	12° 26.5'	141° 30.5'		
185	19.57	04-Nov-95	FF	18	12° 23.5'	141° 33.8'	12° 29.8'	141° 30.4'
186	22.00	04-Nov-95	FF	20	12° 30.1'	141° 30.6'	12° 23.4'	141° 34.8'
187	0.42	05-Nov-95	FF	16	12° 23.7'	141° 34.2'	12° 29.2'	141° 30.8'