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Fisheries Research 40 (1999) 17–27

FISHERIES RESEARCH

The AusTED II, an improved trawl efficiency device 1. Design theories

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Received 30 December 1997; accepted 24 September 1998

Abstract

Improvements to the original AusTED (Australian trawling efficiency device) design were completed in 1994 and the device was renamed AusTED II. New design features, theories and performance of the AusTED II during testing are described. The AusTED II reduced bycatch (including large animals) and slightly reduced byproduct. Variations in prawn catches were dependent on the area being fished. Large fluctuations in net drag precluded any detailed analysis of changes in drag as a result of fitting the AusTED II to standard commercial trawl gear. The AusTED II equipped net required no extra assistance or vigilance from the crew when tested under commercial conditions. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: AusTED II; Bycatch reduction device; Turtle excluder device; Prawn trawling; Fish exclusion

1. Introduction

Capture of non-target species, particularly endangered species, by commercial trawlers is an international concern. The pressure to move towards fishing methods that have a minimal impact on the marine environment means commercial fishing fleets need to reduce bycatch to an acceptable level. Currently, international prawn trawl fisheries have the top nine bycatch rates of all world fisheries (Alverson et al., 1994). The northern Australian prawn trawl fleet ranks third in the world, discarding an average 11.1 kg of bycatch for every 1.0 kg of prawns caught (Alverson et al., 1994).

Catches aboard Australian prawn trawlers can be partitioned into three groups:

- Target catch – animals the fishing operation intends to capture.
- By-product – animals the fishing operation does not intend to capture but can market.
- Bycatch – animals the fishing operation does not intend to capture.

Prawn trawling commenced in Australia's waters in the late 1940s (O'Grady, unpublished, 1955). The trawl gear used evolved as fishers discovered more efficient means of catching prawns. Net design was improved as fishers sought nets that increased catch rates and were easier to work. The user friendliness and longevity of the trawl gear were enhanced as new materials were incorporated into net construction. Multiple rigs (Sainsbury, 1996), soon replaced single nets. When the fishing grounds were thick with jellyfish, some fishers designed devices to minimise the problem. An inclined grid or a soft mesh panel was

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PII: S0165-7836(98)00221-5

placed within the net to separate target catch from jellyfish. These devices, known as blubber shoots, were commonly used by estuarine trawlers (Kendall, 1990; Kennelly et al., 1992). In the late 1970s, devices known as TEDs (turtle excluder devices) were developed to address concerns over capture of sea turtles by trawlers in American fisheries (Watson and Seidel, 1980). Following similar concerns within Australian fisheries in the mid to late 1980s, research agencies investigated the suitability of a number of TEDs to the Australian fisheries (Goeden, unpublished, 1985; Andrew et al., 1993; Robins-Troeger, 1994; Mounsey et al., 1995; Robins-Troeger et al., 1995; Broadhurst and Kennelly, 1996; Broadhurst et al., 1996).

To be acceptable to the industry, TEDs must meet several criteria. They must:

- substantially reduce bycatch;
- maintain catches of target species and by-product;
- be easy and safe to use;
- have a low initial and maintenance cost.

TEDs developed overseas were perceived by Australian fishers to be a hazard to crew and of little benefit to their operations. It was also speculated that a TED from overseas may not suit the conditions encountered within Australia's fisheries. The original AusTED was a compilation of ideas from the US, coupled with innovations making it more suited to Australian conditions. It consisted of five major components and excluded bycatch using both active and passive separation. In testing, the AusTED retained a large percentage of the prawn catch (mean loss 1.38%), showed an 18–55% reduction in non-commercial bycatch, and significant reductions in catch rates of large animals such as stingrays and turtles (Robins-Troeger et al., 1995). Robins-Troeger et al. (1995) concluded that the AusTED had the potential to be developed to suit trawling conditions encountered in Australian prawn fisheries.

With these encouraging results, we aimed to improve the original AusTED by creating a simpler more effective device called the AusTED II.

2. Materials and methods

2.1. Design concepts

The AusTED was developed as a device that had the potential to exclude large animals as well as fish.

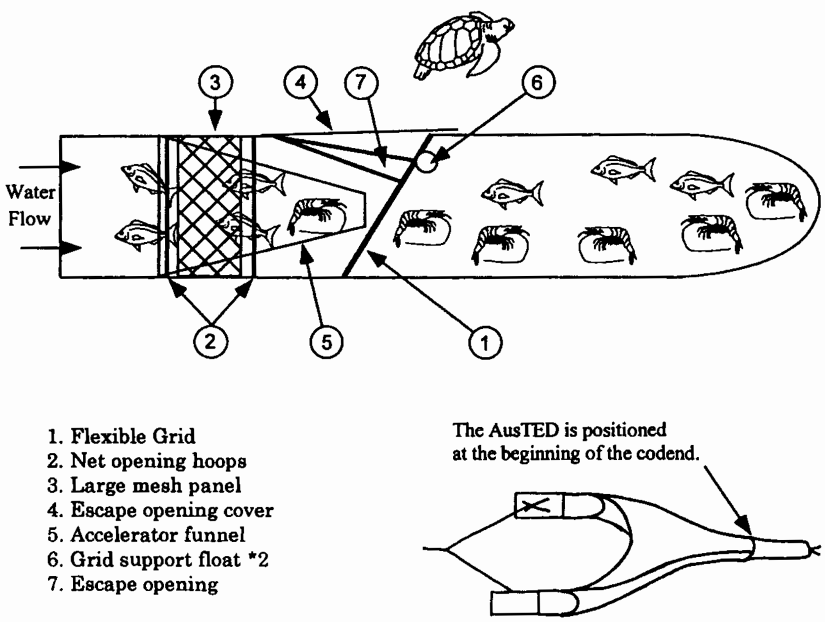

Fig. 1. The original AusTED.

Australian fishers saw the advantage of developing what has been termed an integrated bycatch reduction system (Tucker et al., 1997). Testing of the AusTED (Fig. 1), revealed some limitations in its design, making it unacceptable to commercial fishers. The number of components needed to be reduced to allow for easier operation and repair if damaged. Video footage showed some of the theories applied in the design of the AusTED were not working exactly as intended (Mounsey et al., 1995). The escape opening cover was removed as it had a tendency to lift up during the trawl shot, allowing target catch to escape. Mounsey et al. (1995) recommended removing the large mesh panel and fitting square windows behind the grid. The removal of the large meshes meant the net opening hoops were no longer required.

The first funnel was modified into a guiding flap, and its trailing edge was weighted with chain. It was theorised that the end of the flap would be lifted by water flow to the height of the top horizontal bar on the grid when fishing. The flap served:

- to deflect animals passing down the net towards the base of the grid (away from the large animal escape opening);
- to partially cover the large animal escape opening.

A funnel was added directly behind the grid. Escape openings were cut either side of, and above the funnel and were positioned forward of the funnel's aft edge. Fishes could escape by swimming forward past the outside of the funnel exit and through the openings. Target catch washes through to the codend. Funnels were constructed from three materials (45 mm polyethylene, 25 mm monofilament and canvas) and tested to determine if:

- a different material would alter water flows around the funnel and stimulate a more positive escape response from the fish within the net;
- a material that provided a more rigid shape may increase the fish exclusion;
- the amount of fish gilling in the funnel may be reduced.

Video footage had revealed that fish seemed reluctant to swim towards a moving object. It was theorised that fish exclusion may be aided if the aft edge of the funnel could be made rigid or semi-rigid. Links of chain and 12 mm combination rope moulded into different shapes (circle, oval, diamond, rectangle) were tested. The different combinations of funnel material and exit shapes were filmed during day and night fishing. In all cases fishes were reluctant to swim forward to the escape openings, but a number of fish swam back through the grid and out through the large animal escape opening.

As a result of these observations, the openings behind the grid were filled in and a steep taper (1 knot, 4 bar), sewn into the funnel. The steep taper was intended to discourage fish from falling back into the codend whilst holding them in an area close to the large animal escape opening. Lead core rope was tied along the aft edge of the funnel and served several purposes:

- to further enhance the barrier effect and to direct fish to the large animal escape opening.
- to maintain a steep taper in the funnel by holding its aft edge close to the bottom of the net.
- to block target catch and by-product washing forward during haulback.

2.2. Design details

The AusTED II (Fig. 2) was constructed in two different sizes. The small AusTED II was built around a 750 mm high grid (Fig. 3(a)) for use in nets with headline lengths between 7.3 and 14.6 m. The large AusTED II was built around a 900 mm high grid (Fig. 3(b)) for use in nets with headline lengths greater than 14.6 m. A net plan for both the small and large AusTED II is shown in Figs. 4 and 5.

2.2.1. The small AusTED II

The small AusTED II was constructed from blue polyethylene mesh, 40 mm (stretched mesh) 14 400 TEX, 100 meshes wide and 35 meshes long. The 35 mesh edge was joined by a simple seam (knot to knot), creating the tube shape which formed the basis of the AusTED II.

A fish escape opening (Fig. 2) was positioned in the first 10 meshes of the main tube. The opening was 13 meshes wide along its aft edge and 7 meshes wide along its forward edge. An all bar cut forwards formed the rhomboid shaped escape opening. Polyethylene twine, 24 000 TEX, was used to selvedge the perimeter of the opening.

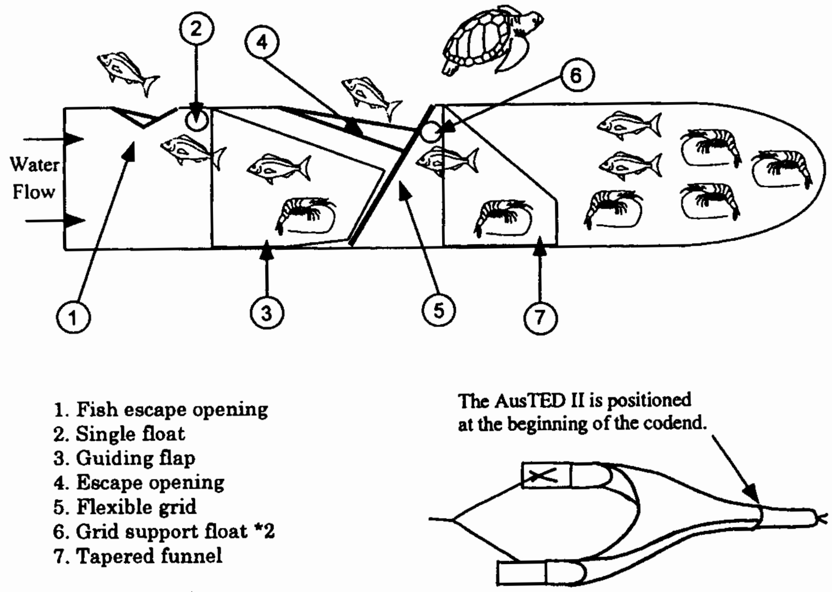

Fig. 2. A diagrammatic representation of the AusTED II showing small fish escape opening (1), single Nokolon trawl float (2), guiding flap (3), large animal escape opening (4), flexible grid (5), two Nokolon grid support floats (6) and tapered funnel (7). Arrows show how the design excludes some animals whilst retaining others.

The escape opening (Fig. 2) was 31 meshes wide along its aft edge and positioned 5 meshes from the end of the main tube. A 30 bar taper gave the escape opening a triangular shape, with 1 mesh left at the forward edge of the opening to give a greater resistance to tearing. The perimeter of the opening was selvedged with 24 000 TEX polyethylene twine.

The flexible, oval shaped grid (Fig. 3(a)) was fabricated from right hand, ordinary lay, round strand, galvanised, steel wire rope with a wire core (7×7 wire). The circumference of the grid was constructed from a 12 mm wire, its two horizontal bars from 10 mm wire and the five vertical bars from 6 mm wire. The components

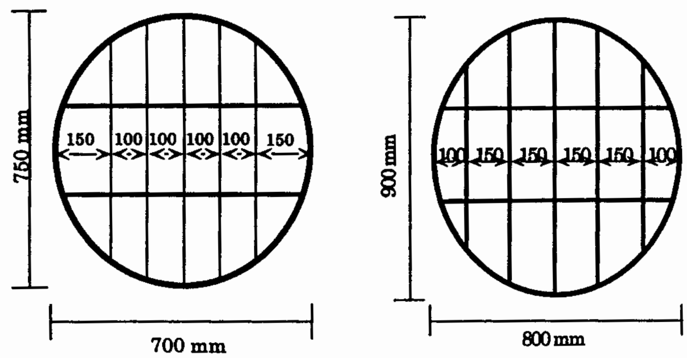

Fig. 3. (a) The dimensions of the small AusTED II grid. The circumference is constructed from 12 mm wire rope, the bars from 10 mm wire rope and vertical bars from 6 mm wire rope. (b) The dimensions of the large AusTED II grid. The circumference is constructed from 12 mm wire rope, the horizontal bars from 12 mm wire rope and the vertical bars from 8 mm wire rope. Bar spacings are 300 mm × 100 mm.

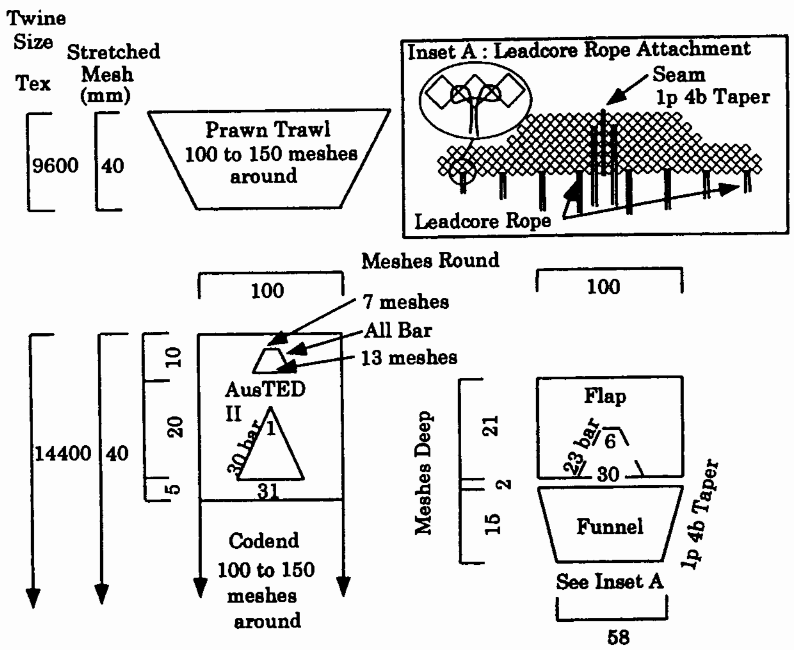

Fig. 4. A netting plan of the small AusTED II. Details of the lead core rope attachment are shown.

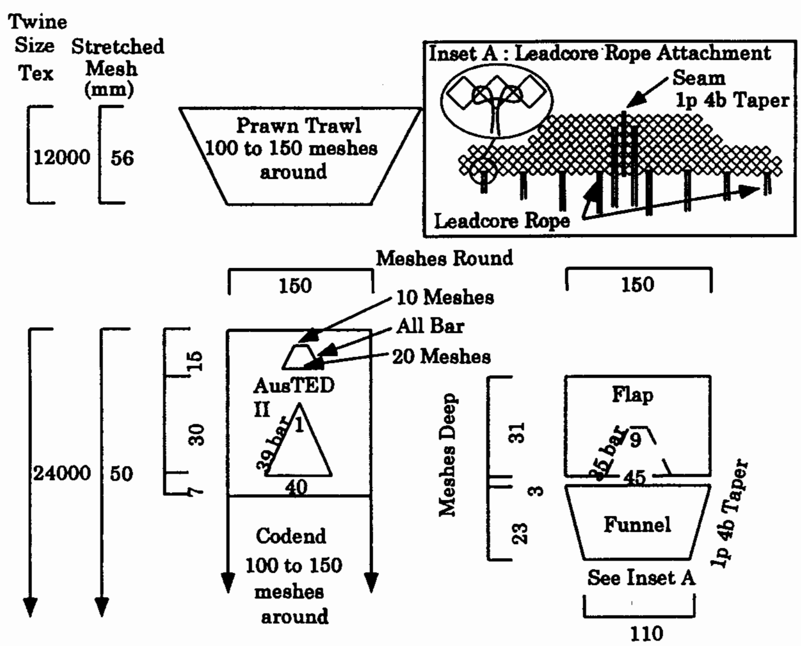

Fig. 5. A netting plan of the large AusTED II.

were spliced together and double dipped in white polyethylene.

The grid was inserted into the net by attaching it in four places with cable ties and lacing the remainder with 6 mm polyethylene rope. The four quarters of the grid circumference were attached to the corresponding meshes (1, 25, 50, 75) in the main tube. The centre mesh of the aft edge of the large animal escape opening was attached to the top centre of the grid. At the 25th and 75th mesh the attachment point was moved forward 2 meshes and at the 50th mesh it was moved forward 5 meshes. Attaching the grid in this manner ensured that the grid formed an angle of 80° from the horizontal (dry angle) sloping back towards the escape opening.

Two 120 mm diameter, high impact, Nokolon trawl floats (working depth 1000 m) were tied behind the top of the grid, making it neutrally buoyant and providing stability when shooting away (Fig. 2). A chaffing mat constructed from a piece of 19 200 TEX polyethylene mesh 25 meshes wide and 20 meshes long was sewn to the bottom of the main tube in front of the grid. Together with the floats the chaffing mat ensured that the damage to the net at the base of the grid would be minimised.

The guiding flap (Fig. 2) was 21 meshes long. Its forward edge was 100 meshes round and was sewn to the main tube 10 meshes aft of its forward edge. At the aft edge of the flap, a 30 mesh × 23 bar × 6 mesh section was removed. It was thought that by removing these meshes the passage of large animals passing down the net was less likely to be impeded. The forward 6 meshes and 5 bars of this section were laced to the corresponding meshes in the main tube. At the end of the flap, 30 links of chain (600 g total) were laced onto the first 15 meshes either side of the centre mesh.

The funnel (Fig. 2) was sewn in 3 meshes before the end of the main tube. The funnel was 15 meshes long and tapered from 100 meshes round at its forward edge to 54 meshes round at its aft edge. Ten lengths of lead core rope (total weight 60 g) were tied to the end of the funnel. Fig. 4 shows the lengths and attachment detail for the lead core rope.

2.2.2. *The large AusTED II*

The large AusTED II was constructed from blue polyethylene netting and while the design did not differ from the small AusTED II, the mesh size, TEX number and the number of meshes round and long were increased (Fig. 5). The amount of chain attached to the guiding flap was increased from 30 links to 45 links. The amount of lead core rope at the end of the funnel was increased 1.5 times. The extra weight compensated for the increased water flow through the larger AusTED II.

The large grid (Fig. 3(b)), was constructed from the same material as the small grid but the diameters of the wire used were larger. The circumference and the two horizontal bars were constructed from 12 mm wire and the five vertical bars from 8 mm wire. Two 150 mm diameter, high impact, Nokolon trawl floats (working depth 1000 m) were attached to the back of the grid providing neutral buoyancy. A chaffing mat constructed from rubber insertion (300 mm wide × 200 mm long) was sewn to the underside of the main tube.

2.3. *Testing methodology*

Test codends (Fig. 6), constructed from 42 mm, 19200 TEX polyethylene mesh, were attached to the fisher's existing nets by autolock plastic slides (zipper). Each zipper was 2 m long and was machine sewn to codend material via a 10 mm strip of heavy duty canvas. The zippers were used to quickly swap codends after each shot to eliminate bias caused by the port and starboard nets fishing differently. Three shark clips attached to 6 mm polyethylene rope were used as safety straps should the zipper part mid-tow.

The control codend measured 100 meshes round × 100 meshes long and the AusTED II codend was 100 round × 135 long. The extra 35 meshes was the AusTED II extension. Skirts, constructed from 115 mm, 36000 TEX polyethylene mesh were added to the last 30 meshes of the codends. Codend lifters (25 meshes × 25 meshes) were attached to the codends using two different methods (Fig. 6).

The small AusTED II was tested against control codends for 90 tows in three different areas of north-eastern Australia. The large AusTED II was tested for 38 tows at Groote Eylandt in the Gulf of Carpentaria, Australia.

2.4. *Drag*

Five tonne drag meters (constructed by agricultural engineers at Queensland Department of Primary

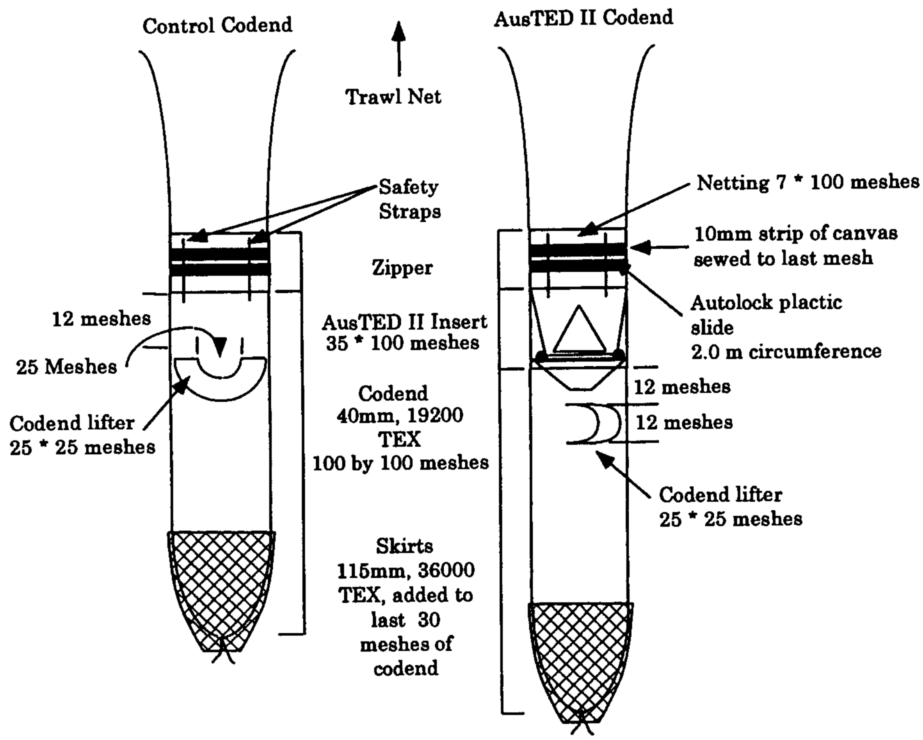

Fig. 6. AusTED II and control codends as used during testing.

Industries, Toowoomba, Qld) were attached between the arm and the block of the trawler. The meters were in a Wheatstone bridge configuration with an output of 2.4 mV/V excitation and a capacity of 40 kN. The drag meters were calibrated and tared before the beginning of each tow. An index of drag for each second during the tow was recorded by a datalogger. Drag was averaged over each 60 s which eliminated surges caused by the wave action on the boat.

Drag was measured for 44 tows. As the work was completed under commercial conditions, the fisher often turned within the course of a tow. This had the effect of dropping drag at the warp for the side to which the boat turned to about zero, whilst almost doubling the tension in the warp on the side opposite to the turn. After a turn was completed, it generally took several minutes for the nets to adjust and settle into a straight line. The turns caused large variations in the recorded drag of the nets, thus only those parts of the tow that were deemed to be "straight line tow" were included in the analysis.

3. Results

3.1. Catch

Both small and large versions of the AusTED II reduced bycatch in all areas. Losses of target catch, i.e. *Penaeus* sp., *Meteapanaeus* sp., and of the by-product, i.e. *Portunus* sp., *Thenus* sp., *Photololigo* sp., teleost fishes, were area dependent. Large stingrays were caught in the control codend but not in the AusTED II codend. No turtles were captured in the AusTED II equipped net during trials, however, two were captured in control codends at Groote Eylandt.

3.2. Operation

Commercial fishers did not have to alter their normal fishing routine while using the AusTED II. The AusTED II equipped net reacted similar to a standard net during fishing operations in both calm and heavy weather. The AusTED II proved no less user friendly than a control net in double, triple or quad rigged gear. The only change from usual fishing practices was to ensure the gear was free of twists before the first shot. Measurements of gear fitted with a large AusTED II using net and board monitors (Scanmar) indicated that the AusTED II did not effect the geometry of the gear (i.e. wingend spread was similar for the TED and control net). There was no

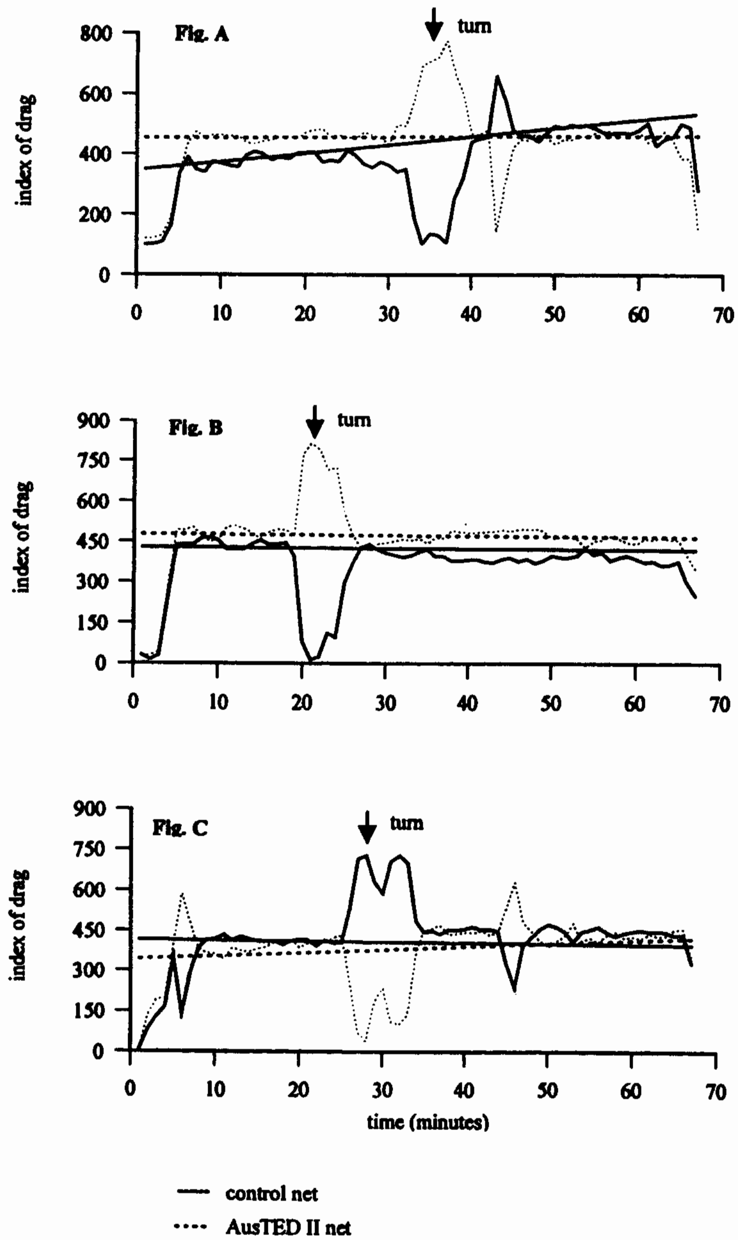

Fig. 7. Three examples of drag measurements recorded from AusTED II and control codends. Regression lines are also plotted.

evidence during the trials that the AusTED II was more likely to be damaged than other parts of the trawl net. The inclusion of flaps and funnels around the grid made cleaning the net at the completion of fishing more time consuming.

3.3. Drag

Drag data for each tow (excluding turns) were plotted and analysed by regression (Fig. 7). The slopes of AusTED II equipped nets and control nets were compared using a standard *t*-test. About 50% of tows had statistically significantly different slopes between the AusTED II equipped nets and the control nets ($P<0.05$).

The estimated regression lines from all 44 tows were compared between the AusTED II net and the control net using an analysis of variance (GENSTAT). There was no consistent trend for the control net to have a steeper slope (=greater drag) than the AusTED II equipped net ($P=0.520$). Overall regression lines derived from the analysis were drag AusTED II net=403.8+0.19x, and drag control net=393.7+0.44x (where x=tow time in minutes).

3.4. Observations and discussion

Commercial fishers have indicated that some aspects of the AusTED II design, such as the open meshes before and after the grid, may be detrimental to prawn retention. The grids larger diameter in relation to the codend diameter tends to open the meshes just before and just after the grid. This may allow smaller prawns (approximately 50 individuals per kilogram) to escape as they can easily pass through an open legal sized mesh (Laurie Holt, personal communication). There is also a tendency for some species of fish to gill themselves in the open meshes. When this occurs it increases the chance of a shark bite in the codend which may lead to catch loss. A possible solution to this problem would be to place more meshes around the grid or use a mesh with a higher TEX number.

The small and large escape openings were also an area where fishers believe prawn loss would occur. Many believe that significant prawn loss can occur through a single broken mesh if it is in a critical area of the net (Herb Olsen, personal communication). The large escape opening represents an area many times that of a broken mesh and may present an avenue for

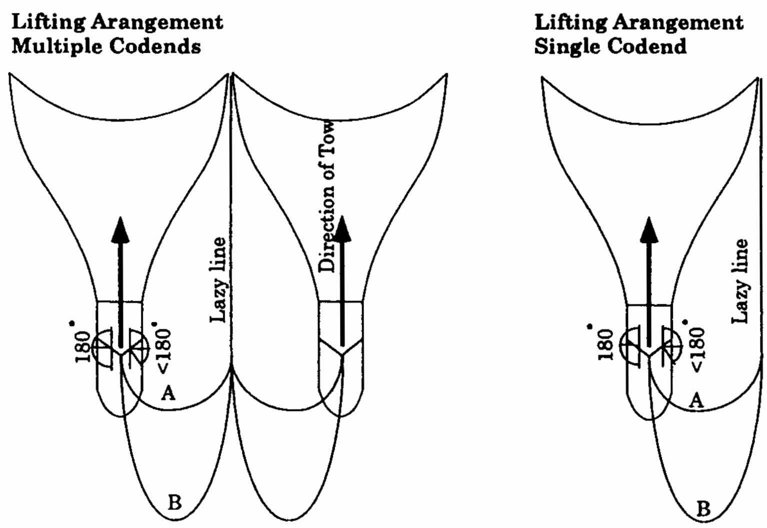

Fig. 8. Optimum lifting arrangements for AusTED II equipped codends. On the left is a set up for multiple codends and on the right the set up for single codends. (A) Depicts a lazy line arrangement which would roll the AusTED II and (B) depicts a set up that would not roll the AusTED II.

prawns to escape. The positioning of the guiding flap ensures that prawn loss is minimised when it is operating effectively. In some circumstances, i.e. dirty ground, the flap becomes fouled by debris, in which case the extent of fouling governs the amount of prawns lost.

During all four testing cruises the highest reduction in prawn catch occurred during tows through areas with large amounts of star fish, sponges, urchins, sea cucumbers and benthic debris. One area which was heavily populated with large starfish caused regular clogging of the AusTED II. Catch loss occurred as a result of starfish blocking the grid or tangling the guiding flap, causing inefficient operation. In dirty areas, further alterations may be needed to make the AusTED II work more efficiently. One such alteration would be to remove the guiding flap and funnel and place a piece of mesh over the top of the escape opening. This would decrease loss of target catch and also decrease the exclusion of fish bycatch.

Lazy line arrangements (Sainsbury, 1996) that allow one or more codends to be winched aboard at once as when fishing with triple or quad gear may effect the performance of the AusTED II. Testing indicated that the lazy line needed to pull at 180° from the direction of tow (Fig. 8). To achieve this fishers must:

- increase the lazy line length on nets spilled singularly, i.e. single and double gear, and
- increase the bridle length when more than one codend is spilled at the same time, i.e. triple and quad gear.

A short lazy line appears to roll the AusTED II inwards, spilling a proportion of the catch out of the escape openings. Closely related to this problem is the attachment positions of the lifters. Lifters which ran in a fore aft direction along the top of the codend seemed to have less effect on the stability of the device.

Redesign of the original AusTED and discussion with industry have made the AusTED II a more appealing proposition to commercial fishers. The current design meets the criteria set by industry in that it is simple, reduces bycatch and in most cases maintains commercial prawn catches. Continued development of the AusTED II by researchers together with industry will result in a more efficient device.

Acknowledgements

The authors wish to thank Laurie Holt – owner/ skipper of the FV Sonya M, Tony Sterling – skipper of the FV C-King, Neil Wade – owner/ skipper of the FV Coral Sea and Ivor Jones – skipper of the FV Roper Therese and their respective crews for the assistance they provided during the testing. The authors also thank Herb Olsen and the crew of the FV John D for their assistance during follow up testing. The authors also wish to thank John Salini from CSIRO, John Wakeford from the Australian Maritime College, for their assistance during testing. Thanks must go to Buck Scott for fabricating the AusTED II grids and Harry Shultz for his help with materials and advice during construction of the AusTED II. This study was funded by the Fisheries Research and Development Corporation (FRDC), together with the Northern Territory Department of Primary Industries and Fisheries and the Queensland Department of Primary Industries.

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