Promoting industry uptake of gear modifications to reduce bycatch in the South East Trawl Fishery

Terence I. Walker, James L. Newman, and Ian A. Knuckey

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NON-TECHNICAL SUMMARY

2001/006 Promoting industry uptake of gear modifications to reduce bycatch in the South East Trawl Fishery

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Objectives:

The present project began with four objectives, but a fifth objective was added when information from overseas indicated that inserting a 'selector panel' of diamond mesh rotated 90º ('T90 selector panel') into the trawl codend can enhance release of small fish while maintaining the strength of the codend netting. Objective 5 provides a basis for evaluating new opportunities and replaces part of Objective 4.

1. Through application in normal fishing practices, industry improve the initial gear modifications (from FRDC Project 1998/204) to retain commercial species and reduce bycatch and discarding.

2. Voluntary uptake of modified gear by a large percentage of commercial fishers in the South East Trawl Fishery.

3. Allow fishers to observe fish behaviour, trial, modify and improve the gear over a 12-month period assisted by underwater video equipment.

4. Review alterations that fishers have made and scientifically test the performance of the modified gear and review changes to fish behaviour within the gear.

5. Compare the catch and catch composition between two trawl codend constructed of 90-mm diamond-mesh netting where one is fitted with a 'T90 selector panel' and the other is not through sea trials using a demersal trouser-trawl rig.

Non Technical Summary:

The present project was developed to build on the outcomes of the earlier successful FRDC Project 1998/204 'Effects of Trawling Sub-program: Maximising yield and reducing discards in the South East Trawl Fishery (SETF) through gear development and evaluation'. Referred to as the Trawl Bycatch Reduction Project, that project demonstrated that modifications to the design of standard demersal trawl gear used by industry can reduce the capture of discarded small fish by up to 60%, whereas the retained catch of commercial-sized fish is reduced by less than 10%. These alternative designs were achieved by testing a range of modifications to the standard trawl codend designs used by industry and by observing fish behaviour via underwater video film.

To achieve the required outcomes from the project whereby industry accepts the need for reduced bycatch and improved escapement of small fish to improve yields from fish stocks, the project approach was to adapt to the stage of industry acceptance and industry uptake of modified codend designs. Through SETFIA discussions, it became clear that the best approach was for the present project to be undertaken gradually through three operational components ('Fish behaviour studies', 'Extension', and 'Trial of modified codends by industry'), all of which were completed successfully. A fourth component—'Experimental sea trials of codend T90 selector panel'—was subsequently added and completed successfully when information from overseas indicated that insertion of a 'selector panel' of diamond mesh rotated 90º ('T90 selector panel') into the trawl codend enhanced escapement of small fish while, unlike square-mesh netting trialled by industry, maintained the strength of the codend netting.

The first component , 'Fish behaviour studies', involved analysing and documenting ~100 hours of underwater video footage recorded as part of the Trawl Bycatch Reduction Project *in situ* at various locations inside trawl nets during demersal otter trawling operations. Several swimming behaviours by the fish were recorded and the behaviours were categorised as impinged, resting, cruise swimming, or burst swimming. Two swimming modes were distinguished: the anguilliform (eel-like) mode and carangiform mode. Species swimming in the anguilliform mode (e.g. the elongate-shaped blue grenadier (*Macruronus novaezelandiae*) are unable to sustain continuous movement for long periods, whereas species swimming in the carangiform mode (e.g. gemfish (*Rexea solandri*)) exhibit more sustained swimming. The amount of escapement of commercial species by swimming through the meshes in the wings, body and codend of the trawl net, or by swimming out of the path or out of the main opening of the trawl nets was quantified. These results are fully documented in a thesis and a scientific paper, and video tapes of fish swimming in trawl nets have been widely distributed to industry and other stakeholders.

The second component of the project, 'Extension', involved promoting to industry the results from the Trawl Bycatch Reduction Project through gear development and evaluation', from other information available in the literature, and from the results of the fish behaviour studies of the present project. The extension required extensive liaison face to face with industry members, an industry workshop, and presentations to SETFIA, SETMAC, GABMAC and port meetings. It also required preparation of extensive promotional material: one video, notes on construction of modified codends for industry members, two posters, and nine published articles in *SeaNet News*, *South East Trawl Fishery News*, and *Fishing Future* promoting gear modifications for bycatch reduction and promoting the present project.

The third component, 'Trial of modified codends by industry', involved fishers discovering for themselves the benefits of modified codends. This component was flexible through encouragement of fishers to use codends constructed with diamond-mesh netting of mesh size larger than the legal minimum mesh size of 90 mm or codends with panels of square-mesh netting of mesh size 90-mm or more. Fishers were subsequently encouraged to consider using single braided netting, or codends with 'T90 panels' or 'T90 lengtheners'. This was achieved by distributing modified codends of various mesh-shape and mesh-size configurations to fishers on 30 separate vessels, operating throughout the SEFT and GABTF in New South Wales, Victoria, Tasmania and South Australia.

The fourth component, 'Experimental sea trials of codend T90 selector panel', involved adopting an experimental approach to test the effectiveness of a T90 selector panel. This involved setting up two identical codends constructed with 90-mm diamond-mesh netting where one had a selector panel (T90) and the other had no selector panel (Control). The two codends were hauled together using a trouser-trawl rig. A total of

10 094 animals (2 species of cephalopoda, 9 species of chondrichthyes, 2 species of crustacea, and 31 species of teleostei) were caught during 16 trouser-trawl tows, where the T90 codend (4190 animals) had a markedly lower catch than the Control codend (5904 animals). The results indicate that retention of animals by the T90 codend increased with increasing length of animal and above ~300 mm total length was higher in the T90 codend than in the Control codend. There is evidence of greater escapement when the T90 selector panel is at the top of the codend than when it is on the bottom of the codend.

Improved awareness of the benefits of modifying codend design in industry was demonstrated by analysis of data on codend mesh-shape and mesh-size available in the SETF logbook returns submitted to AFMA since 2003, which confirmed a steady increase in the use of modified codends. By 2005, 7% of otter trawl tows were with square mesh, and for tows with diamond mesh, 2% were with <90-mm mesh-size (required for prawns), 58% with 90–99-mm, 35% with 100–119-mm, and 5% with ≥120-mm. Initially, uptake of increased mesh size was greater in waters of ≥150-m depth than in waters of <150-m depth, but more recently the pattern of uptake of larger mesh size was more marked in the shallower waters. At depths ≥150-m, use of ≥100-mm mesh-size increased rapidly during the early phase of the study and remained stable at about 50% of the tows during 2003–05 and at depths <150 m, use of ≥100-mm mesh-size increased from 13% of tows during 2003 to 32% during 2005. Uptake of larger codend mesh-size followed the general pattern of decreasing proportions of the tows in waters <150-m depth from New South Wales to Eastern Bass Strait and from Eastern Bass Strait to Eastern Tasmania and then to the more westerly regions of the fishery. Most of the square-mesh netting was used in Eastern Bass Strait (64%) and in the shallower waters of <150-m depth (57%).

Reluctance to use codends constructed with square-mesh selector panels arose because square-mesh netting is more likely to tear or the knots slip than diamond-mesh netting when under strain. This makes square-mesh less popular for large vessels, particularly when operating in the deeper waters of the continental slope and explains why most uptake of square-mesh was in the shallower waters on top of the continental shelf. Adoption of larger diamond-mesh shape or rotated diamond mesh, such as the T90 design, is more appropriate for large vessels.

The increase in use of large mesh-size and square-mesh in codends was achieved despite a difficult time for the trawl industry when economic returns to some sectors were poor, exacerbated by rising fuel price. In addition, the increase in use of modified codends occurred at a time when there was a shift of trawl effort from deep to shallower waters where the species mix tends to favour smaller mesh-size.

Broadly, the stated objectives of the project were met, although the codends developed by fishers were not scientifically tested. Early during the course of project, it was clear that extensive at-sea scientific testing was not a valuable use of the resources available to the project, given that this was the focus of the Bycatch Reduction Project. For the present project, it was preferable to invest in extension activities using available information and in the construction and distribution of codends for fishers to trial alternative codend designs and to invest in trialling the T90 selector panel.

OUTCOMES ACHIEVED

As a direct result of this project and its predecessor the Trawl Bycatch Reduction Project, Industry became convinced of the benefits of various gear modifications in reducing bycatch and eventually took the initiative to seek the legislative changes in gear configuration implemented early 2006. All otter board trawlers now use some method of bycatch reduction in their nets. This consists of either larger diamond-mesh codends or panels of square-mesh or T90 netting fitted. Where a codend has a mesh-size less than 102 mm, there is a legislative requirement for it to be constructed of single-twine mesh, or alternatively, if constructed of double-twine mesh then a panel of square mesh or T90 mesh must be fitted to the codend. All GABTF trawl vessels now use T90 mesh or lengtheners in their codends. All of these gear configurations reduce the capture and subsequent discarding of small fish species.

Industry members require the flexibility to use codend mesh-size of 90 mm (present legal minimum mesh-size) when targeting species such as flathead and squid, but they have demonstrated during the course of the present project that they are prepared to be flexible with codend design. Given 72% of otter trawl vessels reported using codend mesh-size ≥100 mm and 42% of otter trawl vessels reported using codend square-mesh at some stage during the 3-year period 2003–05 demonstrates a willingness to modify the designs of their codends to reduce bycatch and impacts on the pre-recruit components of harvested stocks.

The project disseminated information on fish behaviour in trawl nets and information on modification of codend designs, and enabled many fishers to trial alternative codend designs first hand. The project also contributed to understanding the effectiveness of inserting selector panels constructed from diamond-shape netting turned 90 degrees into standard codends for escapement of small fish and retention of large fish.

Through SETFIA, industry advocated and brought about amendments to the legislation for codend netting. This included use of only single braided netting (prohibit double braided netting) for 90-mm mesh-size and use of an escape panel fitted in codends where double braided netting is used. There is growing interest within industry to replace 'square-mesh selector panels' with 'T90 selector panels' or 'T90 lengtheners'.

The direction to AFMA from the Commonwealth Minister for Agriculture, Fisheries and Forests to cease overfishing, recover overfished stocks, and manage the broader impacts of fishing on the environment created further requirements for adoption of modified codends. Gear modification will play a key role in reduced catch of undersized fish and bycatch.

Keywords: Bycatch, otter trawl codend design, mesh-size, diamond-mesh, and square-mesh.

Acknowledgments

Professional trawler fishers, who willingly trialled modified codends, and the net makers, who participated in construction of codends, are thanked for their essential contributions to the project. The gradual uptake of modified codend design by industry attests to the success of the project.

Mr Terry Moran, Mr Fritz Drenkhahn and Gail Richey of SETFIA, are acknowledged for their support for the project and for encouraging fishers to adopt modified codend designs. Several people are acknowledged for their field and liaison with industry role on the project prior to this role being adopted by James Newman early 2004. These people are Andrew Hogg, formerly of MAFFRI observer based in Mount Gambia, South Australia (18 March 2002–18 October 2003); Ben Leslie, formerly of Ocean Watch Australia Limited (1 July 2002– 30 June 2003); and Ken Smith, formerly a MAFFRI field observer based in Lakes Entrance, Victoria (1 July 2003–27 February 2004). Kate Milner formerly of Ocean Watch Australia Limited coordinated and participated in field operations and prepared the data related to the sea trials testing insertion of T90 selector panels in trawl codends. The Australian Maritime College is acknowledged for allowing the T90 sea trials to undertaken aboard the Fisheries Training Vessels *Bluefin* and for encouraging its students and staff to participate in the trials. Crispian Ashby, of the Fisheries Research and Development Corporation, is acknowledged for liaising with industry to encourage uptake of modified codends, his expertise on codend design, his constructive advice throughout the course of the project, and his comments on the final report.

Matthew Piasente, formerly a postgraduate student at the Australian Maritime College and presently a member of AFMA, is acknowledged for successfully completing behaviour studies of fish caught in codends and preparation of video film of fish caught in codends, which were important components of the project. Dr Paul McShane and Steve Eayrs, of the Australian Maritime College, served as academic supervisors to Matthew Piasente and contributed to publication of some of the results. Thim Skouson of AFMA is acknowledge for the provision of fisher SETF logbook data, collected by AFMA, and Anne Gason of MAFFRI is acknowledged for management of the SETF logbook data used to depict trends in use of codend mesh-shape and mesh-size.

FINAL REPORT

2001/006 Promoting industry uptake of gear modifications to reduce bycatch in the South East Trawl Fishery

Background

Acronyms

AFMA	Australian Fisheries Management Authority
AMC	Australian Maritime College
DAFF	Department of Agriculture Fisheries and Forests
DEWHA	Department of Environment Water Heritage and Arts
FRDC	Fisheries Research and Development Corporation
GAB	Great Australia Bight
GABMAC	Great Australian Bight Management Advisory Committee
GABTF	Great Australian Bight Trawl Fishery
GHATF	Gillnet Hook and Trap Fishery
MAFFRI	Marine and Freshwater Fisheries Research Institute
MCCN	Marine and Coastal Community Network
NPOA-Sharks	National Plan of Action for the Conservation Management of Sharks
SETF	South East Trawl Fishery
SETFIA	South East Trawl Fishery Industry Association
SETMAC	South East Trawl Management Advisory Committee
T90	Codend T90 panel selector or T90 lengthener made by turning netting by 90°

Previous research

The present project has an emphasis on industry extension and was developed as an outcome of the earlier FRDC Project 1998/204 'Effects of Trawling Sub-program: Maximising yield and reducing discards in the South East Trawl Fishery (SETF) through gear development and evaluation'. The earlier project, referred to throughout the present report as the Trawl Bycatch Reduction Project, demonstrated that modifications to the design of standard demersal trawl gear used by industry can reduce the capture of discarded small fish by up to 60%, whereas the retained catch of commercial-sized fish is reduced by less than 10%. These alternative designs were achieved by testing a range of modifications to the standard trawl codend designs used by industry and by observing fish behaviour via underwater video film.

The Trawl Bycatch Reduction Project also indicated that there are potential gains in yield from the resource of some species by increasing the codend mesh-size above the current legal minimum mesh-size of 90 mm for the netting in trawl codends. This suggests that there may be benefits in legislating to increase the mesh-size, but each species taken has its own optimum mesh-size and there is no ideal mesh-size to suit all species in the multi-species SETF. There are advantages in providing fishers with flexibility and choice to vary their mesh-size depending on the species targeted. Hence, the purpose of the present project was to provide trawler fishers with appropriate information and to issue them with codends of larger mesh-sizes for the purpose of gaining experience in the use of these codends to enable them make better-informed choices on mesh-size and mesh-shape (diamond-mesh, square-mesh, or T90-mesh). Other purposes of the project were to encourage industry use of modified gear on a voluntary basis and to assist industry with fine-tuning gear modifications.

Project approach

As with the Trawl Bycatch Reduction Project, work on the present project had strong industry support in most fishing ports maintained through effective collaboration involving industry. Collaboration for the present project involved MAFFRI, Fishwell Consulting Pty Ltd, Ocean Watch Australia Limited, the Australian Maritime College, and industry.

To achieve the required outcome from the project whereby industry accepts the need for reduced bycatch and improved escapement of small fish for improving yields from fished stocks, the project approach was progressively modified and fine-tuned in response to the stage of industry acceptance and industry uptake of modified codend designs.

Initially, the project had three components. The first component was to undertake behavioural studies of fish in trawl nets by analysis and documentation of underwater video footage filmed from inside trawl nets in operation collected as part of the Trawl Bycatch Reduction Project. The second component involved extension promoting to industry the results from the Trawl Bycatch Reduction Project and making available information from the literature and from the results of the behaviour studies from the present project. The third component was to have fishers discover the benefits of trialling modified codends. The third component was flexible through encouragement of fishers to use codends constructed with diamond-mesh netting of mesh-size larger than 90 mm or codends with panels of square-mesh netting of mesh-size 90-mm or more. A fourth component was added to the project following recent evidence from overseas of greater escapement of small fish from the codend when fitted with a T90 selector panel. This additional component was to test experimentally at-sea the effectiveness of inserting a 'selector panel' of diamond mesh-shape rotated 90º ('T90 selector panel') into the trawl codend constructed of diamond-mesh netting.

At the beginning of the project, a MAFFRI field scientist constructed codends, issued these codends to fishers on selected vessels, monitored their use, and undertook liaison work. There was early acceptance in the western region of the fishery, but resistance to change in the eastern regions of the fishery. To improve acceptance by industry, following discussions with SETFIA and FRDC, the period of the project was extended to provide more time to gain industry acceptance and to divert resources for the purpose of:

- increasing publicity within industry on the benefits of increasing mesh-size above 90 mm and adopting panels of square-mesh netting in codends, and
- increasing the number of codends issued to fishers, particularly in the eastern regions of the SETF, by working through commercial net makers.

Towards the end of the project, fishers were encouraged to consider using single braided netting, or codends with 'T90 panels' or 'T90 lengtheners', which at the time had not been used in Australia. The initial response from industry to inserting square-mesh panels in codends or constructing codends from square-mesh netting for reducing bycatch was positive, but because of the subsequent discovery that this weakened the codends, the fourth component testing the effectiveness of a T90 selector panel was added to the project.

Structure of report

The sections of the report Methods and Results/Discussion are each sub-divided as into four sections: 'Behaviour studies', 'Extension', 'Trial of modified codends by industry', and 'Experimental sea trials of codend T90 selector panel' to reflect the four main operational components of the project. There were two major published documents associated with the behaviour studies component (scientific paper and thesis) and nine short articles published supporting the extension work. The scientific paper, published articles associated with the extension work, material presented to SETFIA, SETMAC, and GABMAC and at port meetings, a report from an educational workshop, posters, and printed notes are appended to the report.

Need

To obtain the full benefits from the high success of FRDC Project the Trawl Bycatch Reduction Project there was a need to demonstrate to the fishing industry the advantages of modified codend designs (Knuckey and Ashby 2010) in the reduction of the bycatch of small fish. Apart from benefits to industry from reduced handling of bycatch and from reduced mortality of pre-recruit fish thereby improving harvest yields of sized fish, legislative change and a Ministerial direction to AFMA in recent years created requirements to evaluate better the catches and to mitigate bycatch in Australian fisheries. Hence, the present project was initiated to better inform Industry of the findings of the Trawl Bycatch Reduction Project and of developments in bycatch mitigation, and to enable fishers to gain first hand experience using modified codends. This initiative helped position the demersal trawl fishery for meeting the requirements of the Commonwealth *Fisheries Management Act 1991* and Commonwealth *Environment Protection and Biodiversity Conservation Act (EPBC) 1999*. Although unforeseen at the time of initiation of the present project, the initiative also better placed the fishery to meet the requirements of the Ministerial directive issued during 2006.

Australia's Commonwealth *Fisheries Management Act 1991* requires management arrangements to "ensure that the exploitation of fisheries resources and the carrying out of related activities are conducted in a manner consistent with the principles of ecologically sustainable development and the exercise of the precautionary principle, in particular the need to have regard to the impact of fishing activities on non-target species and the long-term sustainability of the marine environment". Hence, in accordance with these legislative obligations and Commonwealth Government policy prescribed under Australia's Ocean Policy regarding the impact of fishing activities on non-target species and the environment, the Australian Fisheries Management Authority developed bycatch action plans for major Australian fisheries.

More recently, the Commonwealth *Environment Protection and Biodiversity Conservation Act (EPBC) 1999* requires fisheries managed under Commonwealth jurisdiction or fisheries producing products for export to be 'strategically assessed'. This process involves assessing each fishery for ecological impacts on (a) target and byproduct species, (b) bycatch species, (c) threatened, endangered and protected species, (d) marine habitats, and (e) marine food chains. The process requires collection of appropriate data, risk assessment, and appropriate management responses.

In early 2006, AFMA received a direction from the Commonwealth Minister for Agriculture Fisheries and Forests to cease overfishing, recover overfished stocks, and manage the broader impacts of fishing on the environment. This direction created further requirements for adoption of modified codends. These requirements arise from proposed initiatives outlined in AFMA's document "Response to Ministerial Direction – SESSF". Requirements relevant to the present project are as follows:

- discarding of quota species (or target species in non-quota fisheries) will be illegal from 2007;
- a reduction of total discards across all fisheries; and
- additional spatial closures in the Commonwealth trawl sector are to reduce bycatch of juvenile scalefish species, preserve structured benthic habitat on the shelf, protect important school shark habitat in Bass Strait, and protect deep-sea dogfish.

Objectives

The first four objectives of the project were established during the design phase of the project. The fifth objective was added during the course of the present project when information from overseas indicated that inserting a 'selector panel' of diamond mesh rotated 90º ('T90 selector panel') into the trawl codend can enhance release of small fish while maintaining the strength of the codend netting.

1. Through application in normal fishing practices, industry improve the initial gear modifications (from FRDC Project 1998/204) to retain commercial species and reduce bycatch and discarding.
2. Voluntary uptake of modified gear by a large percentage of commercial fishers in the South east Trawl Fishery.
3. Allow fishers to observe fish behaviour, trial, modify and improve the gear over a 12-month period assisted by underwater video equipment.
4. Review alterations that fishers have made and scientifically test the performance of the modified gear and review changes to fish behaviour within the gear.
5. Compare the catch and catch composition between two trawl codend constructed of 90-mm diamond-mesh netting where one is fitted with a 'T90 selector panel' and the other is not through sea trials using a demersal trouser-trawl rig.

Methods

The methods are described under four separate headings, which address the four main operational components of the project: 'Fish behaviour studies', 'Extension', 'Trial of codends by industry', and 'Experimental sea trials of codend T90 selector panel'.

Throughout this report, there are continual references to different net and bycatch reduction configurations. For clarity, these are described below and the abbreviated terminology is used in the remainder of the document. All net measurements refer to the stretched inside knot dimension.

Standard diamond-mesh: 90-mm double-braided diamond polypropylene mesh hung on the point that was used typically on most trawlers prior to this project. The natural lay of the net is parallel to the direction of tow.

Square mesh: Mesh that is turned 45^{o} and hung on the bar.

T90: Mesh that is turned 90^{o} so that the natural lay of the net is perpendicular to the direction of tow.

Larger diamond mesh: Mesh larger than 90 mm hung on the point with natural lay of the net parallel to the direction of tow.

Behaviour studies

Fish behaviour observed in demersal trawls was recorded on ~100 hours of underwater video footage during August 1999–October 2001. Placing a lowlight monochrome camera, housed within a lightweight aluminium pod, at various locations inside trawl nets, the video footage was collected on *FV Shelley H* operating at depths of 90–420 m out of Bermagui, NSW, and on *FV Zeehaan* operating at depths of 200–660 m out of Portland, Victoria (Piasente 2004; Piasente *et al.* 2004). Field work associated with the behavioural studies was undertaken as part of the Trawl Bycatch Reduction Project (FRDC 1998/204), but much of the synthesis of the film footage and the reporting of the work was undertaken as part of the present project.

Extension

The extension work was extensive and ongoing throughout the duration of the project. Details of the extension work are provided in the Results/Discussion section under four components:

- port visits;
- attendance at meetings with industry;

- education workshop; and
- educational and promotional material.

Trial of codends by industry

During 2002, there were several visits to fishing ports throughout the range of the SETF. During these visits, many fishers engaged in demersal otter trawling expressed willingness to trial the use of codends constructed with mesh-sizes greater than the legal minimum mesh-size of 90 mm and some were willing to trial the use of codends constructed with square-mesh netting as an alternative to diamond-mesh netting. Good results from vessels involved in the Trawl Bycatch Reduction Project encouraged uptake of modified gear by other fishers not involved directly in that project. Alternative designs promoted within industry at the time included larger diamond-mesh of 100 mm or 110 mm and replacing codend panels constructed of netting of standard diamond-mesh codends with square-mesh codends.

By late 2002, specially designed codends had been constructed and issued for trial on 13 vessels (1 in the GAB, 2 in Beachport, 5 in Portland, 1 in Lakes Entrance, and 4 in Eden). These codends were mostly constructed with 100-mm diamond-mesh, but 3 were constructed with panels of square mesh. Several vessels used the codends so extensively that they had to be replaced. Because of concerns expressed by fishers that codends constructed entirely of square-mesh netting had less strength than codends constructed of diamond mesh netting, subsequently only panels of square mesh were inserted into codends constructed of diamond-mesh netting. During the early stages of the project, the codends were constructed by MAFFRI, but later the codends were made commercially and distributed by Ocean Watch Australia Limited. By the end of the project, modified codends had been issued for trial on 30 separate vessels across the full range of the fishery (2 GAB, 1 Beachport, 5 Portland, 1 San Remo, 10 Lakes Entrance, 10 Eden, and 1 Hobart). Codends with enlarged mesh-size were also issued to 4 Danish seine vessels.

The success of the present project at encouraging industry to uptake modified codends was evaluated by analysis of available mandatory trawl logbook data on codend mesh-shape and codend mesh-size held by AFMA.

Experimental sea trials of codend T90 selector panel

To achieve the selection benefits of square-mesh and the strength of diamond-mesh, the approach for the present project was to build into the codend a 'T90 selector panel' constructed using diamond-mesh netting rotated 90° (Hansen 2004). Demonstrated as effective in Europe, this was trialled in the SETF as part of the present project during September 2006. More recently, it was trialled with success in the Great Australian Bight trawl fishery (Knuckey *et al.* 2008).

Sea trials adopting an experimental approach were undertaken to test the effectiveness of a T90 selector panel by setting up two identical codends constructed with 90-mm diamond-mesh netting of where one had the selector panel (T90) (see Appendix 5c) and the other had no selector panel (Control). The two codends were towed together side by side using a trouser-trawl rig with the T90 codend alternated to be on the port side for 50% of the tows and on the starboard side for the other 50% of the tows to limit potential side bias. In addition, the T90 codend was attached to the trouser-trawl rig Upwards (i.e. the T90 selector panel was on top) for 50% of the hauls and Downwards (i.e. the T90 selector panel was on the bottom) for the other 50% of the tows. Hence, the experimental design for 16 trouser-trawl tows of the pair of codends during the sea trials provided 32 codend tows comprising 2 Treatments (Control and T90) x 16 Tows, but the 16 Tows were undertaken such that there were 2 T90-sides (Port and Starboard) x 2 T90-orientations (Upwards and Downwards) x 4 Replicates.

For the sea trials, the 16 trouser-trawl tows, each of 30 minutes duration at a mean speed of 3.04 knots (s.d. 0.10, range 3.00–3.40 knots), were undertaken as part of two cruises aboard the Fisheries Training Vessel Bluefin (34.5 m OAL, 53.4 t weight), owned and operated by the Australian Maritime College. The first cruise, off eastern Flinders Island, involved 11 tows during 5–11 September 2006 within the latitude range from 39º 40.76′ S to 40º 21.44′ S, the longitude range from 148º 31.88′ E to 148º 42.85′ E, and the depth range from 28 m to 126 m. The second cruise, off north-eastern Tasmania, involved 5 tows during 18–20 September

2006 within the latitude range from 41º 01.62′ S to 41º 40.22′ S, the longitude range from 148º 20.69′ E to 148º 39.69′ E, and the depth range from 37 m to 132 m. After each tow, the catch was hauled aboard the vessel and each animal in the trawl was identified to species and was measured to the nearest millimeter as total length for teleostei, cephalopoda and chondrichthyes and as carapace length for crustacea.

For data analysis, the length-frequency distribution was grouped into four length-classes (<100 mm, 100–199 mm, 200–299 mm, and ≥300 mm) to establish the categorical factor Length-class for each of the Control and T90 codends. The effects of the factors of Treatment and Length-class could then be tested by combining the data from all 16 tows, but this required ignoring the effects of T90-side and T90-orientation. The effects of T90-side and T90-orientation on the number of animals caught could not be readily separated from the effects of Tow because of the confounding effects of T90-side, T90-orientation and Tow in the experimental design. It was therefore not feasible to include the factors T90-side and T90-orientation with the factors Treatment and Length-class into a single model for testing by ANOVA; there are too many factors and too few replicates. Hence, to explore the effects of T90-side and T90-orientation, it was necessary to appropriately subset the data into the four T90-side–T90-orientation combinations of Port-Upwards, Starboard-Upwards, Port-Downwards, and Starboard-Downwards.

To compare statistically the total catches between the Control codend and the T90 codend, the Kolmogorov–Smirnov two-sample test was applied to test whether the catches by the two codends can be considered as two independent samples drawn from the same population. Where two samples are drawn from the same population distribution, the cumulative distributions of the two samples are expected to be similar. Conversely, if there is large enough deviation between the two cumulative distributions based on the χ^2 distribution, then there is evidence for rejecting the null hypothesis that the two samples come from the one population (Siegel 1956).

In the present study, the Kolmogorov–Smirnov two-sample test (2 Treatments x 4 Length-classes) was applied to various selections of species or combinations of species: all species combined, each major taxonomic group (cephalopoda, chondrichthyes, crustacea, and teleostei) separately, and each species separately, where there were more than 100 animals were caught. The data were managed and tested (‘Proc Freq’) using the statistical package SAS.

Results/Discussion

Behaviour studies

A range of swimming behaviours by the fish was recorded and the behaviours were categorised as impinged, resting, cruise swimming, or burst swimming. Two swimming modes were distinguished: the anguilliform (eel-like) mode and carangiform mode. Species swimming in the anguilliform mode include the elongate-shaped blue grenadier (*Macruronus novaezelandiae*), pink ling (*Genypterus blacodes*), and whiptails (*Coelorhinchus* spp), which are unable to sustain continuous movement for long periods. Species swimming in the carangiform mode include those whereby the body tapers to a narrow caudal peduncle and then broadening to a large caudal fin. These species exhibited more sustained swimming and include gemfish (*Rexea solandri*), jackass morwong (*Nemadactylus macropterus*), silver trevally (*Pseudocaranx dentex*), spotted warehou (*Seriolella punctata*), tiger flathead (*Neoplatycephalus richardsoni*), ocean perch (*Helicolenus* spp), redfish (*Centroberyx affinis*), and New Zealand dory (*Cyttus novaezelandiae*). Also quantified was the amount of escapement of commercial species by swimming through the meshes in the wings, body and codend of the trawl net, or by swimming out of the path or out of the main opening of the trawl nets. Some blue grenadier, ocean perch and whiptails escaped capture by passing through open meshes in the trawl mouth, tiger flathead passed under the gear, and large numbers of spotted warehou outswam the nets (Piasente 2004; Piasente *et al.* 2004).

These *in situ* observations can contribute to fine tuning future design of trawl nets. Differences in swimming capacity and endurance influence the retention of fish in trawls. The behavioural studies indicated that small non-target and undersized target species escaped between the wings and the mouth of the trawl. The fusiform-shaped pink ling and blue grenadier increased escapement by burst-swims through meshes in the anterior section of the trawl, whereas less fusiform-shaped species were less able to pass through these meshes.

These observations indicated that adjustment to the rigging of the trawl mouth affected escapement. Adjustment to footropes in particular can be made to markedly increase escapement of non-target benthic species, but this has to be balanced against retention of target species such as tiger flathead. Specially fitted panels at the top of the net might facilitate escapement of unwanted species, but this would have to be balanced against the loss of target species such as gemfish and blue grenadier, which were observed rising in the trawl net. Such modifications have been successfully deployed in fisheries such as the North Atlantic haddock fishery (Isaksen and Valdemarsen 1994).

Stratified vertical distribution within the trawl by groups of fish indicates that these groups could be separated by horizontal panels partitioning the trawl into upper and lower compartments as trialled in the north-eastern Atlantic, where each compartment has its own codend with specific selectivity characteristics (Fisheries Research Services 2004; Gailbraith and Main 1989). In the SETF, demersal species such as tiger flathead, ocean perch, pink ling, jackass morwong and whiptails entered the trawl close to the bottom panel where they remained. Semipelagic species such as gemfish, blue grenadier, spotted warehou, and New Zealand rose in the trawl and often contacted to upper panel.

There were two major documents produced by the project: a scientific paper (Appendix 3) and a thesis.

Piasente, M. (2004). Observed behaviour of selected fish species within demersal trawl nets in the South East Fishery. Master of Applied Science (Fisheries) Thesis. 150 pp. (Faculty of Fisheries and Marine Environment, Australian Maritime College: Beaconsfield, Tasmania.)

Piasente, M., Knuckey, I. A., Eayrs, S., and McShane, P. E. (2004). In situ examination of the behaviour of fish in response to demersal trawl nets in an Australian trawl fishery. *Marine and Freshwater Research* **55**, 825–835.

Extension

In brief, extension involved the four components of port visits, attendance at meetings with industry, an education workshop, and educational and promotional material. For port visits, various members of the project team routinely undertook extended trips to the fishing ports for maintaining contact with fishers and net makers, for issuing and modifying codends for trialling by industry, and for exchanging information on codend designs. Project members routinely reported on progress of the project at meetings with industry (SETFIA, GABIA, SETMAC, and GABMAC). The education workshop, referred to as the South East Trawl Fishery Stakeholder Education Workshop, was held aboard FTV *Bluefin* during 24–25 October 2002 to demonstrate the benefits of increased mesh-size in demersal trawl codends and to exchange information on codend designs. Educational and promotional material was prepared for promoting gear modifications for bycatch reduction and for promoting the project. Nine articles were published, two posters were prepared publicising information from the Trawl Bycatch Reduction Project and the present project, and two videos. In addition, special notes for industry on how to construct a ‘T90 selector panel’ for insertion in codends, and various notes and POWERPOINT presentations were prepared

Port visits

Various members of the project team routinely maintained contact with fishers and net makers for issuing codends to fishers and for modifying and discussing codend designs for trial by making extended trips to the fishing ports. During some of these visits, meetings were held with groups of fishers and special POWERPOINT presentations (e.g. Appendix 4) were made. These visits usually lasted a week and several fishing ports would be visited in New South Wales, Victoria, Tasmania, or South Australia. Through discussions with fishers on an individual basis and the dissemination of results of trialled codends of enlarged mesh-size or square-mesh netting construction issued as part of the project, additional fishers were persuaded to trial the codends. These visits resulted in a much more receptive response from industry towards trialling codends constructed from larger sized diamond-mesh or square-mesh netting. Also during the port visits, fishers were reminded of the importance of recording details of codend mesh-size and mesh-shape in the logbook returns submitted to AFMA.

Attendance at meetings with Industry

Members of the project team routinely attended meetings of SETFIA, GABIA, SETMAC and GABMAC to report on progress of the project. An example of a project update to GABIA is presented in Appendix 5a. At a SETFIA general meeting on 28 November 2002, a report was tabled (Appendix 5b) and a POWERPOINT presentation given addressing growth overfishing of redfish. An example of a POWERPOINT presentation summarising results from preliminary analysis of logbook data on trends in uptake of modified codends during December 2004 is presented in Appendix 5c.

Education workshop

The South East Trawl Fishery Stakeholder Education Workshop was held aboard FTV *Bluefin* during 24–25 October 2002. This 2-day workshop, co-hosted by SETFIA and Ocean Watch Australia Limited, brought together industry members, researchers and a range of other stakeholders from AFMA, DAFF, New South Wales Fisheries, DEWHA, AMC, WWF, MCCN, and MAFFRI. The purpose of the workshop was to present and exchange information, particularly on the benefits of increased codend mesh-size, and to discuss interpretation of trawl net information in relation to gear development, bycatch, and industry practices. A brief article about the workshop was published in the December 2002 edition of *SeaNet News*. Soon afterwards Ocean Watch Australia Limited released and distributed a report and a 'networking' video tape from the Education Workshop and, during July 2003 a report was produced on the workshop, which includes articles about the workshop published in the Magnet (Eden Newspaper) on 24 October 20002 and Seafood Industry Victoria Newsletter during November 2002 (Appendix 6).

Educational and promotional material

Published articles

Seven educational and promotional articles were published in *SeaNet News* produced routinely by Ocean Watch Australia Limited during the course of the project (Appendix 7a).

SeaNet News, December 2001 Issue, page 5, featured an article titled 'New FRDC funded extension project' promotes the present project and publicises its objectives.

SeaNet News, December 2002 Issue, page 5, featured an article titled 'South East Trawl Fishery'. The article reports and promotes results and outcomes of the present FRDC project

SeaNet News, December 2002 Issue, page 6, featured an article titled 'SET stakeholders hit the high seas'. This article reports the outcomes of the sea-going SETF educational workshop on the FTV *Bluefin*.

SeaNet News, May 2003 Issue, page 5, featured an article titled 'SET nets continue to cut unwanted catch'. The article promotes the present project and explains the advantages reducing bycatch and saving fuel. This article promotes the benefits of increased mesh-size and square-mesh in the demersal trawl codends issued to industry operators as part of the present FRDC project.

SeaNet News, June–July 2004 Issue, pages 5–6, featured an article titled 'Victoria – South East Trawl Fishery Bycatch Reduction'. The article promotes the present project and explains the need for bycatch reduction.

SeaNet News, March–April 2005 Issue, pages 7–8, featured an article titled 'South East Trawl Fishery Bycatch Reduction'. The article promotes the present project and reiterates the message on the large number vessels using modified codends. The article also draws attention to the behaviour studies published by Piesente *et al*. (2004). In addition, the article explains how wastage of square mesh netting in codends can be reduced by removing a panel of diamond-mesh netting and then stitching the same piece back into the gap, orientated across the lay of the rest of the codend.

SeaNet News, July 2005 Issue, pages 5–6, featured an article titled 'South-East and Great Australian Trawl Bycatch Reduction – Uptake'. The article further promotes the present project and explains how wastage of square-mesh netting in codends can be reduced by rotating the mesh by 90° in a codend constructed from diamond-mesh netting. This has given rise to the term "T90 panel".

One article was published in *South East Trawl Fishery News* produced quarterly by SETFIA during the course of the project.

South East Trawl Fishery News, February 2004 Issue of the Quarterly Newsletter produced by SETFIA, featured an article called 'Blow the rubbish away'. John Parkhill, a demersal trawl fisher operating from Lakes Entrance, was particularly enthusiastic about his experience using square-mesh netting in the codend. Not only did he find he had less bycatch to sort with the square-mesh netting, but he can tow the trawl net at 0.5 knots faster than with diamond-mesh netting.

One article was published in *Fishing Future* produced routinely by AFMA during the course of the project (Appendix 7b)

Fishing Future, July 2005 Volume 3, Issue 2, page 4, produced by Australian Fisheries Management Authority: Canberra, ACT featured an article titled 'South East Trawl fishers continue to trial and adopt more selective gears'. This article promotes the benefits of modified codend designs and the project. It also provides statistics on the level of uptake by industry from analysis of fisher logbook data.

Distributional notes

Notes were prepared on 'Installing a rotated-mesh panel in a trawl codend' (2005) and distributed to fishers and net makers as appropriate. Several fishers acted on advice to insert a panel within the codend or inserting a section in front of the codend ('lengthener') to adopt a 'T90 design' where a 'T90 panel selector' or a 'T90 lengthener' is made by turning the netting by 90° (Appendix 8).

Posters

Two posters were produced publicising the FRDC Trawl Bycatch Reduction Project and the present FRDC project (Appendix 9). One is titled 'Promoting industry uptake of gear modifications to reduce bycatch in the South-East and Great Australian Bight Trawl Fisheries'. The other is titled 'Maximising yields and reducing discards in the South East Trawl Fishery through gear development and evaluation'. They were both featured at the Portland Bay Festival and Western Australian Boat Show.

Videos

Two videos relating to the bycatch reduction were produced

Networking: Reducing bycatch in the South East Trawl Fishery, and

South East Trawl Fishery: Stakeholder Education Workshop:

Workshop Report

Workshop Evaluation.

As mentioned above, Ocean Watch Australia Limited distributed to all operators in the SETF and GABTF by February 2003. During July 2003, an additional 40 copies of the latter video were printed for distribution to new operators in the SETF and GABTF, other industry members, and other interested stakeholders.

In addition, extensive video footage was recorded by M. Piasente as part of the Trawl Bycatch Reduction Project, but processed as part of the present study described under behavioural studies above.

Trial of codends by industry

Response from fishers trialling modified codends

During the FRDC Trawl Bycatch Reduction Project, one of the designs of modified codends used in the analytical trials consisted entirely of square mesh (Knuckey and Ashby 2010). When these square-mesh codends distributed to industry as part of the present project, it was quickly apparent that such codends were problematic for industry to work with. A major problem was that entire square-mesh codends used considerably more material than a standard codend. Typically, three standard codends can be cut from one bail of netting, but only two square-mesh codends could be made and there was a lot of material wastage due to the 45º-mesh orientation. In addition, square-mesh codends were difficult to construct and tended to pull out of shape and tear.

Initially, the most positive response to using larger diamond-mesh was in the GABTF and the western region of the SETF. In Portland and Beachport, the operators chose to use larger mesh-size, except they prefer to revert to 90-mm mesh-size when targeting squid. At that time, in New South Wales, particularly in Ulladulla and the more northerly ports, on the other hand, there was a much lower uptake of larger mesh-size by the fishers. Eden operators often used 100-mm mesh-size when targeting redfish, but reverted to 90-mm mesh-size when targeting tiger flathead and some other species. By early 2004, there had been much greater acceptance of the benefits of increased mesh-size or square-mesh selector panels in the eastern ports. In addition, Danish seine fishers based in Port Albert and Lakes Entrance in Victoria sought codends with increased mesh-size for trial.

The difference between the western region (GAB, Western Zone, and Western Tasmania) and eastern region (NSW, Eastern Bass Strait, and eastern Tasmania) of the SETF in uptake largely reflected the difference in the species and size of the fish targeted. Fishers in the west tended to operate in waters >160 m deep where the fish are large, whereas fishers in the east tended to operate in shallower waters where the fish are smaller. The economic returns from the fishery were marginal in some parts of New South Wales, which also deterred some operators from trialling larger mesh-size.

These economic regional differences were largely a result of trends in patterns of fishing effort and stock abundance of specific species across the fishery during the past two decades. Excluding orange roughy (*Hoplostethus atlanticus*), the overall marketed demersal trawl catch increased by almost 50% from 18 578 t during 1986–95 to 24 237 t during 1996–06, but this growth was confined to the western region (Walker and Gason 2009). Fishing effort doubled in the western zone, but remained constant and retracted to shallower waters in the eastern region (Walker and Gason 2007). In the eastern region, while effort remained constant, CPUE fell markedly for several species—eastern gemfish, redfish, blue warehou (*Seriolella brama*), jackass morwong, pink ling, and silver trevally—and thus led to progressively increased economic stress and a reluctance to reduce codend mesh-size.

As the project progressed, square-mesh panels inserted in codends proved to be beneficial for bycatch reduction on top of the continental shelf, but were not favoured by larger vessels operating in deeper water on the continental slope. Some fishers reported that codends constructed with square-mesh panel inserts were more likely to tear or to have knots slip than ones constructed using diamond-mesh netting. Hence, subsequently the project approach was to replace the 'square-mesh selector panel' built into the codend (Arkley 2001) with a 'T90 selector panel' constructed using diamond-mesh netting rotated 90°. Another option encouraged was to insert a 'T90 lengthener' at the front of the codend (Hansen 2004).

Analysis of otter trawl catch and effort logbook codend data

Soon after the initial issue of codends to industry by the present project during 2002, AFMA trawl logbook catch and effort returns in the SETF and GABTF were enhanced at the beginning of 2003 to include codend information on codend mesh-shape (diamond-mesh or square-mesh) and codend mesh-size. Analysis of the available data for the 3-year period 2003–05 confirms that there was a marked increase in both the use of square mesh-shape and of increased mesh-size of diamond-mesh mesh-shape by industry during this period. Catch and effort data were reported for 125 089 tows by 121 vessels engaged in otter trawl (109 vessels) or Danish seine (30 vessels) at some time during 2003–05 (Table 1).

Of the 121 demersal trawl vessels during 2003–05, 105 were engaged in otter trawl and reported mesh-shape (diamond-mesh or square-mesh) for 89 778 tows, which is 92% of all otter trawl tows or 72% of all otter trawl and Danish seine tows combined. Of the 89 778 tows with mesh-shape reported, 97% had diamond mesh-shape (105 vessels, 100%) and 3% had square mesh-shape (44 vessels, 42%). Square mesh was reported for 14 vessels (106 tows, 0.3%) during 2003, for 22 vessels (748 tows, 2.8%) during 2004, and for 23 vessels (2256 tows, 6.9%) during 2005 (Table 2). This shows that 42% of the vessels trialled square mesh-shape and the uptake increased from 0.3% to 6.9% of the tows during the 3-year period from 2003 to 2005. All 44 vessels reporting use of square mesh also reported diamond mesh; 10 vessels reported square mesh for >10% of tows and 2 vessels reported this for >50% of tows during the 3-year period.

Of 86 668 otter trawl tows by 105 vessels during 2003–05, 95 vessels (90%) and 77 172 tows (89%) had mesh-size reported where diamond mesh was used. Mesh-size reported for these vessels increased during this period; mesh-size was reported for 70 vessels and 25 524 tows during 2003, for 67 vessels and 23 550 tows during 2004, and for 77 vessels and 28 098 tows during 2005 (Table 3).

Of 77 172 otter trawl tows by 95 vessels with mesh-size of diamond mesh reported during 2003–05, there was a marked decline in the use of mesh-size <90 mm (from 9% of tows during 2003 to 2% of tows during 2005). While the use of 90–99-mm mesh varied around 60% of tows, there was an increase in the use of 100–119-mm mesh (from 27% during 2003 to 35% during 2005) and of ≥120 mm mesh (from 4% during 2003 to 5% during 2005) (Table 4).

A pattern in the data indicates that the uptake of larger mesh-size is greater in waters of ≥150-m depth than in waters of <150-m depth (Table 5), but more recently the pattern of uptake of larger mesh-size has been more marked at <150-m depths than at ≥150-m depths. About 50% of the tows in waters ≥150-m deep used ≥100-mm mesh throughout 2003–05 (50% during 2003, 48% during 2004, and 53% during 2005). Whereas at depths ≥150-m most of the uptake occurred before 2003, at depths <150 m, uptake was slow before 2003, but then occurred rapidly during 2003–05 (13% of tows during 2003, 11% during 2004, and 32% during 2005).

Table 1. Number of trawl vessels and tows with logbook catch and effort data reported to AFMA

Vessels	Reported on logbooks	Number of vessels				Number of tows			
		2003	2004	2005	Total	2003	2004	2005	Total
Number									
All vessels	Total	103	96	106	121	43075	38397	43617	125089
Danish seine	Total	30	22	22	30	10246	8115	8851	27212
Otter trawl	Total	91	77	84	109	32829	30282	34766	97877
Otter trawl	Mesh-shape	87	72	80	105	30298	26798	32682	89778
Otter trawl	Diamond-mesh	86	71	80	105	30192	26050	30426	86668
Otter trawl	Diamond-mesh & mesh-size	70	67	77	95	25524	23550	28098	77172
Otter trawl	Square-mesh	14	22	23	44	106	748	2256	3110
Per cent									
All vessels	Total	100	100	100	100	100	100	100	100
Danish seine	Total	29	23	21	25	24	21	20	22
Otter trawl	Total	88	80	79	90	76	79	80	78
Otter trawl	Mesh-shape	84	75	75	87	70	70	75	72
Otter trawl	Diamond-mesh	83	74	75	87	70	68	70	69
Otter trawl	Diamond-mesh & mesh-size	68	70	73	79	59	61	64	62
Otter trawl	Square-mesh	14	23	22	36	0	2	5	2

Table 2. Number of otter-trawl vessels and tows with codend mesh-shape reported in logbooks to AFMA

Vessels	Reported on logbooks	Number of vessels				Number of tows			
		2003	2004	2005	Total	2003	2004	2005	Total
Number									
Otter trawl	Mesh-shape	87	72	80	105	30298	26798	32682	89778
Otter trawl	Diamond-mesh	86	71	80	105	30192	26050	30426	86668
Otter trawl	Square-mesh	14	22	23	44	106	748	2256	3110
Per cent									
Otter trawl	Mesh-shape	100	100	100	100	100	100	100	100
Otter trawl	Diamond-mesh	99	99	100	100	100	97	93	97
Otter trawl	Square-mesh	16	31	29	42	0	3	7	3

The slower uptake of increased mesh size in waters <150 m relates to region. The percentage of tows in depths <150 m was 78% in New South Wales, 62% in Eastern Bass Strait (east of Wilson's Promontory), and 54% in Eastern Tasmania. Only 24% of the tows off Western Tasmania and west of Wilson's Promontory were in depths <150 m. In general, the uptake of larger codend mesh-size followed the pattern of decreasing proportions of the tows in waters <150 m from New South Wales to Eastern Bass Strait and from Eastern Bass Strait to Eastern Tasmania and then to the more westerly regions of the fishery.

Most of the square-mesh netting was used in Eastern Bass Strait (64%) and in waters of <150-m depth (57%). Reluctance to the use of codends constructed with square-mesh selector panels is that square-mesh netting is more likely to tear than diamond-mesh netting when under strain. Also knots in square-mesh panels have been reported to slip. This makes square mesh less popular for large vessels, particularly when operating in the deeper waters on the continental slope. Hence, most uptake of square mesh was in the shallower waters on the continental shelf.

Table 3. Number of otter-trawl vessels and tows with diamond codend mesh-shape reporting mesh-size

Vessels	Reported on logbooks	Number of vessels				Number of tows			
		2003	2004	2005	Total	2003	2004	2005	Total
Number									
Otter trawl	Diamond-mesh	86	71	80	105	30192	26050	30426	86668
Otter trawl	Diamond-mesh & mesh-size	70	67	77	95	25524	23550	28098	77172
Per cent									
Otter trawl	Diamond-mesh	100	100	100	100	100	100	100	100
Otter trawl	Diamond-mesh & mesh-size	81	94	96	90	85	90	92	89

Table 4. Number of otter-trawl vessels and tows with diamond codend mesh-shape by mesh-size

Vessels	Mesh-size (mm)	Number of vessels				Number of tows			
	Reported on logbooks	2003	2004	2005	Total	2003	2004	2005	Total
Number									
Otter trawl	<90	21	17	14	30	2202	1817	485	4504
Otter trawl	90– 99	43	48	56	68	15249	15196	16239	46684
Otter trawl	100–119	30	26	33	50	7005	5513	9940	22458
Otter trawl	≥120	12	8	8	18	1068	1024	1434	3526
Otter trawl	Total	70	67	77	95	25524	23550	28098	77172
Per cent									
Otter trawl	<90	30	25	18	32	9	8	2	6
Otter trawl	90– 99	61	72	73	72	60	65	58	60
Otter trawl	100–119	43	39	43	53	27	23	35	29
Otter trawl	≥120	17	12	10	19	4	4	5	5
Otter trawl	Total	100	100	100	100	100	100	100	100

Table 5. Number of otter-trawl tows with diamond codend mesh-shape by mesh-size and depth

Depth	Mesh-size	Number of tows			
(m)	(mm)	2003	2004	2005	Total
Number					
	<100	10946	11387	11386	33719
<150	≥100	1677	1446	5285	8408
	Total	12623	12833	16671	42127
	<100	87	89	68	80
	≥100	13	11	32	20
	Total	100	100	100	100
Per cent					
	<100	6505	5626	5338	17469
≥150	≥100	6396	5091	6089	17576
	Total	12901	10717	11427	35045
	<100	50	52	47	50
	≥100	50	48	53	50
	Total	100	100	100	100

Experimental sea trials of codend T90 selector panel

A total of 10 094 animals were caught during the 16 trouser-trawl tows (5904 in Control codend and 4190 in T90 codend) (Table 6). These animals belonged to 44 species (2 of cephalopoda, 9 of chondrichthyes, 2 of crustacea, and 31 of teleostei). Too few cephalopoda (74 animals) or crustacea (8 animals) were caught for statistical analysis, but there were sufficient animals of chondrichthyes (138 in Control codend and 114 in T90 codend) and teleostei (5737 in Control codend and 4023 in T90 codend).

Whereas the sea trials provide robust results for comparing the catches between the Control and T90 codends, confounding among T90-side, T90-orientation and Tow in the experimental design contribute to uncertainty about the effects of T90-side and T90-orientation. Much of the variation in total catches among the four combinations of T90-side (Port and Starboard) and T90-orientation (Upwards and Downwards)—Upwards-Port (871 animals from Tows 1–4), Upwards-Starboard (2969 animals from Tows 5–8), Downwards-Port (3914 animals from Tows 9–12), and Downwards-Starboard (2340 animals from Tows 13–16)—can be attributed to high variation in the catch of animals among the 16 trouser-trawl tows (Table 7). Much of the variation in the number caught among the 16 tows (mean 631, standard deviation 463, range 186–1692) can be explained largely by the variation in the density of the distribution of fish on the fishing grounds.

Evidence for a T90-orientation effect is the reasonably similar total catches of animals in the Control codends for Upwards (3840 animals from Tows 1–8) and Downwards (3021 animals from Tows 9–16) together with the markedly different total catches of animals in the T90 codends for Upwards (1159 animals from Tows 1–8) and Downwards (3021 animals from Tows 9–16) (Table 7). This suggests that the T90 selector panel was much more effective at releasing animals when orientated Upwards than when orientated Downwards. This is consistent with the tendency for the fish to swim upwards in the codend and with reduced effectiveness when the T90 selector panel comes into direct contact with the seabed. Semi-pelagic fish species are more likely to be at the top of the codend and demersal fish more likely to be at the bottom of the codend (Piasente *et al.* 2004). No direct observations were made during the present trials, but there was markedly higher escapement by *Lepidotrigla* spp and Monocanthidae from the T90 codend than from the Control codend when the T90 codend was oriented Upwards. The only species to have higher escapement when the T90 codend was orientated Downwards was *Trachurus declivis* and *Foetorepus calauropomus*; the latter is clearly a benthic species but *Trachurus declivis* is more pelagic.

The effect of T90-side on the catch of animals is more difficult to determine. There appears to be an absence of animals in the Control codend during Tows 1–4 when the T90 codend was on the Port side of the trouser rig and orientated Upwards, suggesting the Control codend might not have been operating effectively for those tows. The trouser trawl was mostly hauled in a northerly or southerly direction with depth varying by no more than 6 m for each of 14 of the 16 tows, and by 8 m and 16 m for the other 2 tows, indicating the tows were generally parallel to land. Potential differences between the T90 and Control codends arising from these operations include cross drift from wind and tides or lack of balance in construction of the net (e.g. unequal contact between the rubber-line at bottom entrance of the net and the seabed).

Overall, the effects of Treatment and Length-class on the catch of animals were tested effectively across all 16 tows while ignoring the effects of T90-side and T90-orientation. Overall the number of animals of length <300 mm caught was one-third less in the codend with the T90 selector panel (3686 animals) than in the standard codend without the T90 selector panel (5491 animals), whereas the number animals of length ≥300 mm was higher in the T90 codend than the control codend (χ^2 value=80.42, d.f.=3, P<0.0001) (Table 7). This pattern is consistent with the pattern observed for each of the two major taxonomic groups (chondrichthyes and teleostei) and the individual species (*Helicolenus barathri*, *Neosebastes scorpaenoides*, *Lepidotrigla* spp, *Trachurus declivis*, Monocanthidae, *Emmelichthys nitidus*, and *Squalus megalops*) where more than 100 animals were caught. The only exceptions to this pattern are *Foetorepus calauropomus* and *Neoplatycephalus aurimaculatus* (Table 8), which are highly demersal species less likely to escape through the T90 selector panel when orientated upwards.

This indicates that the trawl codend fitted with the T90 selector panel (T90) had a lower catch of animals (Chondrichthyes, and Teleostei) than the standard trawl codend (Control). In addition, these results indicate that retention of animals by the codend with the T90 selector panel increased with increasing length of animal and above ~300 mm the T90 retention rate is higher than the Control retention rate (Table 9, Figures 1 and 2).

The strong Treatment effect indicates that the T90 selector panel was highly effective at improving escapement of small fish from a codend, and provides evidence that its presence improves the catch of fish longer than 300 mm TL.

Table 6. Details of animals caught and measured during sea trials of codend T90 selector panel

N, number of animals caught and measured; l_{mean}, mean length; l_{sd}, standard deviation in length; l_{se}, standard error in length; l_{min}, minimum length; l_{max}, maximum length.

Taxonomic group	Common name	Scientific name	Control						T90						Total					
			N	l_{mean} (mm)	l_{sd} (mm)	l_{se} (mm)	l_{min} (mm)	l_{max} (mm)	N	l_{mean} (mm)	l_{sd} (mm)	l_{se} (mm)	l_{min} (mm)	l_{max} (mm)	N	l_{mean} (mm)	l_{sd} (mm)	l_{se} (mm)	l_{min} (mm)	l_{max} (mm)
Cephalopoda	Cuttlefish	*Sepia australis*	24	97	23	5	64	180	42	95	15	2	66	122	66	96	18	2	64	180
	Gould squid	*Nototodarus gouldi*	1	90			90	90	7	204	38	14	130	240	8	190	53	19	90	240
	Sub-total		25	96	23	5	64	180	49	111	43	6	66	240	74	106	38	4	64	240
Chondrichthyes	Australian angelshark	*Squatina australis*							2	375	32	23	352	397	2	375	32	23	352	397
	Common sawshark	*Pristiophorus cirratus*	9	608	164	55	405	970							9	608	164	55	405	970
	Draughtboard shark	*Cephaloscyllium laticeps*	16	602	186	47	335	841	30	537	160	29	333	1010	46	559	170	25	333	1010
	Elephant fish	*Callorhinchus milii*	3	745	10	6	735	755							3	745	10	6	735	755
	Gummy shark	*Mustelus antarcticus*							2	850	184	130	720	980	2	850	184	130	720	980
	Southern dogfish	*Centrophorus zeehaani*	4	385	11	6	375	400							4	385	11	6	375	400
	Spikey dogfish	*Squalus megalops*	103	377	55	5	214	517	64	405	31	4	329	489	167	388	49	4	214	517
	Tasmanian numbfish	*Narcine tasmaniensis*	2	235	7	5	230	240	6	274	25	10	240	300	8	264	28	10	230	300
	Thornback skate	*Raja lemprieri*	1	550			550	550	10	494	136	43	285	720	11	499	130	39	285	720
	Sub-total		138	425	135	11	214	970	114	114	448	130	12	240	252	436	133	8	214	1010
Crustacea	Spidercrab	*Leptomithrax gaimardii*	1	80			80	80							1	80			80	80
	Velvet bug	*Scyllarus spp*	3	54	3	2	51	57	4	63	7	3	53	68	7	59	7	3	51	68
	Sub-total		4	60	13	7	51	80	4	63	7	3	53	68	8	62	10	4	51	80
Teleostei	Banded morwong	*Cheilodactylus spectabilis*	17	285	52	13	166	360	9	280	23	8	230	310	26	283	44	9	166	360
	Barred grubfish	*Parapercis allporti*							2	207	14	10	197	217	2	207	14	10	197	217
	Barred toadfish	*Contusus richei*							2	184	27	19	165	203	2	184	27	19	165	203
	Bigeye ocean perch	*Helicolenus barathri*	249	172	30	2	90	278	186	180	36	3	105	308	435	175	33	2	90	308
	Blackspot boarfish	*Zanclistus elevatus*	33	193	36	6	85	245	8	196	27	10	160	245	41	193	35	5	85	245
	Blacktip cucumberfish	*Paraulopus nigripinnis*	73	170	23	3	105	212	2	145	2	2	143	146	75	169	23	3	105	212
	Bulldog stargazer	*Xenocephalus armatus*	10	284	37	12	214	325	19	310	38	9	245	379	29	301	39	7	214	379
	Common gurnard perch	*Neosebastes scorpaenoides*	110	193	47	4	110	391	18	321	51	12	215	380	128	211	65	6	110	391
	Common stinkfish	*Foetorepus calauropomus*	146	272	36	3	179	370	234	290	30	2	222	379	380	283	34	2	179	379
	Flounder	*Ammotretis sp.*	5	258	29	13	225	295	5	287	18	8	268	314	10	272	27	9	225	314
	Globefish	*Diodon nicthemerus*	42	240	50	8	125	330	36	175	38	6	110	237	78	210	55	6	110	330
	Grey morwong	*Nemadactylus douglasii*	1	212			212	212							1	212			212	212
	Gurnard	*Lepidotrigla spp*	1707	163	20	0	89	405	1019	171	23	1	106	475	2726	166	22	0	89	475
	Jack mackerel	*Trachurus declivis*	907	233	42	1	93	388	447	233	28	1	151	301	1354	233	38	1	93	388
	Jackass morwong	*Nemadactylus macropterus*	14	246	59	16	158	332	9	264	85	28	162	385	23	253	69	14	158	385
	John dory	*Zeus faber*	4	330	30	15	296	356	4	254	104	52	146	367	8	292	82	29	146	367
	Leatherjackets	*Monacanthidae spp*	1057	159	11	0	130	216	666	163	11	0	133	225	1723	160	11	0	130	225
	Longsnout boarfish	*Pentaceropsis recurvirostris*	1	186			186	186	22	203	24	5	155	246	23	202	24	5	155	246
	Longsnout flounder	*Ammotretis rostratus*	4	306	44	22	275	370	15	283	31	8	218	319	19	288	34	8	218	370
	Mirror dory	*Zenopsis nebulosus*	11	217	132	40	87	416	1	412			412	412	12	233	138	40	87	416
	New Zealand dory	*Cyttus novaezealandiae*	38	91	10	2	62	109							38	91	10	2	62	109
	Ornate cowfish	*Aracana ornata*							2	113	1	1	112	113	2	113	1	1	112	113
	Pink ling	*Genypterus blacodes*							2	459	32	23	436	481	2	459	32	23	436	481
	Red gurnard	*Chelidonichthys kumu*	54	180	49	7	139	445	55	173	18	2	117	269	109	176	37	4	117	445
	Redbait	*Emmelichthys nitidus*	1012	168	11	0	122	205	923	170	11	0	108	263	1935	169	11	0	108	263
	Sand flathead	*Platycephalus bassensis*	27	347	63	12	247	510	46	416	57	8	303	551	73	391	67	8	247	551
	Shaws cowfish	*Aracana aurita*	29	209	101	19	110	440	52	154	22	3	93	200	81	173	68	8	93	440
	Silver dory	*Cyttus australis*	24	114	38	8	80	226	3	224	14	8	213	240	27	126	50	10	80	240
	Southern rockcod	*Epinephelus sp.*	3	457	127	73	320	570							3	457	127	73	320	570
	Threebar porcupinefish	*Dicotylichthys punctulatus*							16	267	32	8	190	315	16	267	32	8	190	315
	Toothy flathead	*Neoplatycephalus aurimaculatus*	159	384	65	5	100	596	220	399	56	4	141	597	379	392	60	3	100	597
	Sub-total		5737	187	57	1	62	596	4023	202	70	1	93	597	9760	193	63	1	62	597
Total			5904	192	70	1	51	970	4190	208	83	1	53	1010	10094	198	76	1	51	1010

Table 7. Results of χ^2-test for effects of treatment and length of fish on catch for all species combined

The χ^2-test was for the Kolmogorov–Smirnov two-sample test. df, degrees of freedom; *, P<0.05; **P<0.01; ***P<0.001; ns, not significant.

Tow no.	Orientation of trouser trawl	T90 side	Treatment	Number of fish caught for each each length class: <100 mm	100–199 mm	200–299 mm	≥300 mm	Total	χ^2-test for effects of treatment: df	Value	P
			Control	0	77	99	79	255			
1–4	Upwards	Port	T90	1	235	186	194	616	3	7.72	0.0522 ns
			Total	1	312	285	273	871			
			Control	28	2036	233	129	2426			
5–8	Upwards	Starboard	T90	14	325	155	49	543	3	170.66	<0.0001 ***
			Total	42	2361	388	178	2969			
			Control	9	1145	468	160	1782			
9–12	Downwards	Port	T90	9	1672	222	229	2132	3	168.58	<0.0001 ***
			Total	18	2817	690	389	3914			
			Control	28	1071	297	45	1441			
13–16	Downwards	Starboard	T90	7	631	229	32	899	3	12.46	0.0060 **
			Total	35	1702	526	77	2340			
			Control	28	2113	332	208	2681			
1–8	Upwards		T90	15	560	341	243	1159	3	362.80	<0.0001 ***
			Total	43	2673	673	451	3840			
			Control	37	2216	765	205	3223			
9–16	Downwards		T90	6	2303	451	261	3021	3	105.41	<0.0001 ***
			Total	43	4519	1216	466	6244			
1–4			Control	9	1222	567	239	2037			
9–12	Port		T90	10	1907	408	423	2748	3	124.18	<0.0001 ***
			Total	19	3129	975	662	4785			
5–8			Control	56	3107	530	174	3867			
13–16	Starboard		T90	21	956	384	81	1442	3	131.73	<0.0001 ***
			Total	77	4063	914	255	5309			
			Control	65	4329	1097	413	5904			
1–16	Total	Total	T90	31	2863	792	504	4190	3	80.42	<0.0001 ***
			Total	96	7192	1889	917	10094			

Table 8. Results of χ^2-test for effects of treatment and length of fish on catch for species where more than 100 fish were caught

The χ^2-test was for the Kolmogorov–Smirnov two-sample test. df, degrees of freedom; *, P<0.05; **P<0.01; ***P<0.001; ns, not significant.

Species		Treatment	Number of fish caught for each each length class					χ^2-test		
Common name	Scientific name		<100 mm	100–199 mm	200–299 mm	≥300 mm	Total	df	Value	P
		Control	2	209	38	0	249			
Bigeye ocean perch	*Helicolenus barathri*	T90	0	146	38	2	186	3	6.19	0.1029 ns
		Total	2	355	76	2	435			
		Control	0	79	25	6	110			
Common gurnard perch	*Neosebastes scorpaenoides*	T90	0	0	7	11	18	2	50.62	<0.0001 ***
		Total	0	79	32	17	128			
		Control	0	3	108	35	146			
Common stinkfish	*Foetorepus calauropomus*	T90	0	0	146	88	234	2	11.78	<0.0001 ***
		Total	0	3	254	123	380			
		Control	1	1626	78	2	1707			
Gurnard	*Lepidotrigla* spp	T90	0	947	70	2	1019	3	7.45	0.0588 ns
		Total	1	2573	148	4	2726			
		Control	1	149	728	29	907			
Jack mackerel	*Trachurus declivis*	T90	0	25	420	2	447	3	44.36	<0.0001 ***
		Total	1	174	1148	31	1354			
		Control	0	1054	3	0	1057			
Leatherjackets	*Monacanthidae*	T90	0	658	8	0	666	1	5.42	0.0199 *
		Total	0	1712	11	0	1723			
		Control	0	1004	8	0	1012			
Redbait	*Emmelichthys nitidus*	T90	0	915	8	0	923	1	0.03	0.8533 ns
		Total	0	1919	16	0	1935			
		Control	0	0	11	92	103			
Spikey dogfish	*Squalus megalops*	T90	0	0	0	64	64	1	7.32	0.0068 **
		Total	0	0	11	156	167			
		Control	0	1	8	150	159			
Toothy flathead	*Neoplatycephalus aurimaculatus*	T90	0	1	5	214	220	2	2.18	0.3356 ns
		Total	0	2	13	364	379			
		Control	0	0	13	125	138			
Sharks and rays	Chondrichthyes	T90	0	0	6	108	114	3	1.55	0.2135 ns
		Total	0	0	19	233	252			
		Control	45	4320	1084	288	5737			
Scalefish	Teleostei	T90	1	2845	781	396	4023	3	114.542	<0.0001 ***
		Total	46	7165	1865	684	9760			

Table 9. Length selectivity of 90 selector panel relative to control net

Catch ratio is catch number for T90 net/catch number for 90-mm mesh-size control net

Length-class (mm)	Catch number Control	T90	Catch ratio
Teleostei			
000–049	0	0	0.00
050–099	45	1	0.02
100–149	763	207	0.27
150–199	3557	2638	0.74
200–249	668	472	0.71
250–299	418	314	0.75
300–349	135	146	1.08
350–399	86	119	1.38
≥400	67	132	1.97
Total	5739	4029	0.70
Chondrichthyes			
000–049			0.00
050–099			0.00
100–149			0.00
150–199			0.00
200–249	4		0.00
250–299	7	1	0.14
300–349	15	4	0.27
350–399	39	31	0.79
≥400	71	72	1.01
Total	136	108	0.79

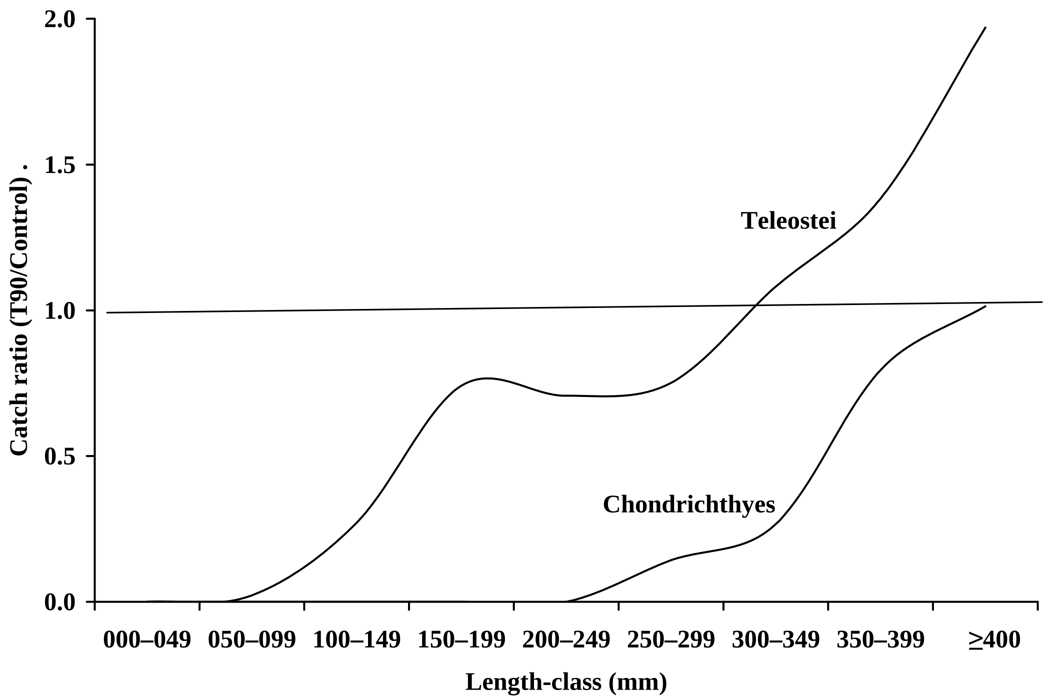

Figure 1. Relative selectivity of T90 selector panel for teleostei and chondrichthyes fishes

Selectivity of the T90 selector panel is relative to the standard 90-mm diamond mesh-shape expressed as the ratio of the T90 catch/control catch for each 50-mm length-class of animal.

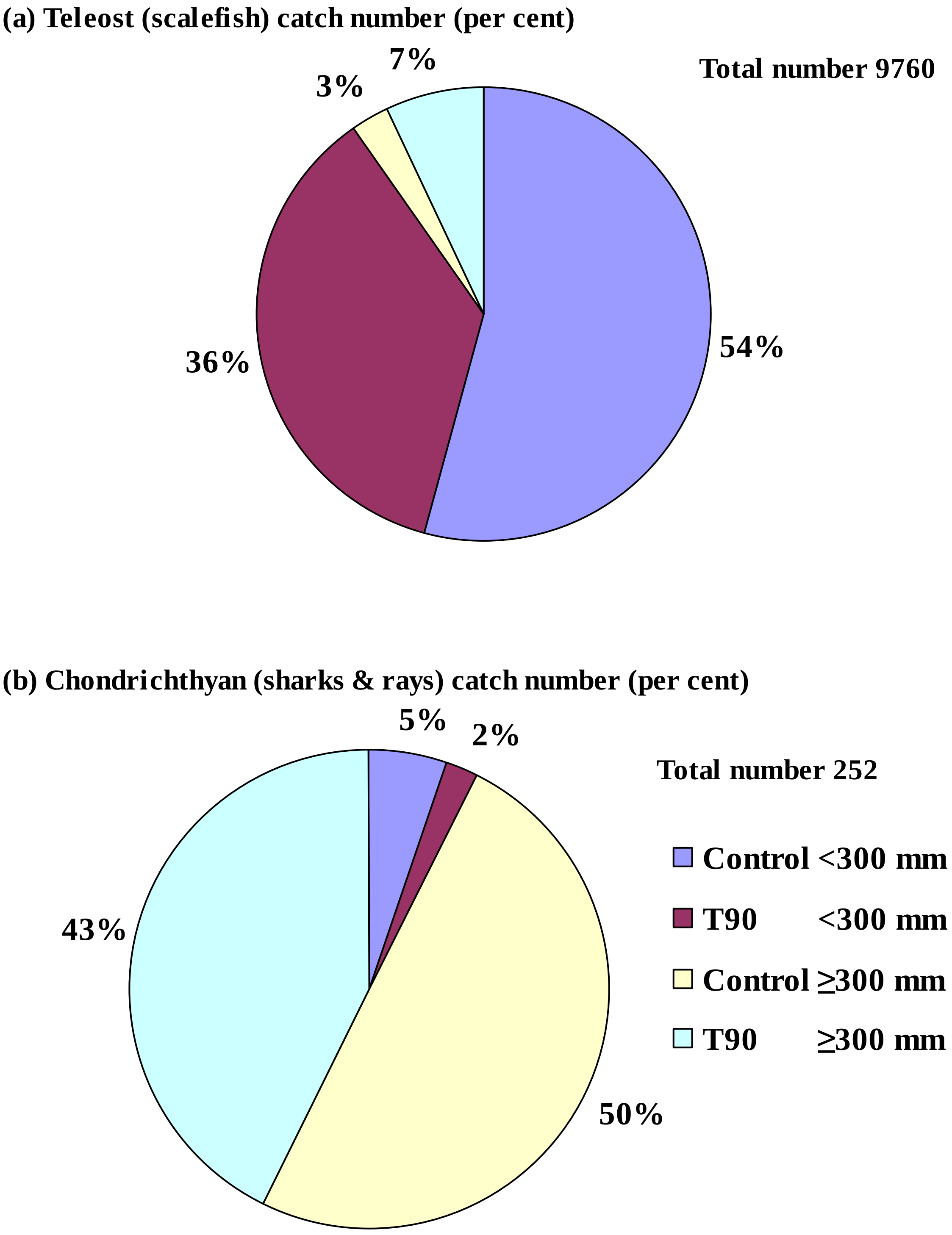

Figure 2. Relative catch by number of fish of length <300 mm and ≥300 mm from the Control and T90 codends expressed as a percentage of the combined catch for (a) teleostei and (b) chondrichthyes fishes.

Benefits and Adoption

There are a range of beneficiaries from the outputs of the project related to the Southern and Eastern Scalefish and Shark Fishery (SESSF). These include the catching sector, fish processors, wholesalers, retailers, consumers, and the broader community though better management of the fish resource and the supporting environment through reduced bycatch.

Comprehensive extension undertaken as part of the present project based on the results, experience, and underwater video footage from the FRDC Trawl Bycatch Reduction Project and, to a lesser extent, published information from other parts of the world led to rapid voluntary uptake of larger mesh-size in codends, particularly during 2003–05. The present project together with AFMA Project 2007/063 ('Trials of T90 mesh configuration in the Great Australian Bight Trawl Fishery') has demonstrated the effectiveness of T90 configurations for markedly reducing the bycatch of small fish, particularly those shorter than 300 mm. Industry became so convinced of the need for bycatch reduction and the effectiveness appropriate gear modifications that through SETFIA it took the initiative to seek appropriate legislative change.

From early 2006, codends for demersal trawl, other than Danish seine and prawn trawl, required single-twine for 90-mm mesh or double-twine for ≥102-mm mesh. A codend of 90-mm double-twine mesh can only be used if constructed with one or more bycatch reduction devices. These devices are a single panel of ≥90-mm square-mesh in the upper side of the codend bag (dimensions 15 bars x 20 bars) or a single panel of ≥90-mm rotated-mesh (T90) in the upper side of the codend bag (15 meshes x 20 meshes). Subsequently, the latter was amended to 15 x 18 meshes.

Further Development

Although the intention of the project was to assist industry make informed choices on codend configurations depending on locality, season, and target species to reduce bycatch, industry itself came to the view that there should be legislative change. At a meeting of SETFIA during October 2005, Industry agreed on the need for improved legislation con the construction of codends. This included the use of single braided netting (prohibit double braided netting) for 90-mm mesh, and an escape panel be fitted in codends where double braided netting is used, which became part of the fishery regulations by early 2006. The initial interest within industry to adopt 'square-mesh selector panels' has now moved to 'T90 selector panels' and 'T90 lengtheners', which have been adopted by all vessels operating in the GABTF.

The direction to AFMA from the Commonwealth Minister for Agriculture, Fisheries and Forests to cease overfishing, recover overfished stocks, and manage the broader impacts of fishing on the environment created further requirements for adoption of modified codends. Gear modification will play an increasingly important role in reduction of discarding of quota species, particularly undersized fish, which became illegal from 2007, and in overall reduction of bycatch.

The main remaining questions about bycatch mitigation relate to post-capture survival of fish escaping the gear and of fish enduring capture and handling before being returned to the water.

Planned Outcomes

There were six essential planned outcomes from the project.

1. Improved awareness within industry that bycatch and impacts on fish habitat from demersal trawling can be reduced to improve sustainability of the harvested fish stocks and ecosystem resilience by modifying codend design.

2. Improved awareness within industry that higher yields and improved catch rates from a fish resource can be achieved by avoiding capture of small fish and capture them when they are larger to avoid growth overfishing.
3. Improved awareness within industry that, by modifying codend design, reduction in drag through the water and reduction in bycatch can provide efficiency gains through reduced handling of bycatch, faster tow speeds, and fuel economy.
4. Improved species selectivity of trawl through the study of fish behaviour in trawl nets and modification of codends.
5. Improved handling and quality of landed product.
6. Increased Industry use of larger mesh-size, square-mesh, and T90 selector panels.

Conclusions

Through preparation of extensive promotional material, liaison face to face with industry members, and trialling one or more modified codend designs on each of 30 separate vessels, there was a gradual but steady increase in the use of modified codends by industry. Convinced of the benefits of various gear modifications in reducing bycatch, Industry eventually took the initiative to seek the legislative changes in gear configuration implemented early 2006. Industry now routinely constructs codends or panels from netting of >90-mm mesh-size.

Experimental sea trials comparing catches in a pair of codends with and without a T90 selector panel showed that the number of fish of length <300 mm were one-third less with the presence of a T90 selector panel, whereas the number animals of length ≥300 mm was higher. This pattern was observed for scalefish and for sharks.

During the 3-year period from 2003 to 2005,

- 42% of the vessels trialled square mesh-shape and industry uptake increased from 0% to 7% of otter trawl tows,
- use of diamond-mesh mesh-size <90 mm declined from 9% of tows during 2003 to 2% of tows during 2005, and
- use of 90–99-mm mesh-size varied around 60% of otter trawl tows.

By the end of 2005,

- use of 100–119-mm mesh-size increased to 35% of tows, and
- use of ≥120 mm mesh-size increased to 5% of tows.

Other conclusions include:

- uptake of larger mesh-size is greater in waters of ≥150-m depth than in waters of <150-m depth, but more recently the pattern of uptake of larger mesh-size has been more marked at <150-m depth than at ≥150-m depth,
- in waters of ≥150-m depth, use of ≥100-mm mesh-size increased rapidly during the early phase of the study and remained stable at about 50% of the tows during 2003–05,
- in waters of <150 m depth, use of ≥100-mm mesh-size increased slowly before 2003, but then increased rapidly during 2003–05 (from 13% of tows during 2003 to 32% during 2005),

- uptake of larger codend mesh-size followed the pattern of decreasing proportions of the tows in waters of <150 m depth from New South Wales to Eastern Bass Strait and from Eastern Bass Strait to Eastern Tasmania and then to the more westerly regions of the fishery, and
- most square-mesh mesh-shape was used in Eastern Bass Strait (64%) and in waters of <150-m depth (57%). Square-mesh netting is more likely to tear than diamond-mesh netting when under strain, which made square-mesh unpopular for some operators. In addition, knots in some square-mesh panels were reported to slip. This makes square-mesh less popular for large vessels, particularly when operating in the deeper waters on the continental slope. Hence, most uptake of square-mesh was in the shallower waters on the continental shelf. Adoption of larger diamond-mesh shape or rotated diamond mesh, such as the T90 design, is more appropriate for large vessels, particularly when operating on the continental slope.

Increased use of modified designs occurred despite a difficult time for the trawl industry when economic returns to some sectors were minimal, exacerbated by rising fuel price. In the eastern region of the fishery, increase use of modified codends occurred at a time while effort gradually shifted from the deep waters on the continental slope to shallower waters on top of the continental shelf where the species mix tends to favour smaller mesh-sizes. As the economic outlook for the fishery improves from recent structural adjustment, codend designs will continue evolving to improve retained catches and to reduce bycatch.

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Appendix 1: Intellectual Property

No intellectual property has arisen from the research that is likely to lead to significant commercial benefits, patents or licences. Intellectual property associated with information produced from the project will be shared equally by the Fisheries Research and Development Corporation and by the Victorian Department of Natural Resources and Environment.

Appendix 2: Staff

Organisation, role, period on the project and percentage of effective full time (EFT) each year on the project are listed for each staff participant on the project.

Staff	Role	Period	EFT(%)
Primary Industries Research Victoria			
Ian Knuckey	Principal Investigator	1 Jul 01–30 Jun 02	10
Terry Walker	Principal Investigator	1 Sep 02–30 Jun 03	10
		1 Jul 03–30 Jun 04	10
		1 Jul 04–30 Jun 05	10
		1 Jul 05–30 Jun 06	10
Andrew Hogg	Fisheries Scientist	1 Jul 01–30 Jun 02	30
		1 Jul 02–30 Jun 03	80
		1 Jul 03–30 Jun 04	30
Ken Smith	Technical Officer	1 Jul 03–27 Feb 04	10
Ocean Watch Australia Limited			
Ben Leslie	Co-investigator	1 Jul 02–30 Jun 03	10
Jim Newman	Co-Investigator	1 Mar 04–30 Jun 05	20
		1 Jul 05–30 Jun 06	15
Fishwell Consulting			
Ian Knuckey	Co-Investigator	1 Jul 02–30 Jun 03	10
		1 Jul 03–30 Jun 04	10
		1 Jul 04–30 Jun 05	10
		1 Jul 05–30 Jun 06	10
Australian Maritime College			
Matthew Piasente	Postgraduate student	1 Jan 01–30 Jun 02	50
		1 Jul 02–30 Jun 03	100
		1 Jul 03–30 Jun 04	100
		1 Jul 04–30 Nov 04	50

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In situ examination of the behaviour of fish in response to demersal trawl nets in an Australian trawl fishery

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Abstract. *In situ* examination of the behaviour of fish was undertaken with underwater cameras positioned on demersal trawl gear used by Australia's South East Trawl Fishery. Blue grenadier (*Macruronus novaezelandiae*), pink ling (*Genypterus blacodes*) and whiptails (*Coelorinchus* spp.) swam in an anguilliform mode whereas other species displayed a carangiform swimming mode. Tiger flathead (*Neoplatycephalus richardsoni*) and ocean perch (*Heliocolenus* spp.) were active in response to the approaching trawl net compared with the generally passive activity of whiptails, New Zealand dory (*Cyttus novaezelandiae*), and jackass morwong (*Nemadactylus macropterus*). However, when in the body of the trawl, gemfish were active while ocean perch, whiptails and New Zealand dory were generally passive. Some blue grenadier, ocean perch and whiptails escaped capture by passing through open meshes in the trawl mouth, whereas tiger flathead passed under the ground gear. In the trawl body, small numbers of blue grenadier passed through open meshes in the top panel whereas numerous spotted warehou swam faster than the towing speed, presumably escaping capture by swimming forwards and out of the trawl. Interspecific behavioural variation in escape response could be utilised to design more efficient trawl gears.

Extra keywords: blue grenadier, jackass morwong, pink ling, tiger flathead, underwater camera.

Introduction

The ecological impact of demersal trawl operations includes potential damage to benthic habitats and the incidental capture of non-target species (Jennings and Kaiser 1998). Recent attempts to improve the selectivity of demersal trawls have focussed on physical modifications to nets, including variation in mesh size and shape (Kennelly 1995; Broadhurst 2000). Such modifications generally select for fish size and can result in the decreased capture rates of immature individuals of target species (to conserve spawning stocks) and small individuals of non-target species (Kennelly 1995). Modifications to shrimp trawls provide for differences in swimming behaviour of shrimp and fish species such that fish can escape capture by swimming forwards and out through wider mesh panels in the top of the trawl net (Kennelly 1995). However, the behaviour of most fish species commonly caught in demersal trawl nets is poorly understood. The behaviour of fish in trawls can clearly influence selection (Wardle 1989; Watson 1989) together with other factors such as mesh size and shape (Robertson 1989; Halliday *et al.* 1999), towing speed, catch rate and volume (Robertson and Ferro 1988; Dahm *et al.* 2002) and sea-state induced vessel motion (O'Neill *et al.* 2002).

The recent development of low-light underwater camera technology has provided opportunities for *in situ* observations of the behaviour of fish in response to towed trawls (Rose 1993; Walsh and William 1993; Glass and Wardle 1995). Fish demonstrate inter- and intra-specific variation in behaviour, which is influenced by swimming speed and endurance (Wardle and He 1988; Videler and Wardle 1991), and visual, tactile or aural response to trawl nets (Main and Sangster 1981; Glass *et al.* 1986; Wardle 1989; Watson 1989; Zhang and Arimoto 1993; Popper and Carlson 1998). It is interesting to note that the studies cited above are all based on northern hemisphere fisheries.

We examined the behaviour of fish in the South-East Trawl Fishery, a multi-species, multi-method fishery targeting 18 species in the coastal waters of south-east Australia (Tilzey 1994; Grieve and Richardson 2001). A legislative requirement for Australian commercial fisheries to demonstrate compliance with the principles of ecological sustainable development has prompted an examination of the ecological impact of the South-East Trawl Fishery (e.g. Garcia *et al.* 2000) and the selectivity of demersal trawl gears in this fishery. With more than half of the catch discarded in some cases (Knuckey and Liggins 1999), there is a need to reduce the

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capture of unwanted fish. Low-light underwater cameras situated on and in demersal South-East Trawl Fishery trawls were used to observe behaviour and quantify the response of fish. As this is the first study of behaviour in a major southern hemisphere fishery, we discuss proactive approaches to the modification of fish trawls to improve selectivity and, potentially, ecological performance.

Materials and methods

Underwater camera systems

A 'Navigator' (Remote Oceans Systems, Bowtech Products Ltd, Aberdeen, UK) low-light monochrome camera was housed within a lightweight aluminium pod to enable observations at the trawl mouth or wingends of the trawl gear. The camera had a 3.8-mm auto-iris lens capable of operation to illumination levels of 3.4×10^{-4} lux. Housed within the camera pod were a Hi-8 analogue camcorder (Model CCD-TRV66E; Sony, Tokyo), two 12-V sealed, lead-acid rechargeable batteries, a 20-W Halogen lamp and a controller box incorporating a variable time delay to facilitate *in-situ* filming of trawl operations. The pod was designed to minimise negative impacts on trawl geometry and to provide for manual pan and tilt capacity.

In situ *observations*

Camera observations of fish behaviour were made during daylight aboard commercial fishing vessels working on established grounds within the South-East Trawl Fishery (off Bermagui, New South Wales, and off Portland, Victoria) between August 1999 and October 2001 (Table 1). The camera system was located at various sections in the trawl, including the wingends and mouth, trawl body, extension, and codend (Fig. 1), and provided both forwards and aft perspectives.

Video records of camera observations served as a basis for a quantitative and categorical assessment of fish behaviour. Categories described included swimming behaviour and the direction and estimated speed of fish relative to the velocity of the trawl (Table 2). The duration and frequency of each category was recorded so that behavioural differences among species could be assessed. Each behavioural category was recorded as either an 'event' or a 'state'. An 'event' is defined as a discrete, instantaneous action such as a burst swim or turn, whereas a continuous action of longer duration such as cruise swimming is defined as a 'state' (after Lehner 1979; Martin and Bateson 1986). Within the trawl mouth and body, the vertical position was noted as bottom (close to the seabed/bottom panel), middle (middle section) and top (close to the headline/top panel). Change in vertical position was recorded as rising, sinking and no change. Trawl velocity was nominally 3.0 kn.

The fish examined varied in morphology, habitat and feeding strategy (Table 3) and are generally dominant in catches from the South-East Trawl Fishery.

Statistical treatment of data

Replication of camera observations of each species in three sections of the net was made through multiple shots at each location. However, for some species, practical requirements in working with commercial trawl operations meant that observations were recorded from more than one location at different times (Table 2), thus introducing additional sources of variation in behaviour that could not be examined directly in the present study. Furthermore, it was not always possible to balance observations of fish within the various sections of the trawl such that robust comparisons of species-specific behaviour could be undertaken. Thus, the data were not considered to be amenable to a formal comparison of

Table 1. Summary data for *in situ* observations of behaviour of fish species in response to commercial trawls. Data are total number of individuals observed

Fish species examined	Total observed (occasions in parentheses)	Dates	Location (occasions in parentheses)	Depth range (m)
Blue grenadier (*Macruronus novaezelandiae*)	765 (7)	March 2000 to October 2001	Portland, Victoria	198–657
Tiger flathead (*Neoplatycephalus richardsoni*)	1045 (3)	26 August 1999; 10, 13 December 2000	Bermagui, NSW	~90
Gemfish (*Rexea solandri*)	219 (4)	November 1999; October 2001	Bermagui, NSW (1) Portland, Victoria (3)	270 450–648
Pink ling (*Genypterus blacodes*)	340 (8)	November 1999; October 2001 August, September 1999	Portland, Victoria (6) Bermagui, NSW (2)	432–657 270–414
Spotted warehou (*Seriolella punctata*)	580 (6)	March 2000; March, October 2001; August 1999	Portland, Victoria (5) Bermagui, NSW (1)	198–657 270
Jackass morwong (*Nemadactylus macropterus*)	357 (4)	November 1999; June 2000; March, October 2001	Portland, Victoria	215–360
Ocean perch (*Helicolenus* spp.)	202 (6)	March, June 2000; August, September 1999; October 2001	Portland, Victoria Bermagui, NSW	378–657 270, 414
Whiptails (*Coelorinchus* spp.)	1163 (5)	March 2000; August, September 1999	Portland, Victoria	198–648 270, 414
New Zealand dory (*Cyttus novaezelandiae*)	1813 (6)	November 1999; October 2001	Portland, Victoria	216–648

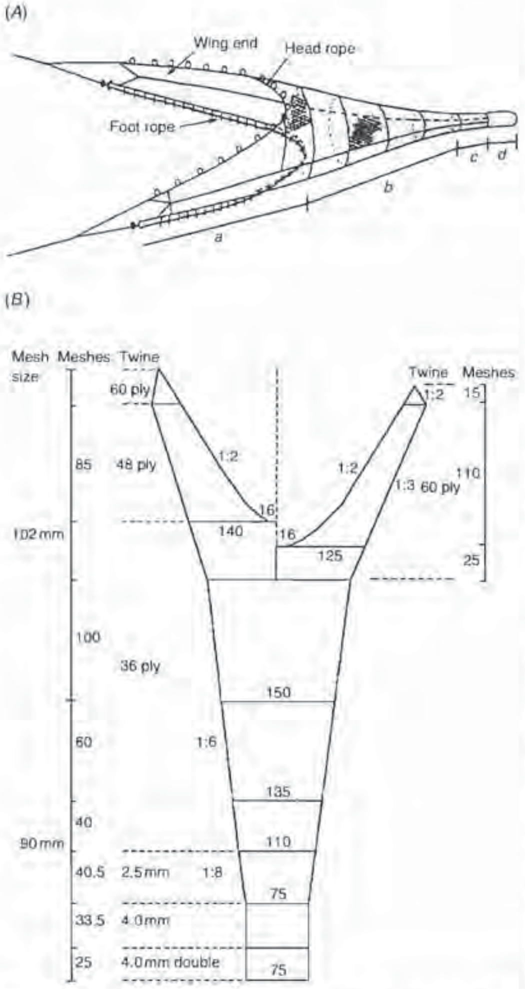

Fig. 1. (*A*) Demersal trawl gear used in camera observations of fish behaviour with the four main locations for camera attachment indicated: (*a*) wingends and mouth, (*b*) body, (*c*) extension and (*d*) codend. (*B*) A net plan shows the mesh sizes and twine ply.

means and *post hoc* comparisons of behaviour among or between the species examined.

Results

Species-specific behaviour

*Blue grenadier (*Macruronus novaezelandiae*)*

Blue grenadier were mostly observed motionless on the seabed, or in the water column (up to the headline height), as the trawl approached. Blue grenadier displayed haphazard, short-burst swimming manoeuvres in response to contact with the trawl gear. Many individuals contacted the netting in the wings and upper panels of the trawl. On contact with the net, blue grenadier responded with rapid changes in orientation and burst swimming in the opposite direction. This behaviour continued as individuals passed through the trawl body and into the extension. Occasionally, individuals escaped through open meshes in the wings. Blue grenadier were observed orientating and cruise swimming in the mouth of the trawl for short periods (usually less than 10 s) before being overrun by the trawl body. Cruise swimming (speed unknown), orientated aft and cruise swimming (slower than the trawl speed) and orientated forwards were the dominant behavioural categories observed for the species (Fig. 2).

After entering the trawl extension, blue grenadier either continued active burst-swim-turn behaviour, or resting motionless in the water column. Active burst swimming was often associated with large numbers of fish accumulating in the trawl. Resting in the water column and burst-swimming responses were the dominant behaviours recorded in the extension (Fig. 2).

*Tiger flathead (*Neoplatycephalus richardsoni*)*

Tiger flathead were generally motionless on the seabed as the trawl approached. Near or at contact with the trawl gear, tiger flathead responded with a haphazard burst-swimming response, then repeated burst and glide (no apparent body movement) manoeuvres in a horizontal direction with the trawl. Between successive manoeuvres, the swimming speed of individuals was less than the trawl net and fish velocity near the trawl wings, and subsequently moved towards the centre of the ground gear and foot rope. After a brief period (generally less than 1 min), tiger flathead stopped swimming ahead of the trawl and either rose a small distance above the seabed and entered the trawl body, or exited between the rubber discs of the ground gear. Burst swimming faster than the trawl speed orientated forwards to the tow direction was the dominant behavioural category recorded at the trawl mouth (Fig. 3).

In the codend, tiger flathead either swam slowly towards the accumulated catch or remained motionless, orientated aft and overrun by the trawl. Individuals resting on the netting were eventually contacted by other fish prompting haphazard burst-swimming behaviour, often resulting in contact with the sides or upper panels of the codend. Cruise swimming directed aft, and cruise swimming slower than the trawl speed either orientated forwards or changing direction were the dominant behaviours observed for tiger flathead in the codend (Fig. 3).

*Gemfish (*Rexea solandri*)*

Gemfish were mostly close to the seabed (within 2 m) as the trawl approached. In, or near, contact with the trawl gear,

Table 2. Categories of fish behaviour (abbreviation) used in examining the response of various fish species to trawl net

Behaviour	Type	Swimming speed[A]	Swimming direction[B]	General description	Code
Cruise swimming (Cs)	State	Faster (f)	Forwards (F)	Fish swimming with a steady tail beat frequency faster than the trawl in the towing direction	*Cs(f)F*
Cruise swimming (Cs)	State	Slower (sl)	Forwards (F)	Fish swimming with a steady tail beat frequency slower than the trawl in the towing direction	*Cs(sl)F*
Cruise swimming (Cs)	State	Same (sa)	Forwards (F)	Fish swimming with a steady tail beat frequency at the same speed as the trawl in the towing direction	*Cs(sa)F*
Cruise swimming (Cs)	State	Unknown (un)	Aft (A)	Fish swimming with a steady tail beat frequency at an unknown speed opposite to the towing direction	*Cs(un)A*
Cruise swimming (Cs)	State	Slower (sl) or same (sa)	Turn (T)	Fish performing a slow movement resulting in a change in orientation or direction after the response is performed	*Cs(sl)T* or *Cs(sa)T*
Rest (R)	State	None	None	Fish motionless, resting on panel of netting or observed drifting back toward the codend	*R*
Impinged (I)	State	None	None	Fish impinged on panel of netting or against other fish in the codend	*I*
Burst swim (Bs)	Event	Faster (f)	Forwards (F) or Aft (A)	Fish swimming with a high tail beat frequency, a vigorous intense but brief high speed response	*Bs(f)F* or *Bs(f)A*
Burst swim (Bs)	Event	Faster (f)	Random, but strikes trawl netting (N)	Fish performing a burst swim resulting in contact with the trawl net	*Bs(f)N*
Burst swim (Bs)	Event	Faster (f)	Turn (T)	Fish performing a burst swim resulting in a change in orientation or direction after the response is performed	*Bs(f)T*

[A]Relative to towing speed; [B]relative to towing direction.

Table 3. Fish species observed in *in situ* studies of behaviour, including general characteristics of size range (in catch), morphology, feeding strategy and habitat preference

Common name (abbreviation)	Species	Size range (TL) (cm)[A]	Morphology[A]	Caudal fin shape[A]	Feeding strategy[B]	Habitat preference[B]
Blue grenadier (BG)	*Macruronus novaezelandiae*	60–80	Rounded	Pointed	Mobile generalist	Pelagic and demersal
Pink ling (PL)	*Genypterus blacodes*	50–80	Rounded	Pointed	Generalist bottom feeder	Demersal/soft bottom
Gemfish (G)	*Rexea solandri*	20–80	Moderately compressed	Forked	Ambush (lie-in-wait)	Pelagic and demersal
Tiger flathead (TF)	*Neoplatycephalus macropterus*	20–50	Moderately depressed	Truncate	Ambush (sit-in-wait)	Demersal/soft bottom
Jackass morwong (JM)	*Nemadactylus macropterus*	25–40	Moderately compressed	Emarginate	Generalist bottom feeder	Demersal/hard bottom
Spotted warehou (SW)	*Seriolella punctata*	30–50	Moderately compressed	Forked	Midwater schooling forager	Pelagic and demersal
Ocean perch (OP)	*Helicolenus* spp.	20–40	Rounded	Truncate	Ambush (sit-in-wait)	Demersal/soft bottom
Silver trevally (ST)	*Pseudocarnax dentex*	30–50	Moderately compressed	Forked	Mobile schooling generalist	Pelagic and demersal
Redfish (RF)	*Centroberyx affinis*	15–30	Moderately compressed	Forked	Schooling generalist	Demersal/hard bottom
New Zealand dory (NZD)	*Cyttus novaezelandiae*	15–25	Compressed	Truncate	Unknown	Pelagic and demersal
Whiptails (W)	*Coelorinchus* spp.	15–40	Rounded	Pointed	Generalist bottom feeder	Demersal/soft bottom

[A]Last *et al.* (1983); [B]Prince *et al.* (1998). TL, Total length.

gemfish demonstrated repeated burst-swimming manoeuvres. Cruise swimming slower than trawl speed generally followed each burst-swim before individuals were overrun by the trawl. Many gemfish in the trawl body rose towards the headline (occasionally contacting the top panel) while swimming forwards. 'Cruise swimming slower than the trawl speed orientated forward' was the dominant behavioural category recorded in the trawl body (Fig. 4).

Gemfish in the extension of the trawl were highly active and, in attempts to swim towards the trawl mouth, exhibited frequent burst-swimming manoeuvres. Each highly-active response was interspersed with individuals quickly regaining

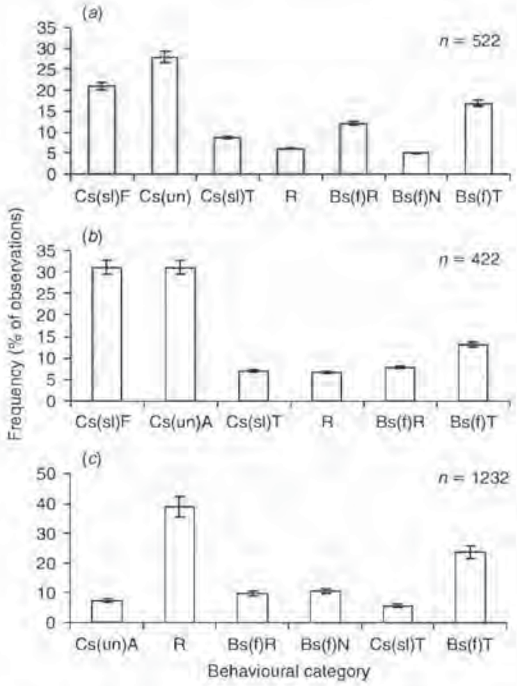

Fig. 2. Summary of behavioural results from *in situ* camera observations of blue grenadier. Data are the proportion of the behavioural categories ± s.e. within the various net sections sampled: (*a*) mouth, (*b*) body and (*c*) extension (*n* is the total number of observations). Refer to Table 1 for a description of behaviour categories.

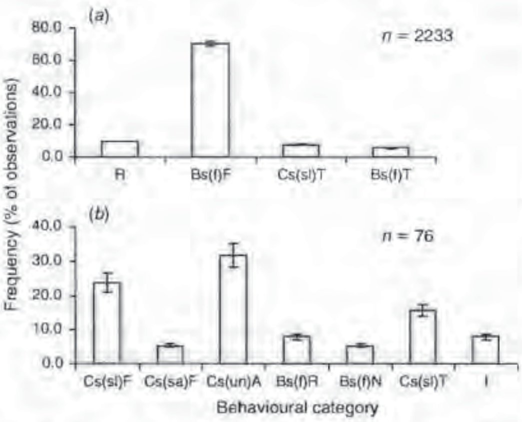

Fig. 3. Summary of behavioural results from *in situ* camera observations of tiger flathead. Data are the proportion of the behavioural categories ± s.e. within the various net sections sampled: (*a*) mouth and (*b*) codend (*n* is the total number of observations). Refer to Table 1 for a description of behaviour categories.

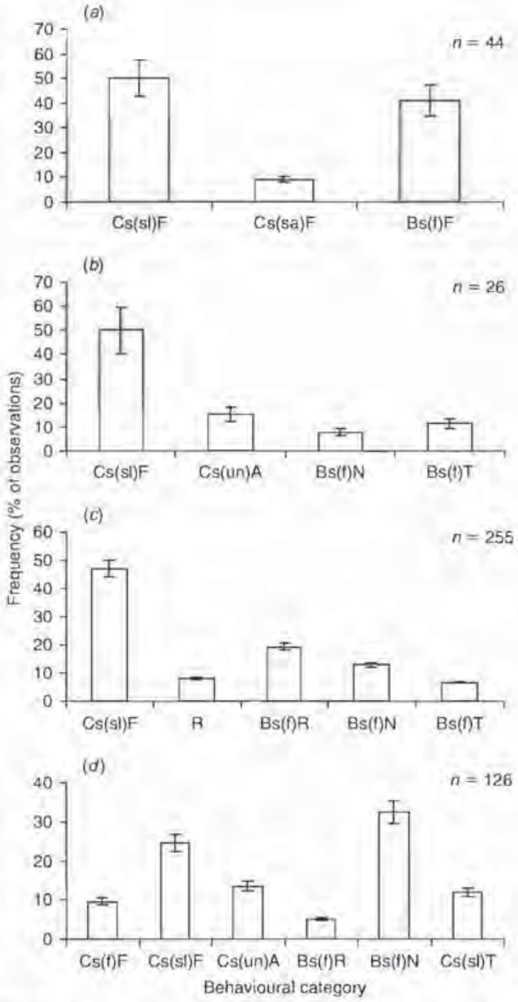

Fig. 4. Summary of behavioural results from *in situ* camera observations of gemfish. Data are the proportion of the behavioural categories ± s.e. within the various net sections sampled: (*a*) mouth, (*b*) body, (*c*) extension and (*d*) codend (*n* is the total number of observations). Refer to Table 1 for a description of behaviour categories.

orientation towards the towing direction and cruise swimming slower than the trawl speed (the dominant behaviour category observed in the extension) (Fig. 4). Gemfish were highly active in the codend. Some individuals used burst-swim manoeuvres towards the accumulated catch, while others repeatedly attempted to escape through the upper panel of the codend (Fig. 4). After this initial frequent activity, most individuals swam slower than the trawl, but orientated towards the top of the net.

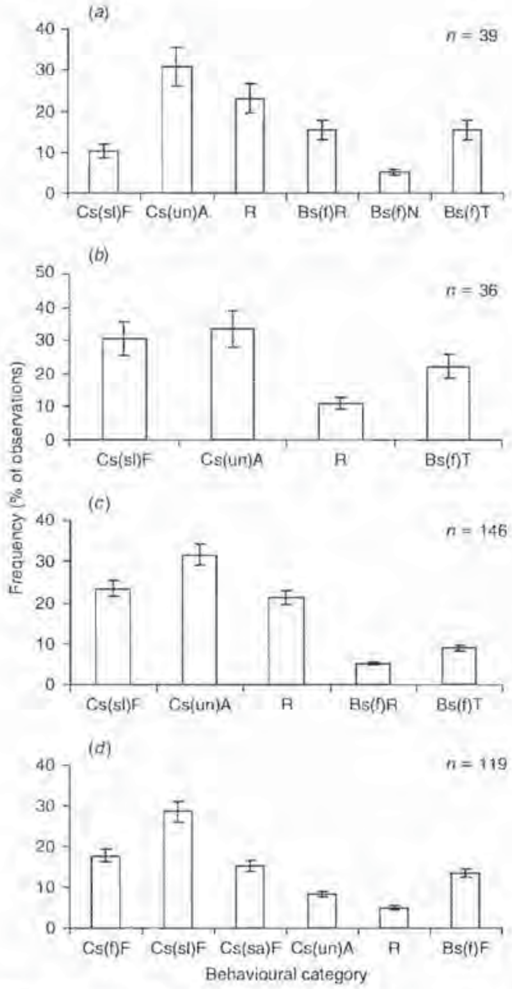

Fig. 5. Summary of behavioural results from *in situ* camera observations of pink ling. Data are the proportion of the behavioural categories ± s.e. within the various net sections sampled: (*a*) mouth, (*b*) body, (*c*) extension and (*d*) codend (*n* is the total number of observations). Refer to Table 1 for a description of behaviour categories.

*Pink ling (*Genypterus blacodes*)*

Pink ling near the seabed (within 2 m) were either motionless or swimming randomly as the trawl gear approached. Immediately before contact with the trawl, individuals appeared startled, responding with horizontal burst-swim manoeuvres away from the trawl. Cruise swimming, speed unknown orientated aft and resting were the dominant behavioural categories recorded (Fig. 5). In the body of the trawl, pink ling were either motionless and quickly overrun by the trawl, cruise swimming slower than the trawl speed orientated forward, or cruise swimming towards the codend (Fig. 5). Contact with other fish or the trawl evoked haphazard burst-swim manoeuvres.

After reaching the codend, most pink ling orientated anterior to the accumulated catch and towards the trawl mouth, swimming at the same speed as the trawl. Following contact with other fish, pink ling displayed burst-swim and turn manoeuvres. Cruise swimming was the dominant behaviour in the codend (Fig. 5).

*Spotted warehou (*Seriolella punctata*)*

At the trawl mouth, some spotted warehou moved back into the trawl body while others swam with the trawl for limited periods (generally less than 5 min) before being overrun by the trawl and entering the body. Individuals located close to the wingends displayed burst-swimming forwards. Cruise swimming slower and at the same speed as the trawl were the dominant behavioural categories recorded at the trawl mouth (Fig. 6).

Most spotted warehou entering the extension were orientated forwards, maintaining position within the trawl via cruise swimming and occasional burst-swimming manoeuvres. Cruise swimming slower than the trawl that orientated forwards to the tow direction was the dominant behaviour recorded in the extension and codend sections (Fig. 6).

*Jackass morwong (*Nemadactylus macropterus*)*

Individuals were motionless or swimming slowly in the trawl path located on or within 2 m of the seafloor. The behaviour of jackass morwong at the mouth of the trawl did not appear to change until immediately before contact with the ground gear. Individuals then reacted with haphazard, horizontal burst swims. These manoeuvres generally continued until the trawl overran the fish. No jackass morwong exited upwards and over the headline of the trawl. Haphazard burst-swim and resting manoeuvres were the dominant behavioural categories observed at the trawl mouth (Fig. 7). In the body, extension, and codend of the trawl, jackass morwong were generally motionless (Fig. 7) and orientated forwards or laterally to the direction of the tow. Some individuals showed burst-swimming behaviour when contacted by other fish.

*Ocean perch (*Helicolenus *spp.)*

Ocean perch responded to the approaching trawl gear with highly active short-burst swims. Some small individuals exited by passing through the meshes in the bottom panels of the wingends. Dominant behaviour in the mouth of the net included haphazard burst swim and resting (Fig. 8). Once in the body of the trawl, ocean perch were generally passive, with occasional burst-swimming behaviour resulting in contact with the trawl. Throughout the tow, many ocean perch were motionless, resting on the bottom panel of the codend and orientated forwards (Fig. 8).

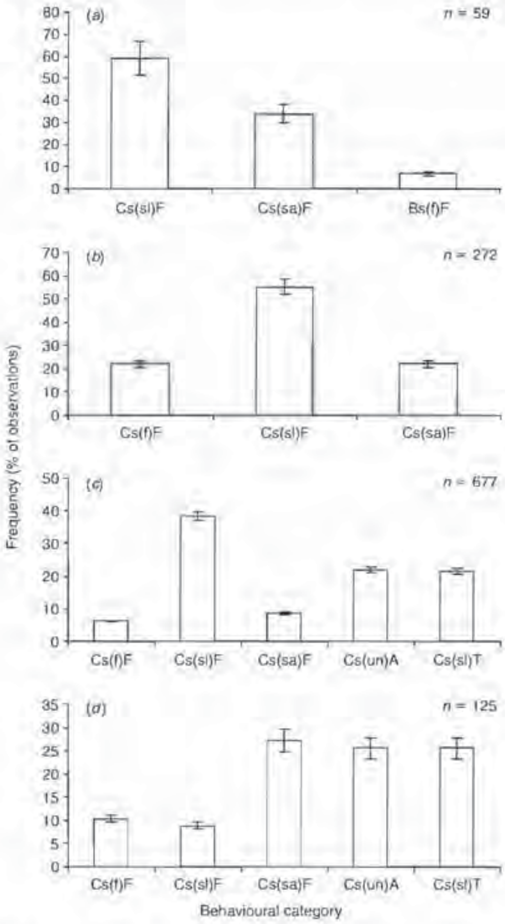

Fig. 6. Summary of behavioural results from *in situ* camera observations of spotted warehou. Data are the proportion of the behavioural categories ± s.e. within the various net sections sampled: (*a*) mouth, (*b*) body, (*c*) extension and (*d*) codend (*n* is the total number of observations). Refer to Table 1 for a description of behaviour categories.

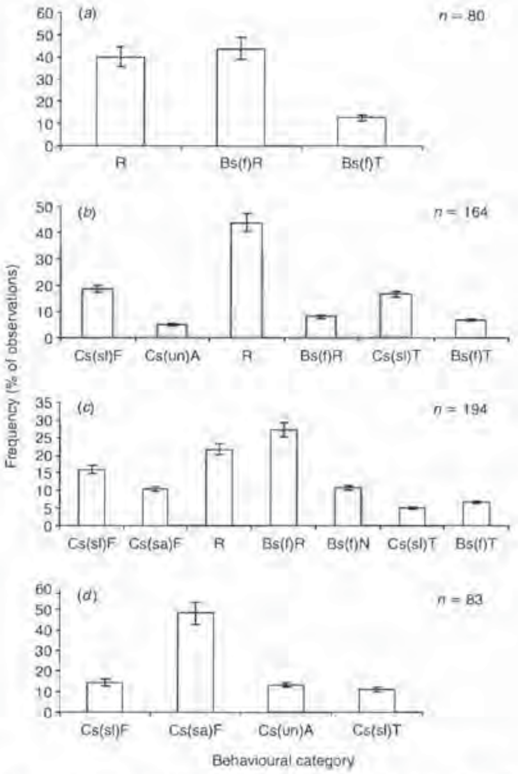

Fig. 7. Summary of behavioural results from *in situ* camera observations of jackass morwong. Data are the proportion of the behavioural categories ± s.e. within the various net sections sampled: (*a*) mouth, (*b*) body, (*c*) extension and (*d*) codend (*n* is the total number of observations). Refer to Table 1 for a description of behaviour categories.

*Whiptails (*Coelorinchus *spp.)*

The initial response of whiptails to the approaching trawl was repeated rapid horizontal burst-swimming. Whiptails were quickly overrun by the trawl with many individuals stationary as they passed into the trawl body (Fig. 9). Some exited through open meshes in the lower panel of the wingend. Resting was the dominant behaviour in all posterior trawl sections (Fig. 9).

*New Zealand dory (*Cyttus novaezelandiae*)*

New Zealand dory were mostly situated above the seafloor (>2 m) and were motionless as the trawl approached. Individuals exhibited burst-swimming near and at contact with the trawl, interspersed with motionless behaviour. In the body, extension and codend of the trawl, rest was the dominant behavioural category recorded, with occasional burst swims after contact with the meshes (Fig. 10).

Interspecific comparisons of escape response

Blue grenadier, pink ling and whiptails swam in an anguilliform mode in which the posterior half of the body is flexed laterally. All other species had a carangiform swimming mode, where the posterior portion of the body and tail oscillate. Compared with generally passive activity in whiptails, New Zealand dory, and jackass morwong, tiger flathead and ocean perch demonstrated a high activity response to the trawl. In the body of the trawl, gemfish were the most active species, while in the codend, New Zealand dory exhibited high activity.

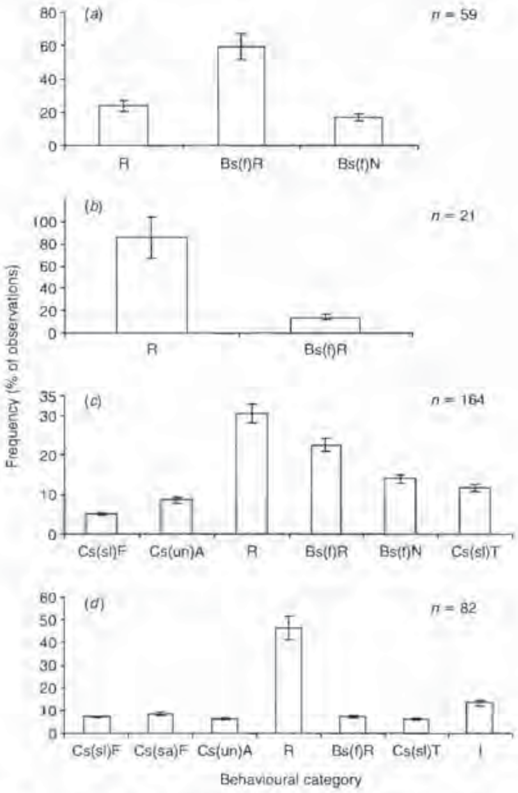

Fig. 8. Summary of behavioural results from *in situ* camera observations of ocean perch. Data are the proportion of the behavioural categories ± s.e. within the various net sections sampled: (*a*) mouth, (*b*) body, (*c*) extension and (*d*) codend (*n* is the total number of observations). Refer to Table 1 for a description of behaviour categories.

Some blue grenadier, ocean perch and whiptails exited by passing through open meshes in the trawl mouth, whereas tiger flathead passed under the ground gear. In the trawl body, small numbers of blue grenadier passed through open meshes in the top panel whereas large numbers of spotted warehou were observed swimming faster than the tow speed, presumably escaping capture by swimming forwards of the trawl path (Table 4).

Discussion

In situ observations of fish species commonly targeted in the South East Trawl Fishery revealed differences in behaviour in response to demersal trawling. The results from the present study suggest differences in swimming capacity and endurance influence the retention of fish in trawls. Knowledge of the behaviour of fish species can be used when designing and applying more selective trawl gear.

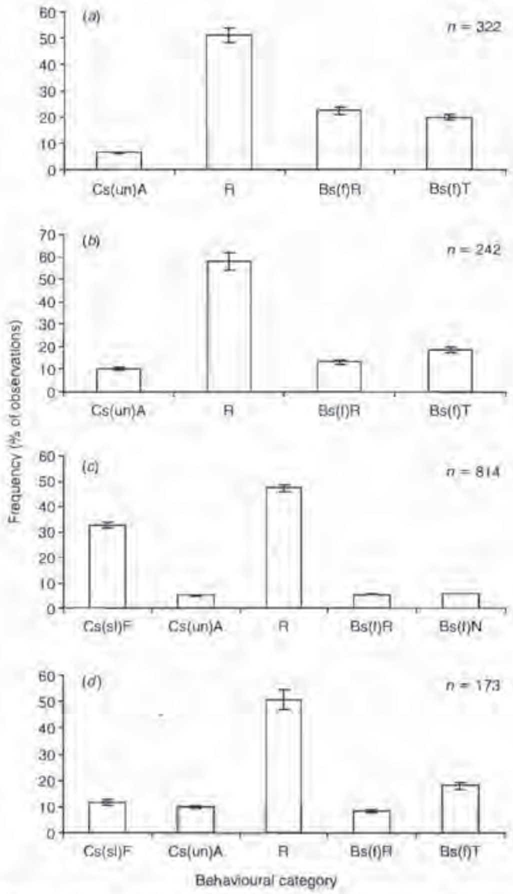

Fig. 9. Summary of behavioural results from *in situ* camera observations of whiptail species. Data are the proportion of the behavioural categories ± s.e. within the various net sections sampled: (*a*) mouth, (*b*) body, (*c*) extension and (*d*) codend (*n* is the total number of observations). Refer to Table 1 for a description of behaviour categories.

This is particularly important given increasing concerns over the ecological impacts of bottom trawling (Jennings and Kaiser 1998).

The behaviour of several fish species observed in the present study revealed potential for the escape of small non-target or undersized conspecifics of commercial species between the wings and in the mouth of the trawl. For example, the fusifom-shaped pink ling and blue grenadier were able to escape with burst-swims through meshes in the anterior section of the trawl. Furthermore, many other species attempted to escape through meshes in the trawl body by using burst-swim manoeuvres, although, owing to their size in relation to the small mesh, few individuals managed to pass through.

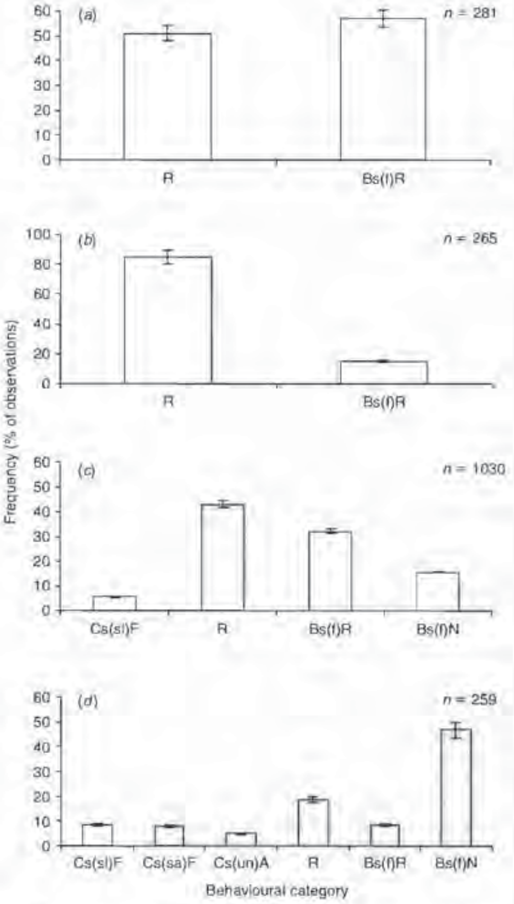

Fig. 10. Summary of behavioural results from *in situ* camera observations of New Zealand dory. Data are the proportion of the behavioural categories ± s.e. within the various net sections sampled: (*a*) mouth, (*b*) body, (*c*) extension and (*d*) codend (*n* is the total number of observations). Refer to Table 1 for a description of behaviour categories.

The commercial trawls used in the present study were made from 90-mm mesh and it is likely that a small increase in mesh size in the body of the trawl would allow many of the undersized commercial species and small non-target species to escape. Broadhurst and Kennelly (1995) demonstrated that increasing mesh size from 90 to 100 mm (stretched mesh) throughout the body and codend of South East Trawl Fishery trawls reduced the unwanted catches of non-target species by 27%.

Other simple and appropriate modifications that warrant investigation might involve adjusting the rigging of the trawl mouth. Specifically, because most species of ground fish were observed to escape under the foot rope, adjustment to disc size, diameter and spacing could reduce the capture of non-target benthic species. Any modifications, however, would need to maintain catches of commercial-sized tiger flathead.

Some species, including gemfish and blue grenadier, were observed rising in the trawl net after they entered the body. Many individuals frequently contacted the top panel of the trawl and so it might be possible to facilitate the escape of unwanted conspecifics by increasing mesh openings in strategic areas. Similar modifications have been successfully used in other trawl fisheries to reduce the capture of small haddock (Isaksen and Valdemarsen 1994).

There was evidence of species-specific vertical distribution at the trawl mouth, which is probably correlated with habitat preferences. Demersal species, including tiger flathead, ocean perch, pink ling, jackass morwong and whiptails entered the trawl close to the seafloor and remained on or close to the bottom panel. In contrast, semipelagic species such as gemfish, blue grenadier, spotted warehou and New Zealand dory, rose in the trawl body and frequently had contacted the upper net panels. These observations suggest that groups of species could be separated, via horizontal panels, into upper and lower compartments (e.g. Galbraith and Main 1989). The compartments could then include different modifications designed to select particular species and sizes. Any improvements in selectivity could also result in improved catch quality because contact with animals with spines and hard shells is reduced (Main and Sangster 1982).

Table 4. Frequency of escape of fish from trawl nets based on *in situ* camera observations

Net section	Species	*n*	Escape frequency (%)	Escape route (% of individuals escaping) Through mesh	Beneath ground gear	Swimming from trawl path
Mouth	Blue grenadier	378	5	100	0	0
	Tiger flathead	996	12	0	100	0
	Ocean perch	36	28	100	0	0
	Whiptails	173	8	100	0	0
	Spotted warehou	33	30	0	0	100
Body	Blue grenadier	319	<1	100	0	0
	Spotted warehou	90	56	0	0	100
Codend	Tiger flathead	49	4	100	0	0
	Gemfish	79	3	100	0	0

The determination of key sensory stimuli that elicit escape responses in fish is a prerequisite to improving gear selectivity via the exploitation of behavioural differences (Wardle 1987). Such stimuli will vary with position in the trawl (from the mouth to the codend). In the trawl mouth, many species including pink ling, ocean perch, jackass morwong, blue grenadier and whiptails responded to the approaching trawl with startled burst-swims. Fish can respond to aural stimuli from the ship, otter boards and trawl itself, but at close range, the reactions of fish are primarily in response to visual stimuli (Wardle 1993).

The influence of the camera system on fish behaviour was not quantified in the present study. With the camera directed towards the codend, fish were occasionally observed moving into the region immediately aft of the camera and swimming with a tail-beat frequency that was noticeably less than that of fish in other observable regions of the trawl. In these instances, the passage of the camera through the water had presumably caused wake eddies, allowing fish to maintain station with the trawl with a reduced tail beat frequency. The use of lights to illuminate the trawl may have also influenced fish behaviour during the capture process. The extent that light influences fish behaviour is difficult to assess, and depends on a combination of factors, including the time of day, ambient light levels, water turbidity, bioluminescent activity, light orientation and intensity. Addressing this issue, Weinberg and Munro (1999) found no effect of artificial light (50-W) on the capture efficiency of fish by demersal trawl gear.

Many fish in the present study, including commercial target species, were observed to escape from the trawl net by swimming forwards of the trawl path, by swimming under the ground gear, and through meshes in the trawl mouth, body and codend. This highlights the need for further research to quantify the catchability of species and their sizes, enabling the development of more selective trawl gears. This is important in improving selectivity and potentially reducing the ecological impacts of demersal trawling.

Acknowledgments

The authors wish to thank Drs Chris Glass and Matt Broadhurst for constructive suggestions in the design and execution of the present study. Dr Broadhurst also provided comments on previous drafts. The assistance of the skippers and crew of commercial fishing vessels, Shelley and Zeehaan, is gratefully acknowledged. Dr Greg Cronin provided helpful advice in the analysis of underwater video data. Crispian Ashby and Ken Graham provided help and support at sea. Tim Shaw provided development and maintenance support for the underwater camera system used in the present study. Funding was provided by FRDC (project 98/204). Two anonymous referees provided constructive comments on a previous draft.

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SeaNet & Extension in the SETF

- SeaNet Victoria (est. 1999) has been providing extension in the SETF for 3 years
- Primary focus has been involvement in projects to reduce bycatch
  - i.e. FRDC funded research projects
- SeaNet has established good working relationships with SETFIA and MAFRI

The Need for Extension….

- Extension is an important component of research work
- Particularly when it involves industry members and the interests of other stakeholder groups
- Effective extension and communication can increase the value of research projects by:
  - Providing industry with easy access to research findings
  - Raising stakeholder and community awareness of important research outcomes

SeaNet Involvement in South East Trawl Research

- SeaNet was first involved during the FRDC funded research project 1999-2001: *"Maximising yield and reducing discards in the SETF through gear development and evaluation"*
- Gear trials were conducted to identify more selective codend mesh types
- Sea trials in Portland and Eden

Research Extension

- Information gathering via communication with researchers, industry members and other key stakeholders involved in project
- SeaNet has conducted extension activities and developed extension material to effectively deliver research information:
  - **Newsletters**
  - **Videos**
  - **Media articles**
  - **Port visits / industry meetings**
  - **Stakeholder Education Workshop (*FTV Bluefin*)**

“*Networking*” Newsletters

<u>BENEFITS</u>

- Comprehensive and easy for audience to digest
  - **Descriptions of research methods with photographs**
  - **Use of graphical means to display results**
- Regular (5) and wide distribution to target audience
- Relatively easy and cost effective to put together
- Good method to provide contact details to stakeholders seeking further information

“*Networking*” Videos

BENEFITS

- Used as project milestone reports (2)
- High quality method of communicating a large amount of important information
- Communicate in detail with footage of key gear components at work
- Distribute widely to industry and stakeholders
- Easy to review

Other Extension Methods

- PORT VISITS
  - **Useful for information delivery, discussion and feedback purposes on a group or individual level**
- INDUSTRY MEETINGS / PRESENTATIONS
  - **Reporting progress and key activities to stakeholders**
- MEDIA ARTICLES
  - **Used to target particular audiences or community groups (inc. SETFIA newsletter)**
- STAKEHOLDER EDUCATION WORKSHOP
  - **Report on bycatch reduction research progress**
  - **Provide stakeholders with access to practical trawl demonstrations, industry members and research staff**

Current Work

- FRDC funded extension project:
  - *"Promoting Industry Uptake of Gear Modifications to Reduce Bycatch in the SETF & GABTF"*
- Use of *"Networking"* video to widely raise awareness of research progress and promote the use of modified codends
- Identifying more selective mesh options for each species and fishery region
- Stakeholder Education Workshop Report

SETF Extension Project

- Research extension and providing industry with modified codends
- Research Extension Officer is promoting further testing and industry adoption of modified codends
- Progress:
  - Vessels using modified codends in Beachport, Portland, Lakes Entrance, Eden and Bermagui
  - 100mm & 110mm diamond mesh; 90mm square mesh
  - 18 SETF vessels testing or using modified codends

SeaNet Work Plan

- Pursue stakeholder and industry feedback on the ***"Networking"*** video
- Consult with industry members regarding the suitability of mesh varieties to reduce bycatch
- Consultation outcomes to be included in **Codend-mesh Option Sheets** being developed
- Use **Option Sheets** to provide industry with best mesh options for each species and fishery region
- Promote industry adoption of modified gear

The Next Step

- Working with researchers and industry members, including fishers already using modified codends
- Objectives:
  - Pinpoint the most selective mesh types for each species (commercial & bycatch)
  - Reducing the discard component of the catch without having a significant impact on commercial catch levels

Industry Partnerships

- SeaNet continues to work successfully through the strong partnerships established with SETFIA and MAFRI
- SeaNet is also continuing work to:
  - Develop new strategic partnerships
  - Enhance the quality of extension provided to industry and stakeholders
  - Promote long term sustainability in the SETF

Contact SeaNet if you require…

- Further information regarding the extension of research from the FRDC funded SETF gear modification project
- Information regarding the progress of the current FRDC funded extension project promoting the adoption of modified codends
- SeaNet Victoria (www.oceanwatch.org.au)
  - 03 9824 0744 / 0413 949 562
  - seanet@siv.com.au

Bycatch reduction project description for GABIA members

Title: *FRDC 2001/006 Promoting industry uptake of gear modifications to reduce bycatch in the South-East and Great Australian Bight Trawl Fisheries*

Aim: to encourage industry members to voluntarily use recognised bycatch reduction measures.

- Funding exists to provide industry with modified gear.
- Project covers costs up to $1000 per codend, one per vessel.
- Costs can cover materials and/or net-makers time.
- It is not necessary to carry observers when using the modified codend, but we would appreciate your feedback on the performance of different gears.
- Codend design is based on providing escape opportunities for unwanted fish using square mesh or larger diamond mesh. The escapement of small latchet would be a major goal of bycatch reduction in the GABTF.
- We are flexible about bycatch reductions designs trialled by industry and are trying to work out what is effective with the particular GAB species composition.
- Participation in the project involves providing some feedback about relative successes/failures, to be shared amongst industry.
- Providing feedback for the trial would be subject to the discretion of the skipper and owner of the vessel. SeaNet will follow up the use of codends directly with skippers if permitted.
- For the terms of the project, square-mesh can be a panel or patch in the codend or extension, which is hung on the bar. Size and position of the panel is flexible. Information from the SETF is available. A similar idea is a patch that is sewn across the lay of the codend. Larger than standard mesh is also an option.

The desired outcome is industry wide use of gear that retains less unwanted fish.

For further information contact:
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Ph: 03 9824 0744
Mob: 0413 949 562
seanet@siv.com.au

An option to address growth overfishing of redfish. SETFIA General Meeting 28th November

Prepared by Ian Knuckey

There is growing concern about the "growth overfishing" of redfish off the NSW coast. This paper has been prepared for SETFIA members to:

- Explain what is meant by growth overfishing
- Examine the selectivity of current trawl gear towards redfish
- Demonstrate why it is thought that redfish are growth overfished
- Discuss the pros and cons of using larger diamond mesh codends to address redfish growth overfishing

Growth overfishing

After they are spawned, young fish generally grow quickly and put on a lot of weight as they grow. As they get older, their growth in length begins to slow, but they still put on weight. If this was the only process at work, best yields would be obtained by waiting until fish got as old and big as possible before catching them. Working against this process, however, is the fact that as soon as fish are spawned, they start to die and the remaining numbers decline. By multiplying the numbers of remaining fish against their weights, it is possible to calculate the total weight of all fish (biomass). If we track the biomass of a cohort of fish as they grow, we find that it reaches a maximum at a certain age when the improved yield from growth is matched by the reduced yield from mortality (Figure 1). Growth overfishing occurs when large numbers of small fish are taken at a size / age before this maximum is reached.

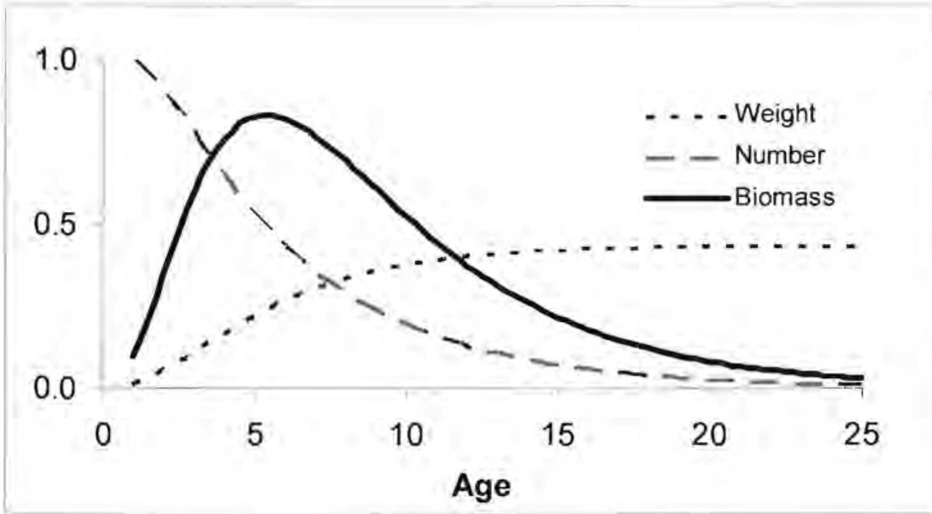


Figure 1. As a cohort of fish grows, their increase in weight is counteracted by declining numbers as fish die. Calculation of the resultant biomass reveals a bell-shaped curve showing the age/size of fish when the biomass is optimised.

"Yield per recruit" models examine the trade-off in yield between capturing large numbers of smaller fish or fewer numbers of larger fish. They use the growth and mortality inputs to calculate the relative yield that can be obtained from a given recruitment depending on what age (or size) the fish is caught and the level of fishing pressure. Such "YPR" models are simple and do not take into

1

account any stock-recruitment relationship (the relationship between the number of mature fish in a stock and how many new recruits they spawn). In other words, a YPR model will tell you if small fish are being captured at a size/age below the optimum potential yield, but it will not tell you if this is happening to such as large extent as to cause a significant decline in recruitment "recruitment overfishing".

Trawl selectivity towards redfish
By using covered coded experiments, we have been able to measure the selectivity of standard industry codends. When redfish enter the back of a net, a 6mm double braided 90mm diamond codend will retain some redfish less than 10cm length, half of redfish around 13 cm long and all of the redfish larger than 18cm. This is the net selectivity curve represented by the red line in Figure 2. Once these fish are on the deck, they are sorted by the crew based on what size that the skipper thinks is marketable. The fish deemed to be too small to market are discarded at sea. This "market selectivity" is represented by the green line in Figure 2, and shows that all fish less than 12cm are discarded, about half the fish around 18cm are retained and all fish above 28cm are kept. Effectively, all of the fish between the red line (what is caught) and the green line (what is retained) are wasted. The vertical dotted blue line represents the approximate size at which redfish mature.

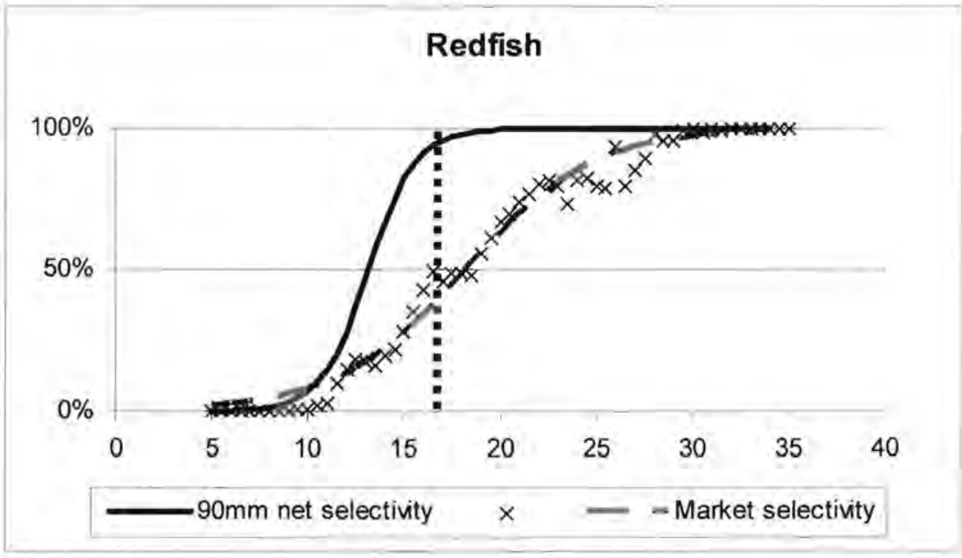


Figure 2. Selectivity curve for redfish using a 6mm double braided 90mm diamond codend (red solid line) and for the discarding of redfish to suit market pressures (green dashed line). The dotted vertical line represents the approximate size at maturity for redfish

Are redfish growth overfished?
The group of curved blue lines in Figure 3 shows the relative yield per recruit at fishing mortality rates $F = 0.13 - 0.20$ per year (around 15 – 18 % mortality) for sizes of 50% selectivity ranging from 10 cm to 30cm. Based on estimates of growth and mortality, the optimum yield per recruit is obtained when redfish are between 18 to 22 cm fork length (Figure 3). Due to the selectivity of standard 90mm diamond codends (50% selectivity at ~13cm) indicated by the red arrow, a large proportion of redfish are captured below the size of optimum yield. In general terms this probably results in 10% drop in the potential kg yield from the fish. Thus, growth overfishing of redfish is occurring in the trawl fishery using current codend configurations.

A factor which is probably of more importance to fishermen is that, in general, the price per kilo for smaller redfish is less than that for larger redfish. This increases the optimal size of capture to

2

about 21 – 25 cm and indicates that a relatively greater loss in dollar yield per recruit of up to 23% is currently occurring (Figure 4).

Although not directly related to optimal yields, it should be noted that preliminary studies of redfish reproduction have revealed that 50% of redfish would be mature at about 15-16cm. By taking large numbers of fish below this size, not only are we harvesting the fish at sub-optimal yields (growth overfishing), but we also prevent them reaching maturity and spawning. If this trend continues over the longer term, it may also lead to recruitment overfishing.

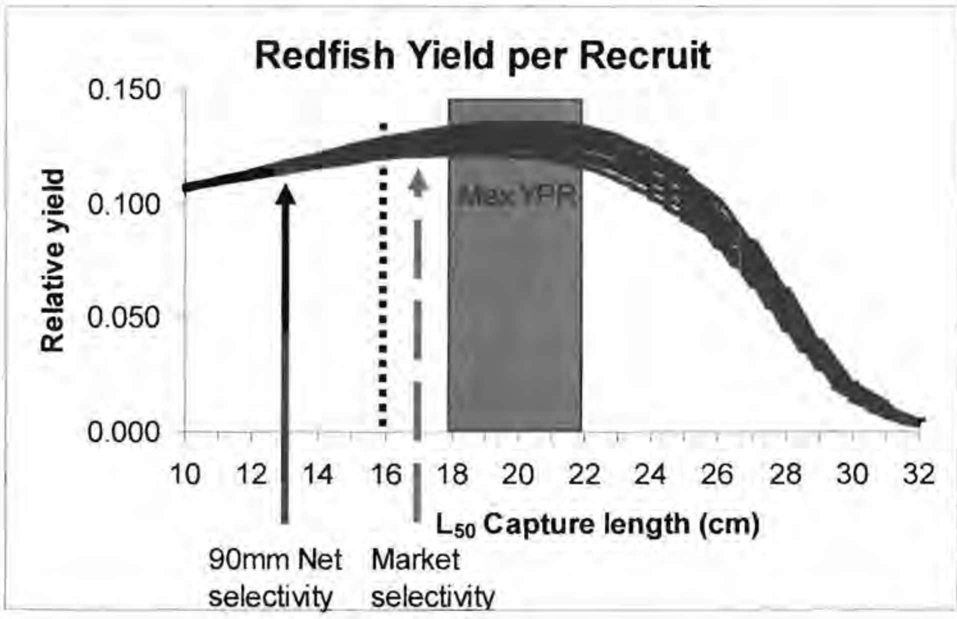


Figure 3. The relative yield per recruit for redfish caught at sizes of 50% selectivity ranging from 10 cm to 30cm. The red solid arrow shows the current 50% net selectivity and the dashed green arrow shows the 50% market selectivity. The dotted vertical line represents the approximate size at maturity for redfish.

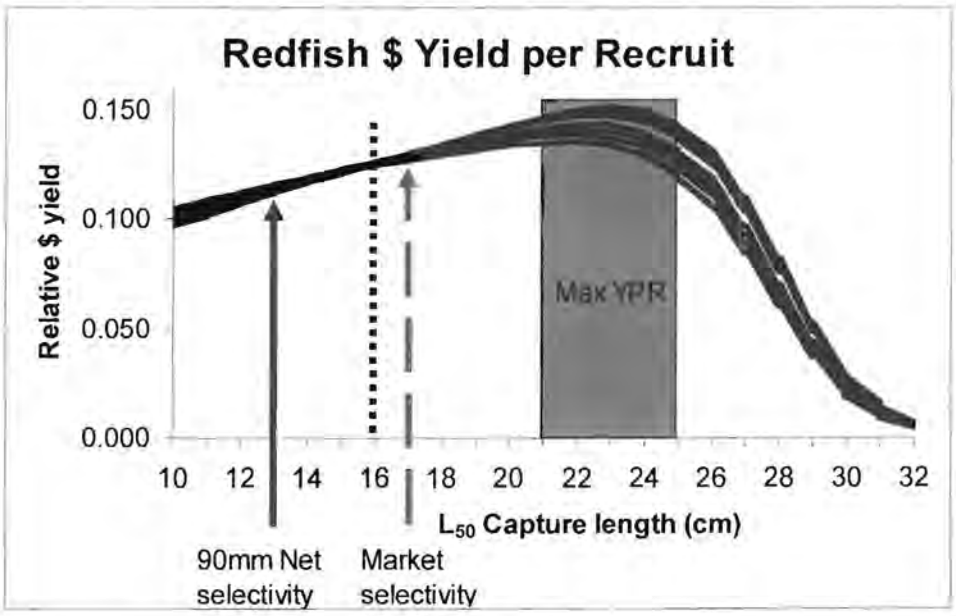


Figure 4. The relative dollar yield per recruit for redfish caught at sizes of 50% selectivity ranging from 10 cm to 30cm. The red solid arrow shows the current 50% net selectivity and the dashed green arrow shows the 50% market selectivity. The dotted vertical line represents the approximate size at maturity for redfish.

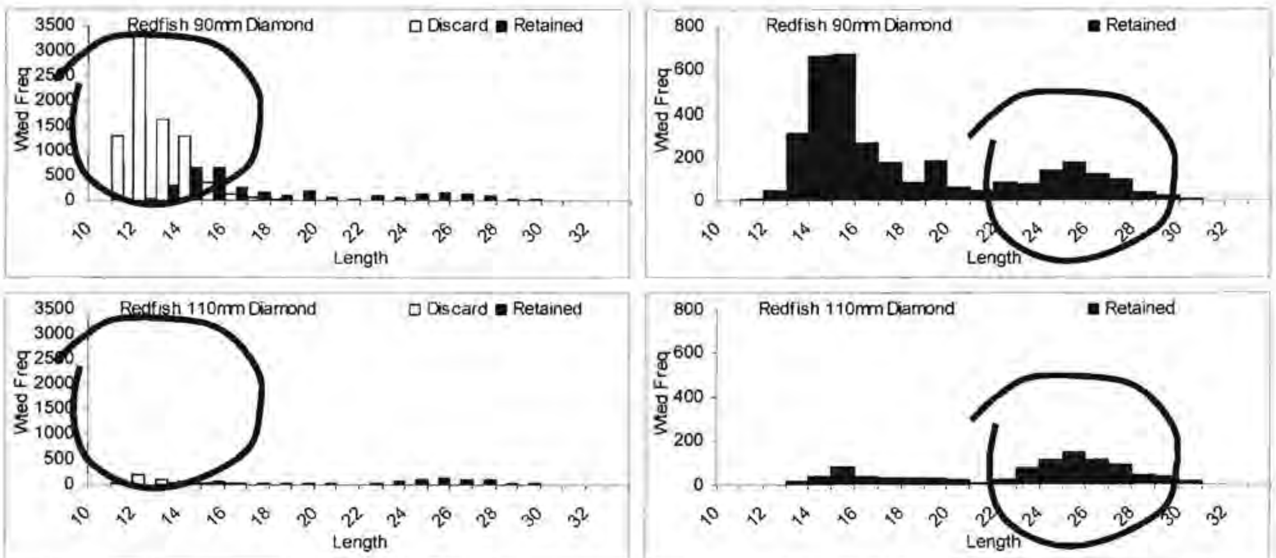
The equations and parameters used in the yield per recruit model are provided in the table below.

Process	Growth	Weight	Mortality	Selectivity
Equation	$L_t = L_\infty*(1-exp(-K(t-t_0)))$	$W = a * L^b$	$N_{t+1}=N_t * exp(-(M_t + F_t))$	$S = 1/(1+exp(a*(L_{50}-L)))$
Parameter estimates	$L_\infty = 28$ cm $K = 0.2$ year^{-1} $t_o = -0.81$ years	a = 6.09E-05 kg/cm b = 2.76	M = 0.1 year^{-1} F = 0.13 – 0.18 year^{-1}	Net: a = 0.822 L_{50} = 13.13 cm Market: a = 0.3 L_{50} = 18.15 cm

Options to address growth overfishing of redfish

Growth overfishing of redfish can be overcome by catching fish at a larger size. The situation would be significantly improved if, as a first step, fish were caught at a size more suitable to the fresh fish market (ie. > 18cm – not the small fish that can be used in the surimi market). Not only would this improve the yield, it would also stop the significant wastage of the redfish resource that is currently occurring (last year 40% of the redfish catch was discarded). Ultimately, it would be good if catches of fish < 20cm could be minimised.

Given that the mortality of redfish once they are landed on the deck is likely to be high, the most obvious solution is to improve the selectivity of the nets so they don't catch as many of the smaller fish. Using the trouser trawl experiments conducted in the recent gear modification project, we were able to compare the size of fish captured in different mesh codends. Due to their shape, redfish escape best through diamond codend (rather than square mesh codend). Use of a 102 mm (4") diamond codend improved the redfish selectivity, but the best redfish selectivity for fish >20cm was obtained using 110 mm (4½ "). The graphs below show that using 110mm diamond codend will result in a large drop in catch of small fish that would generally be discarded without impacting greatly on the catch of redfish >20cm.



The problem is that use of the 110 mm diamond mesh during general market fishing will result in significant initial loss of catches of a number of other species (ie not just the small redfish will be lost). Although this initial loss will result in improved yields to fishers in the longer term, there is no doubt that it will reduce the income of fishers in the short term (maybe by 10-15%).

During shots specifically targeting redfish, however, use of 110mm mesh could be very appropriate. The catch of small <18cm fish would nearly be eradicated, such that minimal sorting of the catch would need to take place and the quality of the retained fish would be better (due to less crushing in the codend and lower sorting times).

Industry has indicated that when targeting redfish they often work more over "slabby" ground and therefore use larger bottom gear (7 – 9″ rubber discs). Such gear is not designed to catch many of the demersal fish species but fishes higher to catch the schools of redfish. Because of this, it would be possible for industry to use larger diamond mesh without incurring any significant losses (other than the loss of small redfish). Ultimately this would prove beneficial to the yields obtained from the redfish resource and could also have benefits for the reproductive capacity of the redfish stocks.

Recommendations

- Industry considers a voluntary adoption of larger diamond mesh when they are using the bigger gear to target redfish.
- The voluntary adoption could be phased in over a six month period as codends need to be replaced
- This could be a two step process: first going to 4″ and then 4½″.

Industry uptake of modified gear to reduce bycatch and discarding

Summary of recent logbook data

Uptake of modified gear
(Otter board – SET, VIT, ECD, STR, GAB)

- 2003/04
- Total number of vessels 95
- No. using modified codends 58

- 60% vessels using modified codends

Uptake of modified gear
(Otter board – SET, VIT, ECD, STR, GAB)

- 2003/04
- Total number of shots 40,000
- Shots without codend info 8,000
- Shots with modified codends 15,000

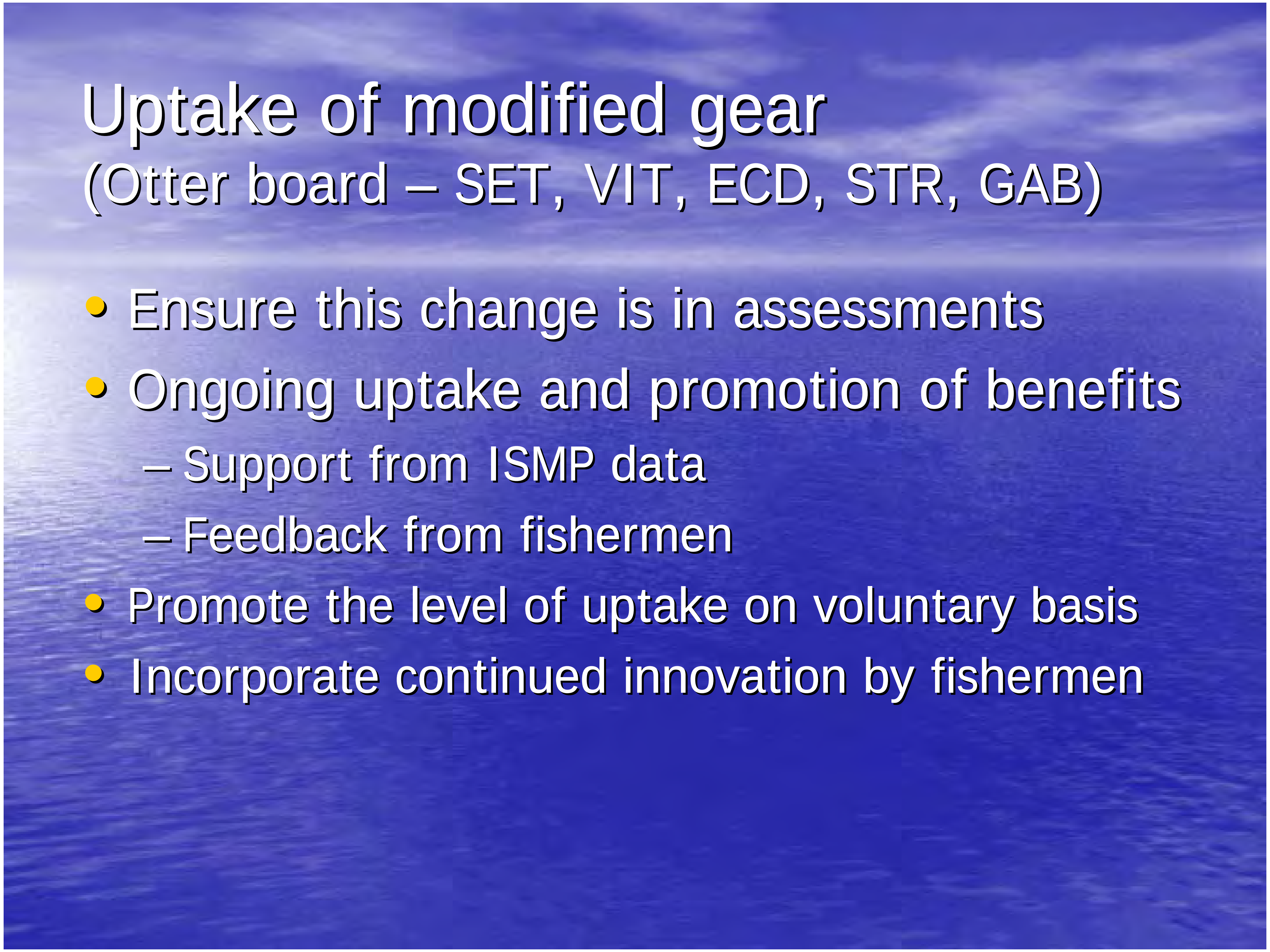
- Approx 50% shots using modified gear

Uptake of modified gear

(Otter board – SET, VIT, ECD, STR, GAB)

- 2003/04
- Shots with modified codends 15,000
- Shots with larger diamond 14,855
- Shots with square codend 400

- Most using diamond
- Limit in what can be put on logbooks
  eg. square-mesh panels, panels in extension


Uptake of modified gear
(Otter board – SET, VIT, ECD, STR, GAB)
Ensure this change is in assessments
Ongoing uptake and promotion of benefits
– Support from ISMP data
– Feedback from fishermen
Promote the level of uptake on voluntary basis
Incorporate continued innovation by fishermen

~ REPORT ~

South East Trawl Fishery Stakeholder Education Workshop

……. on the FTV Bluefin, *24th-25th of October 2002.*

SETFIA

SEANET smarter fishing for industry

OCEANWATCH

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

AUSTRALIAN MARITIME COLLEGE

South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin*

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6. **WORKSHOP MEDIA**
7. **ATTACHMENTS**
   - a. **Workshop Evaluation Questionnaire**
   - b. **SETF Extension Report (SeaNet Victoria)**
   - c. **Workshop Video**
     - i. **Current edit available from SeaNet Victoria upon request**
     - ii. **Final edit on CD (.mpeg file) with voice-over will be distributed with the final Workshop Report incorporating questionnaire results**

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South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin*

Fisheries workshop on the *FTV Bluefin* provides a sea-going opportunity for South East Trawl stakeholders

The inaugural South East Trawl Fishery (SETF) Stakeholder Education Workshop on the *FTV Bluefin* was co-hosted by the South East Trawl Fishing Industry Association (SETFIA) and SeaNet on October 24th-25th (2002). Supported by the AMC, Ocean Watch Australia and the FRDC, the offshore workshop departed and returned to the NSW port of Eden. Both government and non-government stakeholder groups involved in the management of the SETF were represented at this first of its kind practical trawl fisheries workshop.

Trawl fishing demonstrations on the AMC's 35m training vessel the *FTV Bluefin* were a highlight of the workshop, allowing stakeholders a first hand view of trawling procedures, fishing gear and the associated catch from a range of trawl grounds around the NSW south coast.

Information delivery was also a feature of the overnight workshop, with industry members and research staff available to present information and offer interpretations to stakeholders regarding trawl nets, gear development, bycatch and industry practices.

Workshop Focus

The two-day duration of this SETF education workshop enabled a number of important and desirable workshop objectives to be addressed. The overnight schedule provided stakeholders with a realistic sea-going experience and valuable information, keeping participants up to date with industry issues and current developments in the fishery.

It was proposed that a workshop on the *FTV Bluefin* would assist stakeholders involved in the SETF management process to further develop their knowledge of trawl operations – similar to that carried out on commercial vessels – and the associated fishing gear and technology used by industry. With SETFIA skippers at hand to offer descriptions of the experimental trawl demonstrations, stakeholders had a unique opportunity to advance their understanding of industry's fishing practices, the equipment used and the environmental interactions associated with trawling.

The progress of SETF research to reduce bycatch by developing modified codends for trawl nets was another major focus of the workshop. Stakeholders were presented with a valuable insight into this research progress, and the advantages and disadvantages associated with using codends constructed from different mesh types.

Modified mesh codends used during the FRDC research project (1998/204) "Maximising yield and reducing discards in the SETF through gear development and evaluation" were available for on-board trawl demonstrations to highlight catch variation associated with gear types. To complement these practical demonstrations fisheries scientist Dr Ian Knuckey was available to present a report from the research project.

The workshop format and activities presented a range of other benefits to stakeholders including opportunities to better understand the fishery, as well as the commercial industry and a number of it's key issues. Participating in 'hands-on' activities on the *FTV Bluefin's* deck, and taking part in group discussions enabled stakeholders to mix with people from industry, research, management and conservation backgrounds while forwarding their ideas and questions.

Workshop participants were also given the opportunity to examine and discuss other equipment on the *FTV Bluefin,* including technology that currently plays an important role in both commercial operations and industry research projects. Specialised echo sounder and seabed mapping equipment, hydro acoustic net sensors and underwater cameras were readily available and used where practicable.

South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin*

Activities on-board the *FTV Bluefin*

The *FTV Bluefin* proved to be an ideal and stable working platform to stage the SETF Stakeholder Education Workshop, comfortably catering for nineteen workshop participants plus the master and crew of the *FTV Bluefin*. The quality of food and accommodation was of a high standard with all stakeholder needs well met, and the professional and friendly nature of the *FTV Bluefin's* master and crew a valuable addition throughout the workshop.

A 5.00am start at the Eden wharf was arranged to ensure time on the *FTV Bluefin* was maximised. Steaming out of Two Fold Bay, stakeholders familiarised with the boat and were briefed on safety requirements while the fishing gear and associated equipment were organised for trawl demonstrations at nearby fishing grounds.

Fishing operations were staged to give stakeholders an indication of catches associated with the use of modified codends. A purpose built 'trouser trawl' with twin codends was employed during demonstrations, enabling the catch from either square mesh, or larger diamond mesh, codends to be simultaneously compared with the catch from an industry standard 90mm diamond mesh codend.

Experimental shots with the 'trouser trawl' were carried out on 6 occasions, covering a minimum trawl depth of 50m on the first day out to a maximum of 370m on the second day. Shots were also conducted during morning, afternoon and night time periods, giving workshop participants a sample of the species caught at different times of day, as well as species caught at different depth ranges.

Catches from standard 90mm diamond mesh codends were compared with catches from 100mm and 110mm diamond mesh, and 100mm square mesh, codends over the duration of the workshop. After hauling the experimental net, catches from each codend were sorted. Fish species were separated into catch bins for an on-deck comparison of selectivity between mesh types.

The *FTV Bluefin's* back deck provided ample room for the catch to be displayed with a large group of people looking on. Workshop participants were able to view the affects of modified mesh on catch levels first hand, with the variation in mesh selectivity for many species – both commercial and non-commercial – clearly evident. While on deck examining the catch, interpretations of mesh selectivity were readily available from industry members and research staff. The presence of this expertise was particularly useful during group discussions, and to offer feedback to questions raised by stakeholders.

In-between experimental trawl shots a series of information sessions were held in the *FTV Bluefin's* mess (dining) area and wheelhouse. Research presentations conducted by Dr Knuckey were accompanied by structured group discussions and informal discussions. Stakeholders had the opportunity to take in a range of information regarding modified mesh research, fish and seal bycatch issues in the fishery, industry practices, fishing gear and technology.

Stakeholders were also given the opportunity to participate in fishing operations, and did so with interest – helping to sort, sample and process the catch. These activities enhanced the on-board experience and added an extra dimension to the workshop. Hands-on involvement on the *FTV Bluefin's* deck generated enthusiasm and thought, which in turn promoted discussion as stakeholders furthered their understanding of both commercial fishing and research operations.

The *FTV Bluefin* docked back in Eden around 3.30pm followed by a debriefing session. General discussions were held regarding the workshop's activities, information provided and the successful aspects of time spent at sea. Stakeholder involvement throughout the workshop was professional and a number of valuable contributions were made throughout the workshop. Also acknowledged for his input was Eden fisherman and SETFIA member, Lachie Marshall, who presented an industry perspective to stakeholders gathered on the evening prior to the *FTV Bluefin's* departure.

South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin*

Workshop Summary and Outcomes

The South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin* provided stakeholders with a rare experience to build on their understanding of the SETF. Opportunities to examine trawl operations and technology were plentiful, and enhanced by the presence of such a diverse range of industry, government and non-government representatives. Stakeholders offered their thoughts and questions constructively during the research presentations, group discussions and trawling activities, adding to the overall transfer of information.

The presence of industry members was invaluable to the workshop's success. With practical trawl demonstrations at hand, the workshop was an ideal platform for stakeholders to tap into the knowledge of SETFIA's skippers – learning about operations, gear design and how trawl nets interacts with the marine environment.

Trawl demonstrations with modified codends tied in directly with the research information presented by Dr Knuckey. Workshop participants agreed the practical examples of how different codend mesh configurations affect catch rates facilitated their understanding of research in this area and the outcomes to date.

Other potential advantages from the workshop include flow on effects to the administration of the SETF. The increased knowledge and capacity of key stakeholders, provided by the workshop, can no doubt enhance involvement in the fishery's management and decision-making processes.

One of the major outcomes resulting from the workshop has been the consolidation of commitment from industry and key stakeholder to pursue an acceptable resolution to minimising seal interactions and the incidental capture of seals during fishing operations in the SETF. Progressive discussions were held between industry members and stakeholders on-board the *FTV Bluefin*. The incidence of seal interactions with SETF trawlers, and industry's perception of the issue were put forward, along with references from data collected by the Integrated Scientific Monitoring Program. These discussions have been a catalyst to furthering involvement from industry and key stakeholder organisations in the form of a co-ordinated approach to the issue. Currently, a working group is holding dialogue with relevant agencies, seeking support and input to assist in identifying appropriate solutions for the fishery.

A feedback questionnaire, designed to capture the workshop's successes and its potential benefits to the fishery, is provided with this report. The initial positive feedback from workshop participants has been acknowledged, and with the assistance of a formal response through the questionnaire, it is hoped opportunities can be identified for stakeholders to access this type of information through a similar workshop in the future.

South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin*

FURTHER INFORMATION RELEVANT THE WORKSHOP & SETF

SETF Research & Report References

- **Research Report** (FRDC project 1998/204): "Maximising yield and reducing discards in the South East Trawl Fishery through gear development and evaluation."
  - **Contact:** Ian Knuckey (Fishwell Consulting)

- **Research Extension Material** (FRDC project 1998/204):
    - Research Project Video "NETWORKING" (produced August 2002)
    - Research Project "NETWORKING" Newsletters (2000-2001)
  - **Contact:** Ben Leslie (SeaNet Victoria)

- **Current Research & Extension** (FRDC project 2001/006): "Promoting Industry Uptake of Gear Modifications to Reduce Bycatch in the South East Trawl Fishery".
  - **Contact:** Ian Knuckey (Fishwell Consulting); Ben Leslie (SeaNet Victoria) or Terry Walker (Marine & Freshwater Resources Institute)

- **Integrated Scientific Monitoring Program** (South East Fishery on-board and port-based sampling program): Program Annual Reports
  - **Contact:** Ian Knuckey (Fishwell Consulting) or Sonia Talman (Marine & Freshwater Resources Institute)

- **Current Research** (FRDC project 2001/008): "Assessment of seal fishery interactions in the South East Trawl Fishery (SETF) and the development of fishing practices and seal exclusion devices (SEDs) in the winter blue grenadier fishery to mitigate seal bycatch by SETF trawlers".
  - **Contact:** Richard Tilzey (Bureau of Rural Sciences)

Other Relevant SETF Resources

- **Fishery Status Reports 2000-2001** (Bureau of Rural Sciences)
- **Non-Target Species in Australia's Commonwealth Fisheries: A Critical Review** (Bureau of Rural Sciences, 1999)
- **South East Trawl Management Advisory Committee – Chair Summaries** (Australian Fisheries Management Authority Website)

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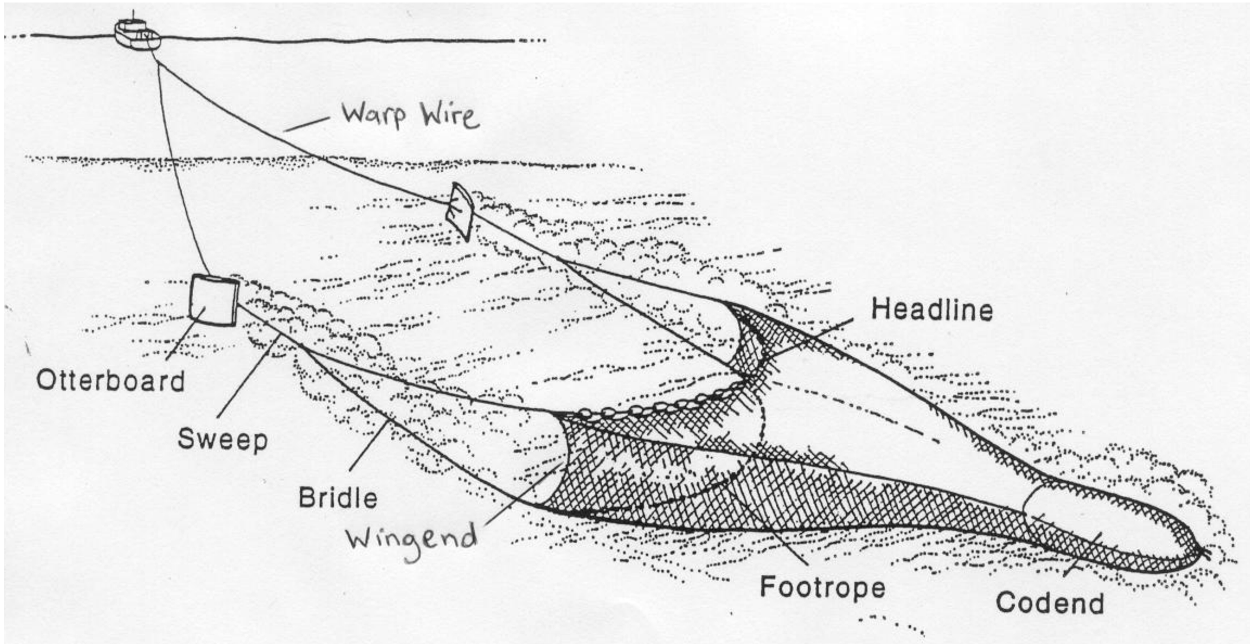
South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin*

DEMERSAL TRAWL NETS, TECHNOLOGY & RESEARCH EQUIPMENT



Reproduced from King, M. 1995: Fisheries Biology, Assessment & Management (Fishing News Books)

FIGURE 1. Diagram of a demersal trawl net

Acoustic net sensors play an important role in both commercial fishing operations and research projects. Sensor readings give skippers a real time indication of the performance of their trawl nets. This increased awareness assists with gear development, and allows skippers to place nets in the desired position with a greater degree of confidence.

Acoustic Net Sensors are used to quantify net performance, and are typically placed:

- Attached to the headline to indicate headline height (vertical opening)
- Attached to both wingends to indicate wingend spread (horizontal opening)
- Attached to both otterboards to indicate otterboard spread

Underwater video cameras are a valuable asset to trawl research operations – as highlighted by successes in recent research to modify trawl gear and reduce bycatch in the SETF. Video cameras attached to trawl nets give an excellent indication of fish behaviour and trawl gear selectivity.

Underwater video cameras, used to capture images of fish and net behaviour, net selectivity and other environmental interactions, are typically placed:

- Attached to the headline, looking down and focused on the footrope area
- Attached to the codend upper panel (either inside or outside the net), looking back and focused on the codend area
- Attached to the lower wingend (inside the net), and looking forward focused on the footrope area

South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin*

STAKEHOLDER CONTACTS LIST

CONTACT	PHONE	MOBILE	Email
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National Oceans Office			
Veronica Sakell (Director)	03 6221 5050		veronica.sakell@oceans.gov.au
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Australian Marine Conservation Society / Marine & Coastal Community Network (NSW)			
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Ian Knuckey (Research Scientist)	03 5258 4399	0408 581 599	fishwell@datafast.net.au
South East Trawl Fishing Industry Association			
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Gail Richey (Executive Officer)	03 6428 7766	0418 620 018	trawline@tassie.net.au
Fritz Drenkhahn (SETMAC Industry Member – Eden)		0428 363 738	drenkhan@acr.net.au
Anthony Jubb (SETMAC Industry Member – Bermagui)		0407 260 006	kendon@acr.net.au
Fisheries Research & Development Corporation			
Kylie Paulsen (Communication Manager – R&D Extension)	02 6285 0415		kylie.paulsen@frdc.com.au
SeaNet Victoria			
Ben Leslie (SeaNet Extension Officer)	03 9824 0744	0413 949 562	seanet@siv.com.au
SeaNet (National Office – www.oceanwatch.org.au)			
Nicole Middleton (Program Manager)	02 9552 3181	0409 719 278	nicole@oceanwatch.org.au

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South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin*

WORKSHOP PHOTOGRAPHS

Courtesy: Dianna Watkins, Craig Bohm & Rob Ferguson

South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin*

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South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin*

**If you are interested in obtaining copies of photographs taken at the workshop contact SeaNet Victoria*

South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin*

WORKSHOP MEDIA

The Magnet (Editorial, Eden Newspaper – Thursday, October 24th 2002)

•Ian Towers (AFMA), Terry Moran (South East Trawl Fishing Industry Association - SETFIA), Jonathon Barrington (DAFF), Ben Leslie (SeaNet), Ian Knuckey (Research Scientist), Margaret Tailby (EA), Fritz Drenkhahn (SETFIA), Victoria Wilkinson (EA), Dianna Watkins (NSW Fisheries), Neil Ward (NSW Trawling Management Committee), Sonia Talman (MAFRI), Rob Ferguson (EA), Katherine Short (Worldwide Fund for Nature), Mark Flannagan (EA), Andrew Hogg (MAFRI) and Craig Bohm (Marine and Coastal Community Network).

Fisheries workshop held

Eden hosted an environmental fisheries workshop on the weekend, including key players from State and Commonwealth government agencies and conservation groups involved in fisheries management.

The workshop was a collaborative project between SeaNet, an environmental extension service for the commercial fishing industry, the Australian Maritime College (AMC), and fishers from the South East Trawl Fishing Industry Association (SETFIA).

It was aimed at bringing together stakeholders from the south east trawl fishery together to learn more about the operations and practices of the fishery.

According to Seanet Extension Officer, Ben Leslie, the overnight workshop aboard the FTV Bluefin was a success in allowing all participants the opportunity to see first hand the impact that fisheries administration had on the actual operators.

He said it also helped participants to understand the needs and concerns of operators at the grass roots level.

"It's all about getting people out of the boardroom, and into the area where the legislation and changes in industry administration actually take effect," Mr Leslie said.

A focus was the issue of by-catch, and recent research into catch selectivity, which has been predicted to have a major impact on the industry, both environmentally and commercially.

Along with representatives from SETFIA, the Department of Agriculture, Fisheries and Forestry, and Environment Australia, the workshop also involved Eden skipper and vessel owner Fritz Drenkhahn.

As well as being an industry member on the South East Trawl Management Advisory Committee (SETMAC), Fritz was able to provide valuable local knowledge during the workshop trawl operations.

SeaNet programs such as this one are funded by the National Heritage Trust and administered by Ocean Watch Australia.

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South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin*

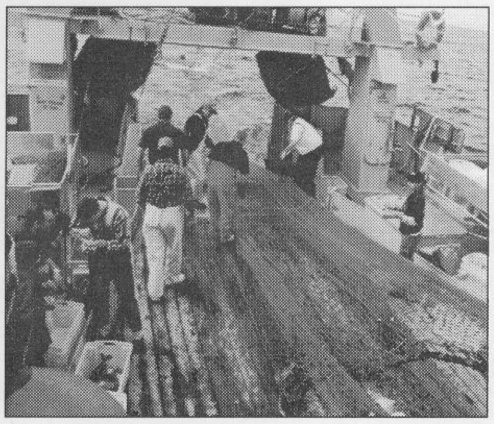
Seafood Industry Victoria Newsletter (November 2002)

SIV News 3

SEANET VICTORIA

South East Trawl Stakeholders Head Offshore for Inaugural Fisheries Workshop

In October, the South East Trawl Fishing Industry Association (SETFIA) and SeaNet co-hosted a range of government and non-government stakeholders involved with the management of the South East Trawl Fishery (SETF) at the very first of its kind, 'hands on' fisheries workshop. This initiative provided stakeholders with the opportunity to view first hand trawl fishing operations within the fishery, including practical demonstrations of the modified nets tested during the recent FRDC* funded research project 98/204: "Maximising yield and reducing discards in the South East Trawl Fishery through gear development and evaluation".



Photography by Craig Bohm (MCCN)

The workshop, supported by the Australian Maritime College (AMC), Ocean Watch Australia and the FRDC*, gave participants a sea-going perspective of the commercial trawl industry and it's fishing operations during the two day education and information workshop on board the AMC's 35m training vessel *FTV Bluefin.* Practical trawl fishing demonstrations and information sessions were conducted off the NSW south coast, with the *FTV Bluefin* departing and returning to the port of Eden.

An overview of the research conducted on modified mesh codends – designed to minimise the catch of small non-target species – was presented to workshop participants by fisheries researcher Dr Ian Knuckey. Stakeholders were able to see the modified fishing gear in practice by way of a number of experimental trawl shots, which demonstrated how the use of different mesh types will result in a distinct variation in the catches bought on board. SETFIA members Terry Moran, Fritz Drenkhahn and Anthony Jubb were present to elaborate on industry's experience in using various types of trawl gear, general commercial operations and the advantages and disadvantages encountered when using modified mesh and other gear modifications. Prior to departure, Eden fisherman Lachie Marshall also provided participants with a broader industry perspective on SETF business operations and other requirements for commercial fishers.

SeaNet, a national environmental commercial fisheries extension service, played a key role in bringing together this diverse range of stakeholders for industry's first partnership-based seagoing workshop. Ben Leslie, SeaNet Officer for Victoria, was impressed with the level of interaction and commitment demonstrated by all participants: "It was a new experience for stakeholders from government and non-government agencies, including Environment Australia, AFFA*, AFMA*, NSW Fisheries, the World Wide Fund for Nature and the AMCS*, who all got together on the back deck of a fishing vessel, examining the catch and discussing the activity of trawl fishing and gear selectivity with industry members and research staff."

A feedback questionnaire is being tabled by SeaNet to identify the successful components of the workshop and possible improvements for similar exercises in the future. Stakeholders were comfortable moving about the *FTV Bluefin*, and expressed strong support for this type of workshop to happen again, placing a high value on the opportunity to experience conditions at sea and to gain a better understanding of industry issues, research projects and new technology.

*FRDC (Fisheries Research and Development Corporation); *AFFA (Dept. of Agriculture, Fisheries and Forestry – Australia); *AFMA (Australian Fisheries Management Authority); *AMCS Australian Marine Conservation Society)

SeaNet has just received 2003 funding from the Natural Heritage Trust to assist commercial fishing industry operators to achieve environmental best practice. SeaNet will be focusing on working with fishers interested in improving fishing gear and methods to minimise environmental impacts. SeaNet will also continue to assist fishers developing codes of conduct and environmental management plans – ideal tools for managing and promoting environmental achievements.

For further information contact Ben Leslie at SeaNet Victoria. Call the SIV office (03 9824 0744), 0413 949 562 or email seanet@siv.com.au

Fishing Industry Advisory Group

Marine Safety Victoria has established an advisory group known as the Fishing Industry Advisory Group (FISAG).

Industry is represented by John Sealey, Rod McDonald, Bill Cull, Peter Clarke and Ross McGowan.

The most recent meeting covered a broad range of issues and opportunities including:

- Pre-sea deckhand training
- Workplace safety – development of industry code of practise
- Slipway availability
- Water police
- Coast Radio Melbourne

If further details are required, please give Ross a call at the SIV Office.

SETF Stakeholder Education Workshop (24th-25th Oct. 2002)

Evaluation Questionnaire

It would be appreciated if you could honestly offer feedback on the following topics…..

Pre Workshop Organisation & Communication	**Rating [0 = No, 'poor' / 5 = Yes, 'good']**					
Generally speaking, was the pre workshop communication and information adequate?	**0**	**1**	**2**	**3**	**4**	**5**
Was information/communication delivered in a timely manner?	**0**	**1**	**2**	**3**	**4**	**5**
Were you sufficiently informed of workshop arrangements and important information before the *FTV Bluefin* departed Eden?	**0**	**1**	**2**	**3**	**4**	**5**
Comments:						
FTV Bluefin						
Was the catering on board the *FTV Bluefin* sufficient for your needs?	**0**	**1**	**2**	**3**	**4**	**5**
Was the *FTV Bluefin's* accommodation acceptable for your needs?	**0**	**1**	**2**	**3**	**4**	**5**
Did seasickness inhibit you from participating in workshop activities?	**0**	**1**	**2**	**3**	**4**	**5**
Comments:						

Workshop Activities	**Rating [0 = No, 'poor' / 5 = Yes, 'good']**					
Did the workshop improve your understanding of commercial trawl fishing operations?	**0**	**1**	**2**	**3**	**4**	**5**
Comments:						
Did the workshop give you a better understanding of commercial trawl fishing operators?	**0**	**1**	**2**	**3**	**4**	**5**
Comments:						
Did the workshop improve your understanding of fishing gear used in commercial trawl operations?	**0**	**1**	**2**	**3**	**4**	**5**
Comments:						
Did the workshop provide you with a better understanding of bycatch issues in the fishery?	**0**	**1**	**2**	**3**	**4**	**5**
Comments:						
Did the workshop improve your understanding of technology used in research and commercial trawl fishing operations?	**0**	**1**	**2**	**3**	**4**	**5**
Comments:						
Did the workshop improve your understanding of potential affects if modified trawl gear is introduced to commercial trawl operations?	**0**	**1**	**2**	**3**	**4**	**5**
Comments:						
Did you find the onboard research presentations useful and informative?	**0**	**1**	**2**	**3**	**4**	**5**
Comments:						
Did the workshop provide you with the opportunity to mix with other SETF stakeholders?	**0**	**1**	**2**	**3**	**4**	**5**
Comments:						

1

SETF Stakeholder Education Workshop (24th-25th Oct. 2002)

Workshop Recommendations	**Rating [0 = No, 'poor' / 5 = Yes, 'good']**					
Was the duration and overnight format well suited to the workshop?	**0**	**1**	**2**	**3**	**4**	**5**
Comment:						
What other types of trawl industry information would be valuable to stakeholders in this type of workshop?						
Relevant to your position, do you see value in this type of practical fisheries workshop?	**0**	**1**	**2**	**3**	**4**	**5**
Comment:						
Are there other staff members in your organisation who would benefit from this or similar workshops being run again?	**No**			**Yes**		
How Many?						
Would you recommend running a future workshop?	**No**			**Yes**		
If so, provide 3 ideas about how the workshop could be improved:						
Do you support the idea of stakeholders contributing/presenting relevant information during future workshops?	**0**	**1**	**2**	**3**	**4**	**5**
Comment:						
Which aspect of the workshop did you personally find the most valuable?						
Do you see that these communication activities are important in contributing to effective fisheries management?	**0**	**1**	**2**	**3**	**4**	**5**
Comment:						
Will your attendance at the workshop influence the way you work with Industry in your current position?	**0**	**1**	**2**	**3**	**4**	**5**
How?						
Did this workshop increase your understanding of the role SeaNet plays within the fishing industry?	**0**	**1**	**2**	**3**	**4**	**5**
Comment:						
Other Comments:						

****Please return to SeaNet Victoria by December 19th**
Suggestion – Print copy, fill it in and return to SeaNet via FAX (03 9824 0755). Thankyou

ORGANISATION: ____________________

POSITION: ____________________

NAME: ____________________

A summary of the questionnaire results will be included in the final workshop report early in the New Year. Thankyou for your assistance.

2

South East Trawl Fishery

The significant progress in the South East Trawl Fishery (SETF) regarding gear development and bycatch reduction research has been, and will continue to be, a key focus of extension activities in the fishery over the next 12 months. Extension will be channelled through a Fisheries Research and Development Corporation (FRDC) funded extension project (2001/006), and supported by the SeaNet Program.

FV Shelly H

A video summary of gear development research, produced by SeaNet and the Marine and Freshwater Resources Institute, was distributed to a wide audience in September. This extension work has played a key role in raising the awareness of SETF stakeholders and vessel operators, highlighting options for bycatch reduction and the predicted benefits for industry. SeaNet Victoria will continue to be involved in this extension, with work based around consultation with industry, further gear testing and promoting the use of modified codends.

The South East Trawl Fishery Stakeholder Education Workshop on the *FTV Bluefin* (October 2002), organised and co-hosted by SeaNet, Ocean Watch and the South East Trawl Fishing Industry Association (SETFIA) has been another major extension exercise in the SETF (see following article). A report is being finalised to incorporate stakeholder input and highlight the benefits and major outcomes from the workshop – hopefully there will be opportunities for a similar exercise in the future.

SET stakeholders hit the high seas

In October, SeaNet and the South East Trawl Fishing Industry Association (SETFIA) co-hosted a range of government and non-government stakeholders – involved with the management of the South East Trawl Fishery (SETF) – for a 'hands-on' practical trawl fisheries workshop in Eden (south coast NSW).

The overnight workshop, supported by Ocean Watch Australia, the Australian Maritime College (AMC), and the Fisheries Research and Development Corporation (FRDC), was conducted at sea on the AMC's 35m fisheries training vessel *FTV Bluefin*.

Workshop participants were presented with opportunities to view experimental trawl fishing operations; examine bycatch reducing modified nets and the associated catches; and discuss industry practices and technology while on the deck of a trawler with SETFIA skippers and SETF research staff.

The benefits of this sea-going workshop were clearly evident, with on-board fisheries scientist Dr Ian Knuckey presenting stakeholders with an overview of current research in maximising yield and reducing discards through gear development and evaluation.

Stakeholders were able to compare catches from industry standard condends and modified codends on the Bluefin deck.

Different gear was used to enable catch comparisons between standard and modified codends to be displayed on the *FTV Bluefin's* deck – giving stakeholders the opportunity to develop their understanding of the affects modified codends can have on commercial trawl operations and bycatch.

An ideal working platform for this extension-type workshop, the FTV Bluefin was well fitted with demersal trawl gear and an extensive array of monitoring equipment.

A variety of other discussion and information sessions were held over the duration of this SeaNet driven workshop initiative. A notable outcome resulting from the workshop has been the increased support and commitment, from both industry and key stakeholders, to further pursue an appropriate resolution regarding seal interactions with commercial vessels in the SETF.

This sea-going SETF workshop was an industry first, giving stakeholders an opportunity to rub shoulders in a practical environment with industry members and researchers while getting up-close to fishing gear, trawl catches and technology used in both commercial and research operations.

A favourable response from all workshop participants, acknowledging the potential benefits to individuals involved and the industry as a whole, has left the door open for similar extension based workshops to be held in the future.

If you would like more information about the outcomes of this workshop contact Ben Leslie on seanet@siv.com.au or 0413 949 562

SEANET NEWS *MAY 2003*

SET NETS CONTINUE TO CUT THE UNWANTED CATCH

New designs and modified trawl nets are continuing to offer skippers in the South East Trawl (SETF) a cleaner commercial haul by excluding the small and unwanted fish sometimes caught in fishing operations. Trawl skippers are using modified nets to significantly reduce their unwanted 'bycatch', while benefiting from improved catch quality and fuel efficiency, plus shorter catch sorting times.

Industry leaders working out of Victoria's Portland and South Australia's Beachport have adopted these modified nets, enabling them to reduce environmental impacts on non-target fish stocks. When rigging trawl nets to minimise unwanted catch, skippers are taking into account the intended area to be fished, and the species likely to be encountered. The positive reaction from skippers using this gear is a clear indication of recent developments where industry, researchers and net makers have been working hard to improve the efficiency of trawl gear and the benefits are really starting to show.

FV Zeehaan preparing a 100mm diamond mesh codend for trawling operations in the Portland area.

These improved gear options are giving both fishers and the wider community a boost in confidence, knowing that good quality seafood is being provided, whilst industry is striving to preserve the integrity of fisheries ecosystems. Preferred gear designs include a 'balloon trawl', developed and patented by NetworkTN, a local net maker in Portland. High water flow rates are a defining characteristic of these nets, allowing many small and unwanted fish to pass through the net. This is a huge advantage to skippers working in areas with a diverse range of fish species.

In Beachport, trawl skippers are also fishing with square mesh and larger diamond mesh in their codends, further improving flow rates and reducing bycatch. The Fisheries Research and Development Corporation (FRDC) has provided a range of these modified codends to SETF operators over the last 12 months, as part of it's substantial contribution to reducing the effects of fishing on small non-target fish species. Further FRDC funding has been allocated to install underwater cameras on modified commercial trawl nets over the coming months.

Andrew Hogg, a MAFRI field scientist will be working with industry to further highlight positive net design features, including the effectiveness of square mesh panels in allowing small fish to escape. This investment will provide fishers with improved certainty over net design, and greater confidence when determining the most suitable gear for their operations. Please contact Ben Leslie, SeaNet Victoria on 0413 949 562 for further information on modified trawl gear u

Victoria - South East Trawl Bycatch Reduction

Reducing discards and bycatch in the South East Trawl Fishery is the aim of an FRDC funded extension project. Bycatch is the portion of the catch that is taken by the trawl gear but is discarded back into the sea due to being inappropriate for market. Bycatch in the fishery varies greatly making consistent solutions to the issue difficult to promote. Conditions in the fishery also vary by season, locality, gear configuration and target species.

Square mesh panels in a codend.

Modifications to trawl gear codends has been identified as a means to reduce the incidental capture of small and unwanted fish. The project seeks to gain the support of fishers in adopting and further developing modifications that are tailored to specific circumstances and conditions within the fishery.

The skills of fishers are sought to improve the effectiveness of the modifications through trials and feedback that can be shared amongst other participants. By providing the means to trial and improve existing gear, the project allows fishers flexibility to adapt the ideas to their particular operations.

Gear modifications include the use of larger than standard mesh codends or alternative mesh configurations. Larger meshes simply provide bigger spaces through which small fish can escape.

The other trend is to orientate the meshes of the codend, or part of the codend, so that they remain open while fishing in a square mesh, rather than a diamond mesh configuration. This method also results in small fish being able to escape rather than being hauled to the surface.

Modified codends are currently being constructed or are already in use by vessels in Portland, Lakes Entrance and Eden. The knowledge and experience of local netmakers is valuable in tailoring modifications to suit local conditions. Trials have also been planned for a vessel based in Ulladulla and SeaNet officer Jim Newman will assist local fishermen to adapt the gear to their operations.

Jim is providing a distribution and feedback focal point for interested fishers to obtain codends through local suppliers. For more information contact Jim Newman on (03) 9824 0744 or

Darren 'Wombat' Laidlaw, FV Ben Boyd from Eden, currently using a codend with square mesh panels.

South East Trawl Fishery Bycatch Reduction

SeaNet Victoria is continuing work with fishers in the South-East Trawl Fishery on reducing bycatch. This work is part of the FRDC funded project *FRDC 2001/006 Promoting industry uptake of gear modifications to reduce bycatch in the South-East and Great Australian Bight Trawl Fisheries.*

This project is facilitating the uptake of modified codends that reduce the bycatch of small fish, by promoting the benefits of reduced bycatch levels and assisting fishers to adopt larger mesh and square-mesh codends in their operations. Recent figures from logbooks suggest that about 40% of vessels in the fishery, contributing up to 60% of all fishing 'shots', are using modified codends of some description (AFMA Logbooks).

The majority of these vessels are using diamond mesh codends larger than the 90mm legal minimum. The larger meshes enable small non-commercial fish and juvenile commercial fish to swim through the codend and escape the net, thereby reducing the amount of small fish retained. The fishers benefit by retaining larger, better quality fish and reducing the amount of deck work necessary to sort the catch.

The use of square-mesh panels is also being adopted, though this method requires considerable experimentation to adapt the concept to the practices and gear of individual vessels. This approach is based on the principle that meshes are oriented to stay more open during the trawl, presenting an opportunity for smaller fish to escape. This method, however, presents some difficulties in locating the panel in the best position, difficult installation, and some wastage of materials. Fishers and netmakers have worked out some good solutions to these issues such as the rotated mesh concept.

Fishers have found that the benefits of square mesh can be achieved, while sidestepping the issues of awkward codend weight distribution, material wastage and difficult installation associated with square mesh. To achieve this, they have removed a panel of meshes from a diamond mesh codend, and stitched the same piece back into the gap, orientated across the lay of the rest of the codend. This panel is cut an appropriate size as extra meshes are needed lengthways to compensate for the resistance of the net material to stretch this way.

The result is a panel of meshes that are held open by the structure of the rest of the codend, but do not stretch in an awkward manner when bearing weight. These panels are easy to install and do not result in the waste of trimmed materials. This method is being deployed on a number of vessels to test it s value in the fishery . One of the recent benefit s of this modification is that it allows small grenadier, currently prevalent in the fishery to escape.

The location of these panels is an important aspect to their success. Fish behaviour studies have shown that dif ferent fish respond to trawl nets in different ways, which has implications for selectivity of trawl gear (Piasente *et. al.* 2004♦). In the codend, fish often show a response to escape through the upper panels, which has resulted in good bycatch reduction when positioning square mesh panels in the upper side of the codend.

A codend with a square-mesh panel to facilitate the escape of small fish. This design may be superseded/ improved upon by the rotated mesh concept being developed.

Fishers are now developing a range of modified gears to reduce the bycatch of small fish that specifically suit their operations and the target fish. Depending on the area or depth in which they are working, a number of different net configurations may be used. Furthermore, by using these modified gears, fishers can achieve better yields from larger, more valuable fish preferred by the markets.

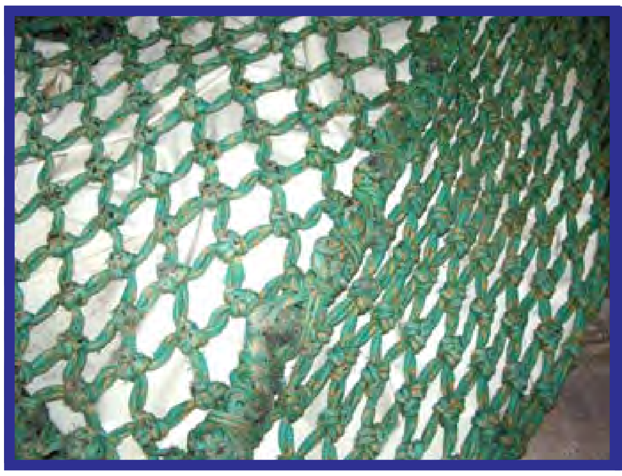
Contact Jim Newman (SeaNet Vic) on: (03) 9824 0744 or email: seanet@siv.com.au.

♦Piasente, M., I.A. Knuckey, S. Eayrs and P.E. McShane (2004). In situ examination of the behaviour of fish in response to demersal trawl nets in an Australian trawl fishery. Marine and Freshwater Research 55(8): 825–835.

South-East and Great Australian Trawl Bycatch Reduction - Update

SeaNet's promotion of industry uptake of modified gear for bycatch reduction (FRDC Project 2001/006) has led to significant interest in the rotated mesh approach, dubbed "T90" by fishing gear technologists.

Feedback from the last edition of SeaNet News revealed a wealth of information about the selective properties of the T90 approach to improving trawl gear selectivity and fish quality (for more information go to www.sintef.dk/ and click the projects icon). This feedback is being used to continue promoting effective bycatch reduction measures in the South-east and Great Australian



Close-up showing a seam where the T90 panel is joined to the codend, note how the meshes are held open.

South-east trawl fishers with a modified T90 panel codend.

Bight Trawl Fisheries by providing industry with the information needed to make bycatch reduction strategies commercially viable.

The project has identified potential benefits of using areas of mesh in nets that are turned 90^{o} (i.e. T90) from their ordinary orientation. This approach was first used in Australia as a means to retain the selectivity benefits of square mesh panels while reducing the waste of net material and making installation easier. The first T90 panels also proved to have better load-bearing characteristics than square mesh panels which would often stretch and distort, becoming ineffective.

In other countries, the T90 approach has been incorporated into the extension part of the codend rather than the 'bag' as trialed in Australia. Early scientific assessments and anecdotal information from industry suggests this approach credits further investigation. More information contact Jim Newman on: (03) 9824 0744 or e-mail: seanet@siv.com.au.

FISHERIES NEWS

South east trawl fishers continue to trial and adopt more selective gears

MODIFIED TRAWL NET DESIGNS ARE CONTINUING TO OFFER BENEFITS TO FISHERS IN THE COMMONWEALTH TRAWL SECTOR OF THE SOUTHERN AND EASTERN SCALEFISH AND SHARK FISHERY THROUGH OPTIMISED QUOTA YIELDS, REDUCED AMOUNTS OF DISCARDS AND CLEANER COMMERCIAL CATCHES.

A project funded through the Australia's Government Fisheries Research and Development Corporation (FRDC) is encouraging the voluntary uptake and trial of some modified net designs.

Over the past few years, various codend (end of trawl net) designs have been trialled against the legally allowed minimum 90mm diamond mesh codends on board commercial vessels in the Western and Northern Zones of the Commonwealth Trawl Sector (South East Trawl).

These trials have found that modifying the mesh designs allows for small or non-target fish species to pass through the net, resulting in better and cleaner catches, with less unwanted catch.

Following on from this success, a project to encourage the voluntary uptake of these modified designs among fishers was embarked on by researchers from the Department of Primary Industries in Victoria.

Various modified codend designs from the earlier trials were constructed and made available to industry to allow fishers to see for themselves the effects of using modified net designs in their fishing operations.

The positive reaction from skippers to initially trial modified gear, and then to voluntarily take up this gear in their fishing operations, is a clear indication of the fishing industry's commitment to work with researchers and net makers to improve the selectivity and efficiency of their trawl gear.

Figures from AFMA's logbooks report the number of vessels using modified codends of some description increased from 43% in 2002 to a very positive 71% in 2004.

Larger meshes

The majority of these vessels have been using larger diamond mesh codends than the 90mm minimum requirement. Larger meshes within the codend increases the selective properties of the gear by allowing a greater opportunity for juvenile commercial fish and non-commercial fish to escape, thereby reducing the amount of small fish retained. The fishers benefit by retaining larger, better quality fish and reducing the amount of time necessary to sort and store catch.

Square meshes

The use of square mesh codends and square mesh panels have also been trialled and adopted in the SETF. Square meshes are designed to provide a greater area of opening in comparison to diamond mesh. A higher flow rate of water through square meshes is another

SET skipper Russell Bradshaw and crew member Allan Delany show the rotated mesh panel codend currently used on the vessel. Photo by Jim Newman, SeaNet.

defining characteristic of these designs, allowing many small and unwanted fish to pass through the net.

Rotated mesh panels

In trialling square mesh panels in codends, it has occurred to netmakers and fishers that the same benefits could be achieved by cutting out a strategically sized panel, rotating the panel 90 degrees, and sewing it back into the codend. This results in a rotated-mesh panel of meshes that are orientated across the lay of the rest of the codend.

The panel is sewn in such a way that the meshes are held open during the trawl presenting an opportunity for escape similar to square-mesh panels. This approach has several advantages including improved load-bearing characteristics, no wastage of net materials and being considerably easier to install than a square mesh panel.

The project is showing that fishers are continuing to develop and trial a range of modified net designs that specifically suit their fishing operations. By using these more selective gears, fishers can achieve better yields from larger, more valuable fish preferred by the markets. Industry should be applauded for their continuing efforts to trial, improve and adopt these gears.

The adoption of more selective gear options should also boost the confidence of the wider community, knowing that while good quality seafood is being provided, the fishing industry is striving to preserve the integrity of fisheries ecosystems.

For further information contact Jim Newman, SeaNet Extension Officer (Victoria) on: (03) 9824 0744, mobile 0413 949 562 or email: seanet@siv.com.au.

SEANET

Installing a rotated-mesh panel in a trawl codend.

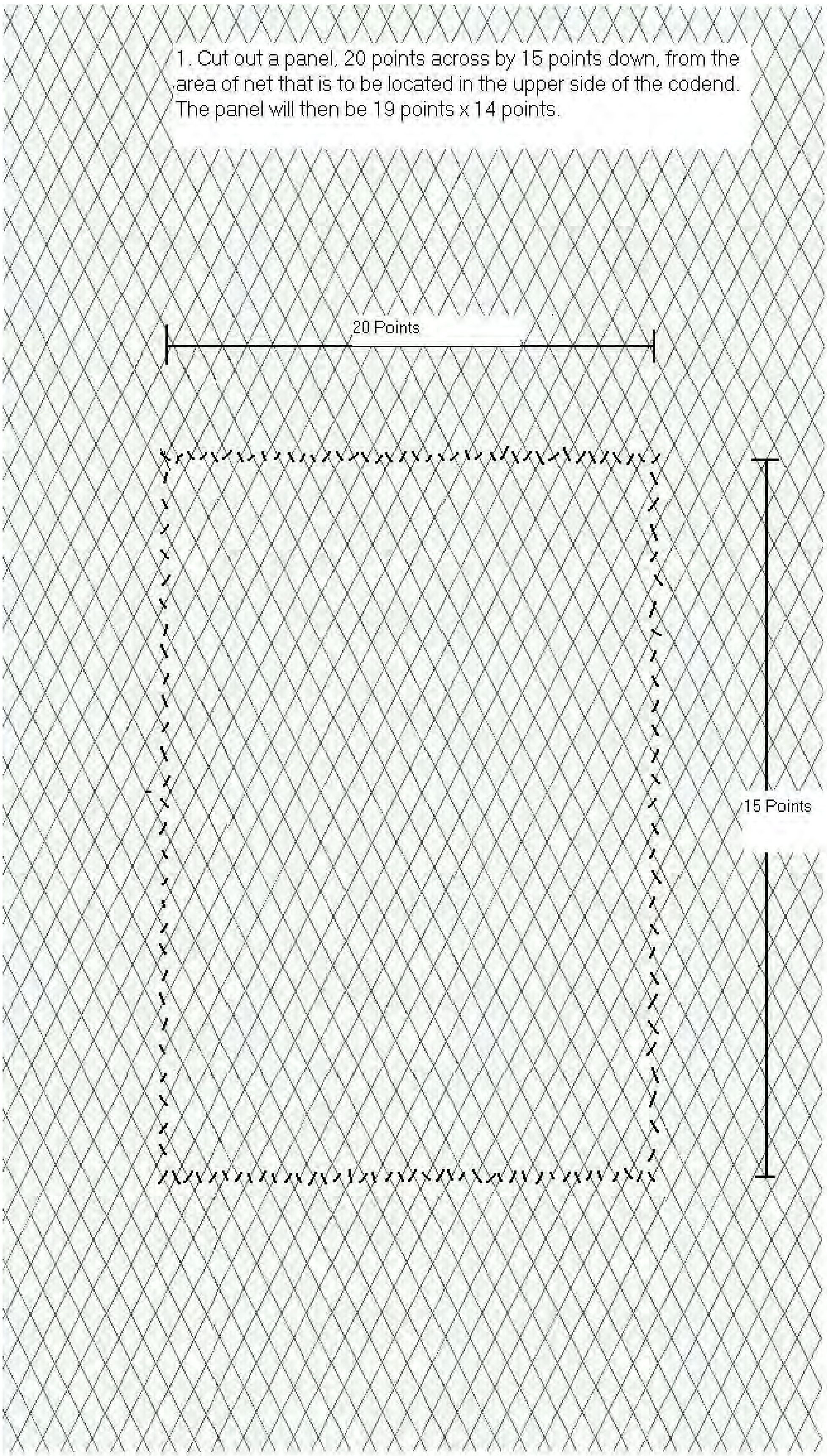
This guide assists fishers to install a panel of rotated-mesh into an ordinary codend. The panel is designed to allow small fish to escape in the same manner that a square mesh panel works. This method achieves that aim of keeping meshes open during the shot, but does not result in material wastage and is not as prone to the stretching and lifting constraints of square mesh. The panel is also easier to install than square mesh.

The panel is located in the upper side of the codend which is the normal pathway for escape for many fish species. In some cases it may be appropriate to install two panels, one in the codend proper and another above the splitter. This is important so that there is still opportunity for small fish to escape once the first panel is 'blocked' by the retained catch.

The following diagram series shows the cut-out, rotating and sewing-in procedure.

Instructions:

1. Cut out a panel, 20 points across by 15 points down, from the area of net that is to be located in the upper side of the codend. The panel will then be 19 points x 14 points.
2. Take the panel out and rotate it 90 degrees so that it is orientated across the lay of the rest of the codend.
3. Replace the panel into the gap. Stretch it against the lay of the codend to fit into the gap.
4. Sew the rotated-mesh panel into the codend. In the diagram example, it is necessary to 'pick up' 5 extra meshes on the top and bottom of the panel. The sides can be laced down as seams, remembering that there are 4 extra meshes in length to account for the reduced stretch of the meshes across the lay.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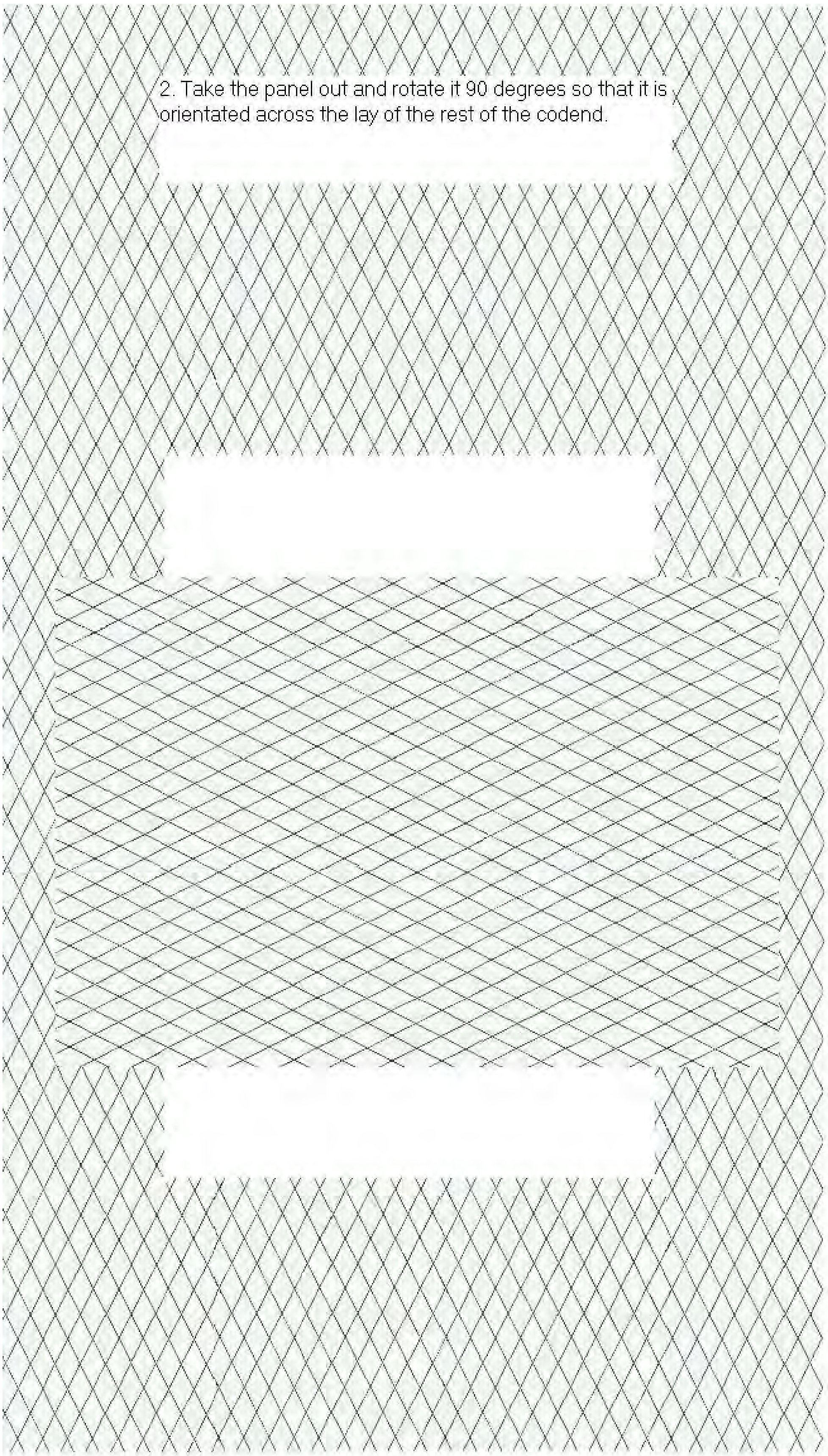
15 Points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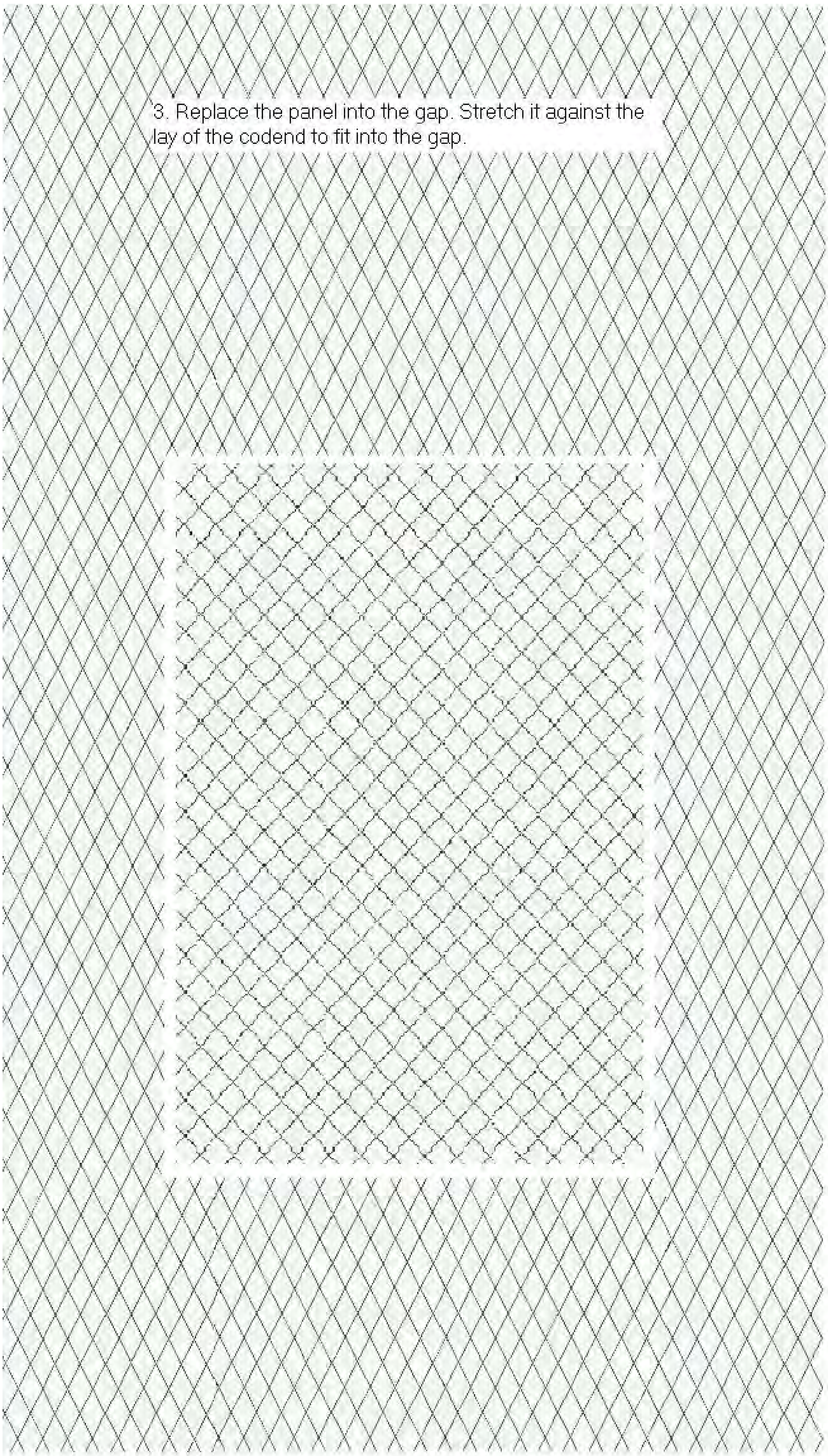
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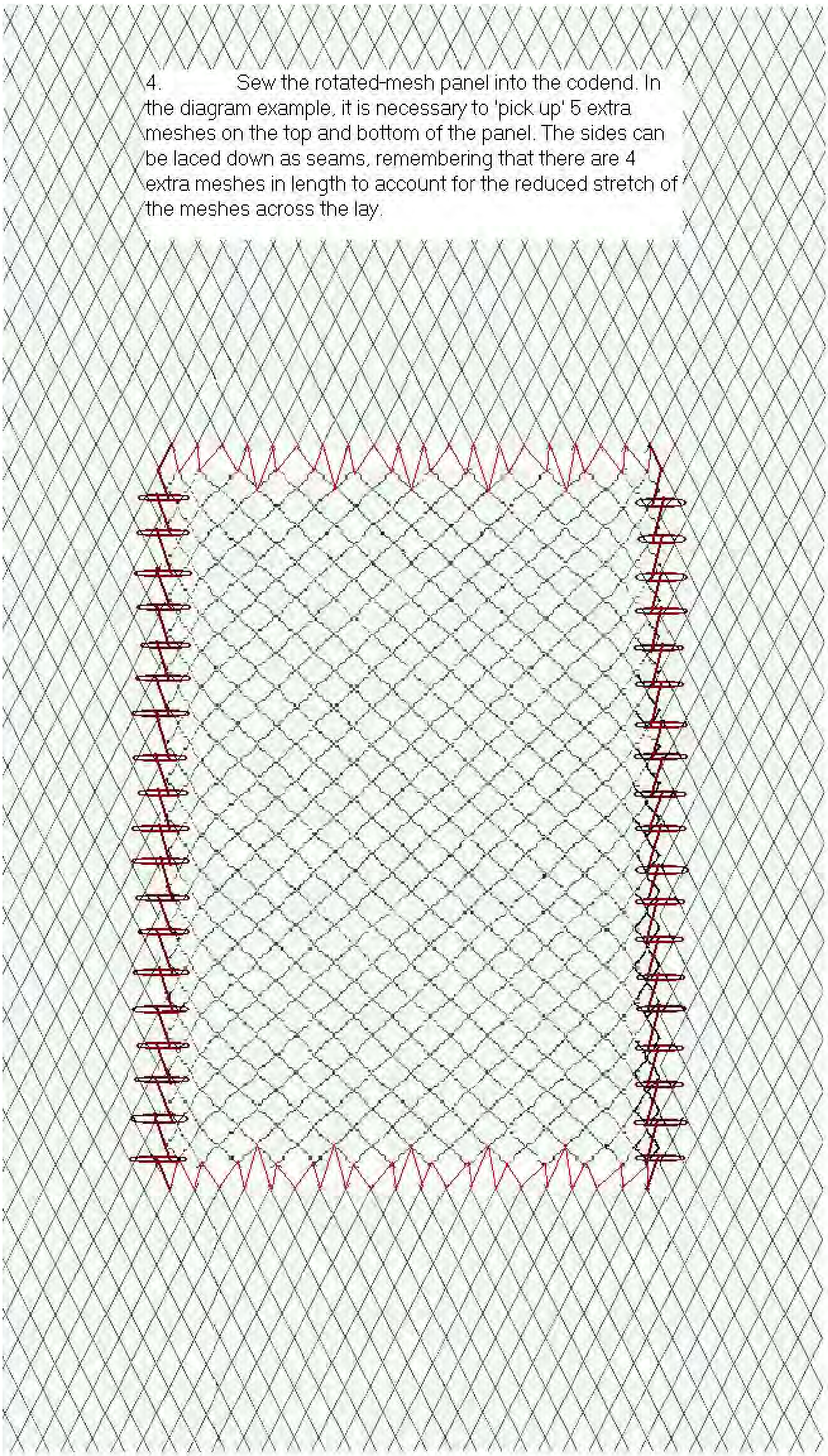
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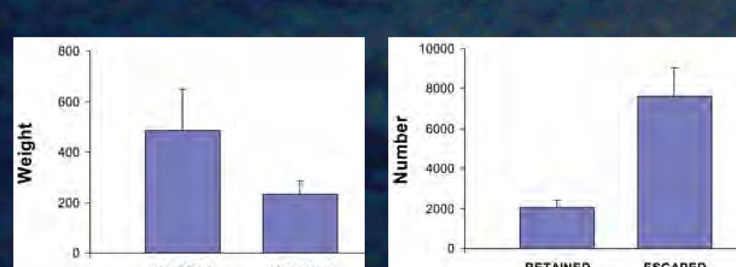
Maximising yields and reducing discards

in the South East Trawl Fishery through gear development and evaluation

FRDC Project 98/204

Cooperation – Scientists and industry assessing selectivity and bycatch

The South East and Great Australian Bight Trawl Fisheries supply much of the local fresh fish to markets in Australia. Some sectors of these fisheries have a significant 'bycatch', which is the unwanted portion of the catch consisting of species for which there is little or no market as well as juvenile commercial fish. These fish are discarded at sea but have a very high mortality rate. Research using a covered codend showed that existing standard gear was already quite selective for target species, but could be improved.



These graphs show the average weight and number of fish that are retained by, or escape from, a standard trawl codend. The results demonstrate that while a standard codend retains most of what is encountered by the trawl by weight, the codend allows a large number of small fish to escape.

Fine mesh codend cover

Measuring and recording catch and bycatch for scientific analysis

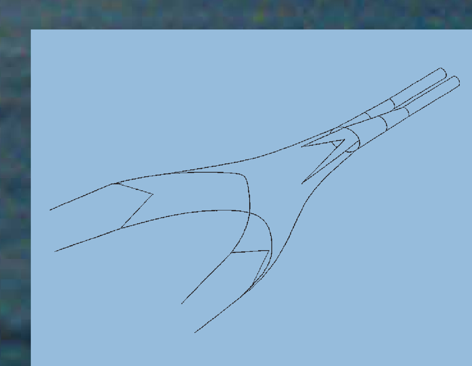
Preparing the underwater camera to be shot away in the trawl

Collaboration – Industry participation to find workable solutions

Reducing the bycatch of small fish is an investment in the future of fish stocks. Selectivity is the capacity of fishing gear to catch a certain type and size of fish. Research explored improvements in codend selectivity to reduce discards of small fish but maintain catches of larger commercially valuable fish. To test selectivity of modified gear types, an experimental trouser trawl was constructed that had two codends. Using this net, the selective properties of new codends could be tested against the industry standard 90mm codend.

This work showed that selectivity could be improved by using larger mesh or square mesh codends but, because of the multi-species nature of the fishery, there was not one simple solution – different modifications suited different parts of the fishery. Significant reductions in the bycatch of small fish could be achieved but it was usually associated with some loss of commercial catch. This loss reduced over time because of the improved yields that could be obtained from larger fish.

The project has also included an investigation of fish behaviour in trawl nets using underwater video. This research provided a reliable understanding of fish responses when they encountered trawl gear, which in turn helps improve the design of bycatch reducing gear.



Design of the Trouser Trawl

Testing a modified codend using theTrouser Trawl

Underwater image of fish escaping from a codend

Australian Government Fisheries Research and Development Corporation
State Government Victoria Department of Primary Industries
fishwell
SETFIA
Australian Government Australian Fisheries Management Authority
SEANET smarter fishing for industry
Sustainable Fishing - Healthy Seafood Seafood Industry Victoria Inc.
CSIRO


Promoting industry uptake of gear modifications
to reduce bycatch in the South-East and Great Australian Bight Trawl Fisheries
FRDC Project 2001/006
Facilitating Change
Promoting research results to the fishing fleet and other stakeholders.
The extension project enables industry members to adapt those lessons learned from research to be incorporated into everyday fishing activities. Making these modifications a commercial reality involves adapting the principles of gear selectivity to individual vessels operations.
Working across the whole industry, development of the modifications is encouraged and facilitated by the fishers own communications networks: netmakers in fishing ports, SeaNet, AFMAs Management Advisory Committees (MACs) and the industry associations South East Trawl Fishing Industry Association (SETFIA) and Great Australian Bight Industry Association (GABIA).
To improve the understanding of bycatch issues amongst other stakeholders, a demonstration trip was arranged on the AMC's research/education vessel Bluefin. This trip from the port of Eden allowed government and NGO stakeholders to view trawl operations and witness the Trouser Trawl testing modified codends.
Progress of the extension project has contributed to the now widespread use of larger codends, as well as the continued development of the square mesh approach.
A codend with a Square mesh panel being readied for sea
A square mesh codend full of fish
Industry members and other stakeholders discussing bycatch on the Bluefin
Continuing Development
Using industry knowledge to continue to seek solutions
Although useful for bycatch reduction, the square mesh codend used in the research project presented logistical problems for industry that inhibited adoption, including considerable wastage of net materials, awkward load bearing characteristics and difficult construction. This was first addressed by reducing the square mesh portion of the gear to a strategically positioned window or panel in the net. This approach was successful but still presented similar issues. Netmakers and some industry members floated the idea of turning the meshes in the panel 90 degrees so that mesh lay across the rest of the codend – dubbed the "rotated mesh". By doing this with a proportioned panel, the benefits of open meshes are retained, but it is easier to construct with no waste and good load bearing characteristics. Further to this idea, feedback from overseas has suggested an entire section of the rotated mesh before the codend improves fish quality, selectivity and water flow. Dubbed the "T90", industry are also investigating its potential in the South East and Great Australian Bight Trawl Fisheries.
Smaller, strategically positioned square mesh windows in a codend under construction
Netmaker constructing gear
The next phase? Crew prepare a T90 extension on a SETF vessel
Australian Government
Fisheries Research and Development Corporation
Department of Primary Industries
Victoria
SETFIA
Australian Government
Australian Fisheries Management Authority
SEANET
Seafood Industry Victoria
CSIRO