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EVALUATION OF A NEW DESIGN OF SEMI-DEMERSAL TRAWL

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SUSTAINABLE FISHERIES

THE DEPARTMENT OF PRIMARY INDUSTRY AND FISHERIES IS COMMITTED TO THE PRINCIPLES AND PRACTICES OF SUSTAINABLE FISHERIES

Definition:

Sustainable fisheries is the use of practices and systems which maintain or enhance:

- the economic viability of fisheries production:
- the natural resource base: and
- other ecosystems which are influenced by fisheries activities.

Principles:

1. Fisheries productivity is sustained or enhanced over the long term.
2. Adverse impacts on the natural resource base of fisheries and associated ecosystems are ameliorated, minimised or avoided.
3. Harmful residues resulting from the use of chemicals for fisheries are minimised.
4. The nett social benefit (in both dollar and non-dollar terms) derived from fisheries is maximised.
5. Fisheries systems are sufficiently flexible to manage risks associated with the vagaries of climate and markets.

SUSTAINABLE FISHERIES IN THE NORTHERN TERRITORY

ABSTRACT

Mounsey, R.P. and Ramm, D.C. (1991). Evaluation of a new design of semi-demersal trawl. **Fish. Rep. No. 25.** (Department of Primary Industry and Fisheries, Northern Territory).

The Fisheries Division, Northern Territory Department of Primary Industry and Fisheries, and the Australian Fisheries Service, Canberra, initiated an investigation of "environmentally -friendly" trawls suitable for use in the demersal trawl fishery operating on Australia's northern continental shelf. The study was conducted by staff from the Research and Development Branch, Fisheries Division, during July 1990 - April 1991; funds were provided by the NT Government and a grant from the Fisheries Development Trust Account.

A new design of semi-demersal trawl (named "Julie Anne") was developed. This net is a four-seam box trawl with equal length headline and footrope, and fly wire rigging. The net used in the study had a headline and footrope length of 38m, and an estimated opening height of 8m. The footrope was adjusted to a minimum height of 30cm above the substrate. The performance of this net was compared to that of a conventional Paulegro demersal trawl during a paired series of 14 trawls conducted in the Arafura Sea near 137°E and 10°S during February-March 1991.

The Julie Anne net was successful in:

. catching only 3% of benthos and 43% of the bycatch, by weight, of that caught with the Paulegro net;
. reducing the bottom contact of the trawl and rigging to 3% of the width of the trawl path;
. producing product of a high quality; and,
. reducing wear on the net and rigging.

Mean catch rates of "red" snappers (*Lutjanus malabaricus* and *L.erythropterus*) in the Julie Anne trawl (321 kg/3h) were comparable ($P > 0.1$) to those achieved with the Paulegro net (215 kg/3h). Seven other commercial taxa had comparable catch rates. Three commercial taxa (eg blacktip shark) had higher catch rates in the Julie Anne trawl, and 5 commercial taxa (eg painted sweetlip) were more abundant in the Paulegro trawl.

Length-frequency distributions were examined for 10 commercial taxa, and 11 non-commercial taxa. Size compositions of fish from both types of net were comparable ($P < 0.1$) for taxa with sample sizes > 10 fish/net. Lengths to caudal fork ranged from 26-59cm for scarlet snapper, and from 32-54cm for red snapper.

The product quality of individuals from seven species of commercial fish were assessed visually. In all cases, fish from the Julie Anne trawl were rated higher than those from the Paulegro net; significant differences ($P< 0.05$) were observed for 6 of the 7 species.

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INTRODUCTION

Since 1970, vast areas of Australia's northern continental shelf have been swept by demersal fish trawls. In what was then international waters, distant water pair trawlers from Taiwan began fishing the demersal resources of the Arafura Sea, and later those of the Timor Sea and Northwest Shelf. When the Australian Fishing Zone was ratified in 1979, Taiwanese trawlers continued operating under fee-fishing arrangements. Thai and Chinese vessels joined the northern trawl fleet in 1985 and 1989, respectively. Fishing effort in the northern trawl fishery was initially concentrated on the Northwest Shelf between longitudes 114-118°E. During the mid 1980s, the concentration of fishing effort shifted to the Arafura Sea between longitudes 134-138°E. The retained catch from the foreign trawl fleet was dominated by emperors (*Lethrinus*), snappers (*Lutjanus* and *Pristipomoides*), threadfin-breams (*Nemipterus*) and lizardfish (*Saurida*) (Ramm *et al*, in prep). Fishing effort in the Arafura Seas during the mid to late 1980s was directed mainly at the "red" snappers, *Lutjanus malabaricus* and *L.erythropterus*. These fish, typically 40-50 cm in length, are popular on western markets both within Australia and overseas.

Sainsbury (1988) reported two major trends evident in the catch from trawlers operating on the Northwest Shelf during the 1970s and 1980s. Firstly, lethrinids and lutjanids which dominated the catches during the early phase of the fishery have been replaced by nemipterids and lizardfish; the overall biomass has remained relatively constant. Secondly, the quantity of benthic organisms (benthos) caught by demersal trawlers operating on the Northwest Shelf is presently lower than that caught during the early 1970s. Further, his research indicated that lethrinids and lutjanids occur predominantly in areas with large benthic organisms, such as sponges. In contrast, nemipterids and lizardfish are found mostly in areas with light benthic cover such as sand flats. It is likely that the observed changes in the composition of catches from the trawl fishery on the Northwest Shelf during the past 20 years were associated with changes in habitat, in turn, induced by trawling.

Recent changes in the northern trawl fishery, including increased fishing effort in the Arafura Sea, increased activity by Australian trawlers, and targeting for "red" snappers, have raised concern about the sustainability of the fishery in waters adjacent to the Northern Territory. In October 1990, the Australian Fisheries Service, Canberra, introduced a development plan for the northern trawl fishery. Under the plan, fishing by foreign trawlers ceased, and 11 licences were issued to Australian vessels to operate in the offshore trawl grounds of the Timor and Arafura Seas. All vessels operating in the fishery presently use conventional demersal trawls with heavy ground gear and bobbin lines; the preferred design is a two-seam, medium-opening Paulegro trawl.

Under the development plan, access to inshore areas, and areas which had historically sustained a low level of fish trawling activity, was withheld until further knowledge of the resources has been acquired, and the use of semi-demersal trawl gear investigated. This type of gear would minimise damage to the environment.

In June 1990, the Northern Territory Fisheries Division and the Australian Fisheries Service initiated a study to investigate "environmentally-friendly" trawl gear for use in the northern trawl fishery. The study, consisting of a design and construction phase (Plate 1) and an evaluation phase, was conducted by staff of the Research and Development Branch, NT Fisheries Division. Funds for the study were provided by the NT Government and a grant from the Fisheries Development Trust Account. The design phase was conducted during July 1990 - February 1991 and resulted in a new design of semi-demersal trawl (named the "Julie Anne" trawl). The commercial viability of the Julie Anne trawl was evaluated during February-March 1991.

The concept of the Julie Anne net was based on fly wire rigged semi-demersal trawls used by vessels of 800-1200 Hp fishing for herring in the North Sea and English Channel (Maucorps and Portier, 1971). The net was designed to maximise the catch rate of "red" snappers, presently targeted, and minimise environmental damage. To achieve this, the height of the headline was raised to some 8-10m above the substrate, while the footrope was raised off the bottom; there was no bobbin line. The design of the net, and its performance relative to the Paulegro trawl, are reported.

TRAWL DESIGNS AND CONFIGURATIONS

Julie Anne trawl

The Julie Anne net is a four-seam box trawl with equal length headline and footrope of 38m (21 fathoms). The wing and belly panels were made of 90 ply polyethylene netting with mesh sizes of 300mm (12 inch) and 225mm (9 inch), respectively. The throat and extensions sections were made of 60 ply polyethylene netting with mesh sizes of 150mm (6 inch) and 112.5mm (4.5 inch), respectively (Fig.1). The codend was made from 5mm braided polyethylene netting with a mesh size of 110mm.

The headline was buoyed with 13 high pressure screw-on floats of 300mm (12 inch) diameter providing a total lift of 130kg. The footrope was weighted by one 60kg steel weight at either extremity of the wings, and 7 lengths of chain spread over a distance of 4m in the centre. Each length of chain weighed 10kg and was folded back on itself so that its total length was approximately 50cm.

The rigging and trawl board configuration are shown in Figures 2a,2b,2c. The trawl boards used were 2.3 m x 1.5 m steel "V-Doors". Measurements using light cords of known lengths stretched between the boards indicated that the spread of the boards was approximately 65m.

Paulegro trawl

The net used was a 46m (25 fathom) two-seam trawl with an overhanging headline and cut-away bottom wing tips (Fig.3). The wing and belly panels consisted of 90 ply polyethylene netting with mesh sizes of 225mm (9 inch) and 150mm (6 inch), respectively. The throat and extensions sections were made of 60 ply polyethylene netting with a mesh size of 112.5mm (4.5 inch). The codend was constructed of 5mm diameter braided polyethylene netting with a mesh size of 110mm.

The headline had 54 high pressure trawl floats of 200mm (8 inch) diameter; the total buoyancy was 135kg. The footrope was linked to a bobbin line with 150mm (6 inch) diameter rubber disks, lead weights, chains and steel cable with a total weight of approximately 500kg.

The configuration of the boards, sweeps and bridles was similar to that used throughout the fishery (Figs.4a,4b). The trawl boards were the same as those used with the Julie Anne net; estimated spread between the boards was 65m.

METHOD OF EVALUATION

Preliminary trials

The original concept of the Julie Anne semi-demersal trawl was examined using a 1:10 scale model (Plate 2). The model was tested from the division's 7.5m FRV "John Lake" operating in shallow water in Shoal Bay (12°20'S, 131°00'E). Diver observations on the net indicated that the design was successful and that the trawl configuration was stable.

Commercial evaluation

Gear trials and evaluations were conducted from the FV "Clipper Bird" (Plate 3). The vessel was chartered from A.Raptis & Sons during the period 24 February - 17 March 1991. The FV "Clipper Bird" is a 25m steel stern trawler presently operating in the northern trawl fishery in the Arafura Sea. The vessel is powered by a Calleson main engine of approximately 500 Hp driving a variable pitch propeller; the bollard pull is 6t. Positions and trawl speeds were obtained from a Furuno global positioning system; depths and fish marks were recorded using a Koden colour depth sounder.

Gear trials with the Julie Anne net were conducted during 24-27 February, and 1 March. Further adjustments to the net were made during 3-7 March. The performance of the Julie Anne trawl was assessed against that of

the Paulegro demersal trawl during 8-16 March. The comparison was based on a paired series of 14 trawls using each type of net. Trawl duration, defined as the period from the start of trawling to the start of hauling (ie bottom time), averaged 3h. Each series of 14 trawls required 4 days for completion, and both series were made under similar tidal amplitude and weather conditions. Four trawls targeting "red" snappers were made with the Julie Anne net on 12 March.

Data collected for each trawl included: the weight of all species of fish and elasmobranchs caught; the length of fish from selected species; and the weight of benthos caught. Weights were measured to the nearest 0.05kg, and lengths were measured to the nearest 1cm. Videophotography of the footrope of both Julie Anne and Paulegro trawls were obtained using a camera (Sony CCD-TR55E) mounted in an underwater housing (Amphibico TR5) within a custom designed alumimium frame (Plate 4). Halogen video lights (Amphibico) were used. Neutral buoyancy was achieved using 2 high pressure trawl floats.

Comparison of catch rates were made using ANOVAs; data were normalised by a square root transformation. Catch rates for the paired series of 14 trawls are reported per 3h period (ie average trawl duration). Catch rates during the target trawls are reported per 1h period (ie average bottom time of target trawl). Similarities in length-frequency distributions were assessed using the Spearman rank coefficient of correlation. Statistical differences were considered significant when probability < 0.1.

The evaluation was based on the following criteria:

catch rate of benthos;
catch rate of commercial fish;
catch rate of "non-commercial" fish;
quality of product;
impact on the substrate; and,
power requirements.

The distinction between commercial and "non-commercial" fish was based on present trashing practices within the northern trawl fishery.

Product quality was evaluated at the International Food Institute of Queensland, Brisbane. For each species, 3 individuals from each type of net were bled, placed in ambient temperature sea water for approximately 30 minutes, and subsequently frozen at -40°C. Following four weeks frozen storage, the fish were thawed at +4°C over a period of 24h. Three experienced judges visually assessed the fish according to: appearance and skin colour; presence of scales and slime; external damage; gill and eye appearance; and, resilience of the flesh. Scores were expressed as a percentage of the maximum attainable score (ie quality was proportional to the score).

Trawl grounds

The paired series of 14 trawls, and the target trawls, were conducted in the Arafura Sea between longitudes 136°40' - 137°30'E and latitudes 9°40' - 10°50'S (Fig.5). These grounds were chosen for their abundance of "red" snappers following limited exploration during the gear trials. The depth of water on the grounds ranged from 43-55m, and the substrate ranged from soft mud to low-lying reefs.

RESULTS

Gear trials

Trials of the Julie Anne trawl revealed two main problems. Firstly the pin swivels and 10mm diameter cables used on the fly wires were too light. This was rectified by replacing the swivels with ball bearing swivels, and upgrading the cables to 16mm diameter.

Secondly, the Julie Anne net was too large for the FV *"Clipper Bird"* to tow; trawl speeds of 3.5-4.0 knots could

not be achieved. This problem could not be addressed onboard, and the vessel returned to port where the net was modified and cut down. Side panels were cut to reduce the bosom of the net from 130m (5200 inches) to 113m (4500 inches). Other modifications included: (1) reducing the number of floats from 25 to 13; (2) adding 70kg of weight (ie 7 lengths of chain) to the centre of the footrope; (3) re-arranging the position of the fly wires to suit the cut-down net.

Catch rates for 3h trawls

Benthos

The following categories of "benthos" were recorded: mixed benthos (including sponges, hydroids and seapens); bugs (*Thenus orientalis*); crabs; scallops (*Amusium pleuronectes*); shell; starfish; and, rock. Catch rates for each of these categories were significantly lower (probability: $P < 0.01$) in the Julie Anne trawl than those observed in the Paulegro trawl (Table 1). The overall mean catch rate for benthos in the Julie Anne trawl was 0.6kg/trawl, or 3% of that observed for the Paulegro net.

Commercial fish

While the total catch of scarlet snapper (*Lutjanus malabaricus*) during the series of 14 Julie Anne trawls (4106kg) was greater than that observed in the Paulegro series (2701kg), there was no significant difference ($P > 0.1$) in mean catch rates between the two types of net (Table 2). The overall mean catch rate was 243 kg/trawl.

Similarly, no significant differences ($P > 0.1$) in mean catch rates were observed for red snapper (*Lutjanus erythropterus*), golden snapper (*L.johni*), mangrove-jack (*L.argentimaculatus*), Russell's snapper (*L.russelli*) , red-spot emperor (*Lethrinus lentjan*), and 3 species of sharks (*Carcharhinus sorrah*, *Hemigaleus microstoma*, *Rhizoprionodon acutus*) (Table 2).

The mean catch rate for blacktip shark (*Carcharhinus tilstoni*) and Spanish mackerel (*Scomberomorus commerson*) in the Julie Anne trawl were significantly higher ($P < 0.1$) than those observed with the Paulegro trawl (Table 3).

Four commercial species had significantly greater ($P < 0.05$) mean catch rates with the Paulegro trawl than those with the Julie Anne net. These species were: red emperor (*Lutjanus sebae*); gold-band snapper (*Pristipomoides multidens*); painted sweetlip (*Diagramma pictum*); and, blackspot shark (*Carcharhinus dussumieri*) (Table 4). Catch rates for gold-band snapper were low throughout the period of gear evaluation.

"Non-Commercial" fish

The paired series of 14 trawls yielded 105 species of "non-commercial" fish and elasmobranchs (2734kg) in the Julie Anne trawl, and 131 species of "non-commercial" fish and elasmobranchs (6335kg) in the Paulegro net. Overall, the mean catch rate for "non-commercial" species in the Paulegro net (453 kg/trawl) was significantly higher ($P < 0.001$) than that for the Julie Anne net (195 kg/trawl).

At the species level, there were no significant differences ($P > 0.1$) between the mean catch rates of both nets for 51 species (Table 2). In addition, catches of squid and octopus were similar in both nets. However, 7 species had greater catch rates in the Julie Anne trawl (Table 3), and 79 species had higher catch rates in the Paulegro net (Table 4). Notably, the Paulegro trawl caught more stingrays (*Himantura* spp) and catfish (*Arius thalassinus*). The Paulegro net also caught more cuttlefish.

Comparison of length-frequency distributions

Length-frequency distributions for 10 species of commercial fish, and 11 species of "non-commercial" fish were compared between the Julie Anne and Paulegro trawls. Size compositions of fish from both types of net were similar ($P < 0.1$) for taxa with sample sizes > 10 fish/net (Table 5). Scarlet snapper ranged from 26-59cm, with most fish between 45-55cm (Fig.6). Similarly, red snapper ranged from 32-54cm with a mode at 46cm (Fig.7).

Catch rates for 1h target trawls

Target fishing with the Julie Anne trawl during 12 March produced 2130 kg of "red" snappers (*L.malabaricus* and *L.erythropterus*) for a total bottom time of 4.8 h. These catch rates were compared with the 3-hour trawls made in the same region with the Julie Anne trawl (11 March) and the Paulegro (13 March) (trawl pairs 11-14, Fig.5). Catch rates for this comparison were standardised to 1h; the average bottom time during target trawls. No significant difference ($P > 0.1$) in mean catch rates were observed for scarlet snapper. In contrast, the mean catch rate of red snapper during target trawling was significantly higher ($P < 0.05$) than those recorded during the 3h trawls using both Julie Anne and Paulegro nets; the mean catch rate during target trawling was 220 kg/h.

Quality of product

On-deck inspection of fish indicated that the quality of the product from the Julie Anne trawl was superior to that from the Paulegro net. Fish from the Julie Anne trawl were "clean" and had very little physical damage. Fish in the Paulegro net were at times muddy, noticeably bruised from large rays and benthos, or spiked by spines from catfish and tripod fish. Photographs of typical catches from Julie Anne (Plate 5) and Paulegro (Plate 6) trawls are included.

Mean scores from the visual assessment of fish caught in the Julie Anne net were significantly higher ($P < 0.05$) than those of fish from the Paulegro trawl for all species tested, except red snapper (Table 6). The evaluation revealed that fish from the Julie Anne net sustained minimal physical damage. The fish retained their bright characteristic species colour, and the scales remained intact and firmly adhered to the dermis. In contrast, fish from the Paulegro trawls often showed moderate to excessive physical damage, including substantial loss of scales and characteristic colour (Plate 7). Visual examination of fillets from scarlet snapper indicated that fish from the Paulegro trawl incurred severe bruising, while fish from the Julie Anne catches sustained little bruising (Plate 8).

Impact on substrate

Examination of the "shine" on the rigging of the nets, and videophotography, revealed that the Julie Anne trawl made contact with the substrate at 9 points: the seven lengths of chain in the middle section of the footrope; and, the two steel weights at the extremities of the footrope (Fig.8). It is estimated that these 9 contact points impacted on some 2m (3%) of the trawl path of the Julie Anne net. The impact consisted of 9 furrows of width 10-30cm and depth 5-10cm. The height of the footrope was set at a minimum distance of 30cm above the substrate.

In contrast, the Paulegro bobbin line and sweeps were in contact with the substrate along the entire width of the trawl path. Video footage and benthic catches indicated that the bobbin line was penetrating the substrate and dislodging the benthos.

Power requirements

Main engine revolutions (around 410 rpm) and propeller pitch (usually 80%) were comparable for both types of trawls. However, the average trawl speed of 3.4 knots while towing the Julie Anne net was significantly slower ($P < 0.001$) than the average speed of 3.7 knots while towing the Paulegro net.

DISCUSSION

Gear trials and evaluation indicated that the Julie Anne trawl was environmentally friendly, catching significantly less benthos and non-commercial fish than a conventional demersal trawl of similar size. This was achieved by raising the footrope to a minimum height of 30 cm above the substrate. This distance was chosen so as to maximise the catch of snappers, and minimise the catch of benthos. The largest benthic structures in the region of the gear evaluation were sponges up to 25cm in diameter. This type of substrate is typical of most offshore trawl grounds in the Arafura Sea (Ramm, unpub. data). The configuration of the Julie Anne trawl is such that future fine-tuning of the rigging may result in the removal of all floats from the headline, and weights from the footrope.

The height of the footrope of the Julie Anne trawl can be readily adjusted by altering the lengths of chain which fasten the steel weights to the extremities of the footrope. The configuration used during the evaluation was suitable over trawl grounds with light benthic cover. In principle, the footrope can be raised to any height required to clear the benthos. In the Timor Sea, for example, where fishing activity has been low and sponges may be as large as 90cm in diameter, the footrope could be adjusted to a height of 1m above the substrate so as to clear the benthos. However, it remains to be proven whether such a configuration would catch commercially viable quantities of target species.

Comparative catch rates indicated that the Julie Anne trawl was commercially viable in the offshore regions of the Arafura Sea. While the overall catch of scarlet snapper in the Julie Anne trawl series was approximately 50% greater than the catch from the Paulegro net, statistically, mean catch rates (kg/trawl) for scarlet snapper were similar to those achieved with the Paulegro net. This result may be attributed to large variations in catch rates, and the small sample size. These catch rates, and the significantly slower trawl speed when towing the Julie Anne net, indicated that the Julie Anne trawl was more efficient at catching scarlet snapper.

Data collected during target trawling indicated that catch rates in excess of 220 kg/h can be achieved for "red" snappers. In particular, significantly higher catch rates were achieved for red snapper (*L.erythropterus*). During such a fishing operation, the trawl is deployed on schools of fish identified on the sounder. One school may be fished repeatedly by towing the trawl through the school, winching the gear up until the boards are above the surface, and turning the vessel around to shoot away again. The stability of the Julie Anne trawl at the surface while the vessel was turning sharply was paramount to the efficiency and success of the targeting operation.

The visual assessment of species from the Julie Anne trawl rated their market acceptability as good to excellent. These same species were rated as poor to good when caught in the Paulegro net. Differences in mean scores supported previous studies which indicated that species such as gold-band snapper, red emperor and red snapper are more "robust", suffering less damage during capture, than species such as golden snapper and scarlet snapper (Poole and Hay, unpub. data). These studies indicated, also, that mangrove-jack suffered severe scale loss when captured by most methods of fishing. The mean score for this species in the Julie Anne catches indicated a marked improvement in quality using this type of fishing gear.

Discard practices onboard Australian trawlers are different from those observed from foreign fishing vessels (Ramm *et al*, in prep). Fish such as butterfish (*Psenopsis humerosa*), catfish (*Arius thalassinus*) and thread-fin bream (*Nemipterus hexodon*), which are considered here as "non-commercial", formed important components in the retained catches of Taiwanese and Thai trawlers operating in the Arafura Sea during the 1980s. Clearly, the Julie Anne trawl would not be viable for catching such fish.

Increased market acceptability, and simplified sorting due to greatly reduced quantities of benthos and bycatch, highlight the commercial advantage of the Julie Anne trawl over conventional demersal trawls. Further commercial benefits of the new design include reduced wear and tear on the net and rigging due to reduced contact with the substrate, and the potential to increase catch rates by target fishing. Catches while target trawling for "red" snappers during this study were limited by the capacity of the vessel's blast freezer. Comparable main engine revolutions and propeller pitch under both trawl configurations indicated that fuel consumption (l/h trawling) was similar for both nets.

Following the trials and evaluation of the new trawl, the Australian Fisheries Service approved a long-term loan

of the Julie Anne trawl to A.Raptis & Sons. The FV *"Clipper Bird"* is presently fishing with the net. Recent communication with the skipper of the vessel indicated that the Julie Anne catches were consistent with those observed during the study. Comparisons between catches from the Julie Anne trawl and conventional demersal trawls will be further analysed as logbook data become available.

Details regarding the net plan and the construction of the Julie Anne trawl and rigging, can be obtained from the Research and Development Branch, Fisheries Division Darwin, or the Australian Fisheries Service, Canberra. A video tape based on the findings of this report is also available for viewing.

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Table 1. Mean catch rates (kg/trawl) for benthos in the Julie Anne and Paulegro trawls. Standard trawl durations was 3h.

	Mean Catch Rate	
Benthic Component	Julie Anne	Paulegro
benthos (mixed spp)	.2	6.8
bugs	.2	.7
crabs (mixed spp)	<.05	.4
scallops	<.05	.1
shell	<.05	1.4
starfish	.2	4.7
rock	<.05	6.0
Total	.6	20.1

Table 2. Taxa with no significant difference (P > 0.1) in mean catch rates (kg/trawl) between the Julie Anne and the Paulegro trawls. Mean catch rates < 0.05 kg/trawl are indicated (+). Standard trawl duration was 3h.

Taxon		Mean Catch Rate	
Scientific Name	Common Name	Julie Anne	Paulegro
Commercial Taxa			
Lutjanus malabaricus	scarlet snapper	293.3	192.9
Lutjanus erythropterus	red snapper	27.3	22.2
Lutjanus johni	golden snapper	10.5	2.5
Lutjanus russelli	Russell's snapper	6.1	6.9
Lethrinus lentjan	red-spot emperor	4.8	12.3
	milk shark	2.3	2.5
Rhizoprionodon acutus	sorrah shark	1.5	.1
Carcharhinus sorrah	weasel shark	.9	1.5
Hemigaleus microstoma	mangrove-jack	.5	.4
Lutjanus argentimaculatus			
"Non- Commercial" Taxa	onion trevally	32.1	34.6
Carangoides uii	long-nosed trevalley	19.9	21.4
Carangoides chrysophrys	brown stingray	14.1	27.3
Hymantura sp	moon-fish	11.9	11.6
Mene maculata	black pomfret	10.0	17.4
Apolectus niger	sandbar shark	7.0	3.3
Carcharhinus plumbeus	malabar trevally	6.9	8.5
Carangoides malabaricus	broad-banded ponyfish	4.5	.9
Leiognathus fasciatus	blue-spotted trevalley	4.2	5.7
Caranx bucculentus	fossil shark	3.8	6.3
Hemipristis elongatus	spotted eagle ray	2.9	2.1
Aetobatus narinari	malabar rock-cod	2.7	4.6
Epinephelus suillus	black kingfish	2.5	4.0
Rachycentron canadus	mirror-mouthed trevally	2.3	1.3
Ulua aurochs	leopard catshark	2.1	1.4
Stegostoma varium	military sea-pike	1.9	5.0
Sphyraena putnamiae	Indian eyebrow-fish	1.8	3.3
Ariomma indica	hump-headed batfish	1.5	6.2
Platax batavianus	big-eye scad	1.5	.7
Selar crumenophthalmus	barbless duckbill ray	1.4	3.0
Aetomyleus nichofii	small-mouth scad	1.2	2.1
Alepes sp *(melanoptera)*	munro's spanish-mackerel	1.2	1.2
Scomberomorus munroi	nine-spined batfish	1.2	.6
Zabidius novemaculatus	high-brow pennantfish	1.1	1.8
Alectis indicus	school mackerel	1.1	1.5
Scomberomorus queenslandicus	round-headed pennantfish	.9	1.7
Alectis ciliaris	sharp-toothed hammer croaker	.9	.4
Johnius vogleri	ox-eye scad	.8	1.1
Selar boops	Indian scad	.7	.1
Decapterus russellii	white-tongued jack	.6	.9
Uraspis uraspis	epaulet trevally	.5	1.3
Carangoides humerosus	black-spot butterfish	.5	.6
Psenopsis humerosa	scalloped hammerhead shark	.4	2.3
Sphyrna lewini	unicorn leatherjacket	.3	.4
Alutera monoceros	red-spot monocle-bream	.2	.3
Scolopsis taeniopterus	yellow-spotted rock-cod	.1	.3
Epinephelus areolatus	toothed ponyfish	.1	+
Gazza minuta	half-smooth golden pufferfish	.1	.2
Lagocephalus spadiceus	large-spined big-eye	.1	.1
Priacanthus macracanthus	Indian mackerel	.1	.3
Rastrelliger kanagurta	yellow-tail scad	+	+
Alute mate	large-spotted flying-gurnard	+	.1
Dactyloptena papilio	slender suckerfish	+	.1
Echeneis naucrates	silver-stripe pufferfish	+	+
Lagocephalus sceleratus	ponyfish	+	+
Leiognathus moretoniensis	yellow-tipped threadfin-bream	+	+
Nemipterus nematopus	blotched javelin-fish	+	.4
Pomadasys maculatum	pot-bellied leatherjacket	+	.1
Pseudomonacanthus peroni	long-finned sea-pike	+	+
Sphyraena obtusata	sunrise goatfish	+	+
Upeneus sulphureus			
Loligo spp	squid	.1	.1
Octopodidae	octopus	+	+

Table 3. Taxa with mean catch rates (kg/trawl) in the Julie Anne trawl significantly greater than those in the Paulegro trawl. The level of significance (P<0.1 *), and mean catch rates < 0.05 kg/trawl (+) are indicated. Taxa which occurred exclusively in the Julie Anne net (JA), and taxa which occurred once only (JA_1) are also indicated. Standard trawl duration was 3h.

Taxon		Mean Catch Rate		
Scientific Name	Common Name	Julie Anne	Paulegro	
Commercial Taxa				
Carcharhinus tilstoni	blacktip shark	14.3	3.5	*
Scomberomorus commerson	Spanish mackerel	6.2	.6	*
Carcharhinus macloti	shark	.1	.0	JA_1
"Non-Commercial" Taxa				
Megalaspis cordyla	finny scad	8.0	2.1	*
Makaira indica	black marlin	3.5	.0	JA_1
Protonibea diacanthus	black jewfish	.2	.0	JA_1
Chirocentrus dorab	wolf-herring	.1	.0	JA_1
Thunnus tonggol	long-tail tuna	.1	.0	JA_1
Anchisomus multistriatus	many-striped pufferfish	.1	.0	JA_1
Gerres filamentosus	whipfin silver-biddy	+	.0	JA

Table 4. Taxa with mean catch rates (kg/trawl) in the Paulegro trawl significantly greater than those in the Julie Anne trawl. The level of significance (P<0.1 * and P<0.01 **), and mean catch rates < 0.05 kg/trawl (+) are indicated. Taxa which occurred exclusively in the Paulegro net (P), and taxa which occurred once only (P_1) are also indicated. Standard trawl duration was 3h.

Taxon		Mean Catch Rate		
Scientific Name	Common Name	Julie Anne	Paulegro	
Commercial Taxa				
Diagramma pictum	painted sweetlip	11.7	35.4	*
Carcharhinus dussumieri	wide-mouthed blackspot shark	10.6	28.8	**
Lutjanus sebae	red emperor	1.6	7.6	**
Pristipomoides multidens	gold-band snapper	.2	1.2	**
Lethrinus fraenatus	blue-lined emperor	.0	.1	P_1
"Non-Commercial"Taxa				
Himantura toshi	coachwhip stingray	1.3	82.3	**
Arius thalassinus	giant salmon catfish	5.3	57.9	**
Rhynchobatus djiddensis	white-spotted shovelnose-ray	.2	18.3	**
Hymantura sp A	leopard-spotted stingray	2.1	15.0	*
Priacanthus tayenus	threadfin big-eye	3.4	12.5	**
Abalistes stellaris	starry triggerfish	3.6	7.9	**
Nemipterus hexodon	ornate threadfin-bream	1.1	7.4	**
Nebrius ferrugineus	tawny nurse shark	.0	5.9	P_1
Trixiphichthys weberi	long-nosed tripodfish	.5	5.9	**
Saurida micropectoralis	short-finned lizardfish	.3	5.8	**
Psettodes erumei	tropical halibut	.6	5.7	**
Lagocephalus lunaris	rough golden pufferfish	1.1	4.7	*
Lutjanus vittus	one-band snapper	1.7	4.0	*
Gymnura australis	rat-tailed ray	.1	3.1	**
Pomadasys kaakan	yellow-finned javelin-fish	.0	2.5	P_1
Argyrops spinifer	long-spined sea-bream	.3	2.4	**
Cyclichthys hardenbergi	plain porcupine-fish	.4	1.8	*
Scomberomorus semifasciatus	grey mackerel	.4	1.5	*
Caranx ignobilis	giant trevally	.0	1.0	P
Mobula diabola	manta ray	.0	1.0	P_1
Aetobatus vespertilio	rare eagle ray	.0	.8	P
Amphotistius kuhlii	blue-spotted stingray	.0	.6	P
Velifer hypselopterus	high-finned veilfin	.1	.6	**
Fistularia petimba	rough flutemouth	+	.5	**
Lepidotrigla sp 1	blue-finned gurnard	.1	.5	**
Seriolina nigrofasciata	black-banded kingfish	.3	.5	*
Amphotistius sp 3	black-spotted stingray	+	.4	**
Lagocephalus inermis	smooth golden pufferfish	.1	.4	*
Pseudorhombus diplospilus	four twin-spot flounder	.0	.4	P
Saurida undosquamis	checkered lizardfish	+	.4	**
Paramonacanthus filicauda	threadfin leatherjacket	+	.3	**
Rhynchostracion nasus	small-nosed boxfish	.1	.3	*
Pentaprion longimanus	long-finned silver-biddy	+	.2	**
Sargocentron rubrum	red squirrelfish	.1	.2	*
Arothron stellatus	starry pufferfish	.0	.1	P_1
Cyclichthys orbicularis	short-spined porcupine-fish	.0	.1	P_1
Epinephelus sexfasciatus	six-banded rock-cod	.0	.1	P
Epinephelus heniochus	three-lined rock-cod	.0	.1	P
Gnathanodon speciosus	golden trevally	.0	.1	P_1
Lutjanus lutjanus	big-eye sea-perch	.0	.1	P
Nemipterus peronii	notched threadfin-bream	.0	.1	P
Rhina ancylostoma	shark ray	.0	.1	P_1
Selaroides leptolepis	yellow-striped trevally	+	.1	*
Sphyraena forsteri	blotched sea-pike	+	.1	*
Trichiurus lepturus	large-headed hairtail	+	.1	**
Leiognathus bindus	orange-tipped ponyfish	+	+	P_1
Apogon quadrifasciatus	broad-banded cardinal-fish	.0	+	P_1
Apogon ellioti	flag-fin cardinal-fish	.0	+	P_1
Blennidae	blenny	.0	+	P_1
Bregmacerotidae	unicorn cod	.0	+	P_1
Carangoides sp	trevally	.0	+	P_1
Champsodon sp	sabre gill	.0	+	P
Cyclichthys jaculiferus	long-spined porcupine-fish	.0	+	P
Dexillichthys muelleri	tufted sole	.0	+	P
Dussumieria elopsoides	slender rainbow sardine	.0	+	P
Elates ransonnetii	dwarf flathead	.0	+	P_1
Grammatobothus polyophthalmus	three-spot flounder	.0	+	P_1
Lutjanus quinquelineatus	five-lined snapper	.0	+	P_1
Myripristis melanostictus	toothed crimson squirrelfish	.0	+	P_1
Nettastomatidae	duckbill eel	.0	+	P_1
Opisthognathus latitabundus	blotched jawfish	.0	+	P_1
Parachaetodon ocellatus	ocellate coralfish	.0	+	P_1
Parupeneus pleurospilus	spotted golden goatfish	.0	+	P_1
Pellona ditchela	ditchelee	.0	+	P
Pseudorhombus elevatus	deep-bodied flounder	.0	+	P
Pterocaesio digramma	twin yellow-striped fusilier	.0	+	P
Pterois russelli	spotless butterfly-cod	.0	+	P_1
Saurida longimanus	long-finned lizardfish	.0	+	P_1
Scarus ghobban	blue-barred orange parrotfish	.0	+	P_1
Scomberoides tol	needle-scaled queenfish	.0	+	P_1
Secutor insidiator	pugnose ponyfish	.0	+	P_1
Siganus fuscescens	pin-spotted spinefoot	.0	+	P
Suggrundus macracanthus	large-spined flathead	.0	+	P_1
Suggrundus sp 1	flathead	.0	+	P
Terapon jarbua	crescent grunter-perch	.0	+	P
Terapon theraps	large-scaled grunter-perch	.0	+	P_1
Tetrosomus gibbosus	black-blotched turretfish	.0	+	P
Upeneus sp	orange-barred goatfish	.0	+	P
Uranoscopus cognatus	two-spined yellow-tailed stargazer	.0	+	
Sepiidae	cuttlefish	.3	1.2	**

Table 5. Comparison of length distributions for selected taxa caught in both types of net. Modes and sample sizes (n) are given for both nets. Significant Spearman rank correlations (r_s) in frequency distributions are indicated (P<0.1 * and P<0.01 **). No comparisons were made for n < 10. Lengths were measured to the caudal fork except where total lengths (T) are indicated.

Taxon		Julie Anne		Paulegro		r_s	
Scientific Name	Common Name	Mode(cm)	n	Mode(cm)	n		
Commercial Taxa							
Diagramma pictum	painted sweetlip	47	69	48	345	.71	**
Lethrinus fraenatus	blue-lined emperor	-	0	39	1	-	
Lethrinus lentjan	red-spot emperor	28	131	27	341	.85	**
Lutjanus argentimaculatus	mangrove-jack	45	3	-	4	-	
Lutjanus erythropterus	scarlet snapper	46	253	46	227	.85	**
Lutjanus johni	golden snapper	46	85	48	30	.63	**
Lutjanus malabaricus	saddle-tailed snapper	48	1485	45	680	.84	**
Lutjanus russelli	Russell's snapper	34	146	33	164	.83	**
Lutjanus sebae	red emperor	32	28	32	93	.57	**
Pristipomoides multidens	gold-band snapper	-	3	39	19	-	
"Non-Commercial" Taxa							
Abalistes stellaris	starry triggerfish	28	92	26	260	.84	**
Epinephelus heniochus	three-lined rock-cod$_T$	-	0	33	5	-	
Epinephelus areolatus	yellow-spotted rock-cod	-	4	33	9	-	
Epinephelus sexfasciatus	six-banded rock-cod$_T$	-	0	23	6	-	
Epinephelus suillus	Malabar rock-cod$_T$	70	7	-	15	-	
Lutjanus lutjanus	big-eye sea-perch	-	0	17	11	-	
Lutjanus vittus	one-band snapper	21	93	22	253	.86	**
Nemipterus hexodon	ornate threadfin-bream	19	99	19	677	.76	**
Parupeneus pleurospilus	spotted golden goatfish	-	0	24	1	-	
Psenopsis humerosa	black-spot butterfish	18	39	20	41	.72	*
Saurida micropectoralis	short-finned lizardfish	-	16	27	280	.53	**

Table 6. Comparative mean scores (%) from the visual assessment of fish caught in the Julie Anne and the Paulegro trawls. Significant differences are indicated (P<0.1 *, P<0.01 ** and P<0.001 ***).

Taxon		Mean Score		
Scientific Name	Common Name	Julie Anne	Paulegro	
Lutjanus johni	golden snapper	91	25	***
Lutjanus sebae	red emperor	91	78	**
Lutjanus malabaricus	scarlet snapper	88	38	***
Pristipomoides multidens	gold-band	86	75	*
Lethrinus lentjan	snapper	81	68	**
Lutjanus erythropterus	red-spot	80	77	
Lutjanus argentimaculatus	emperor	60	22	**
	red snapper			
	mangrove-jack			

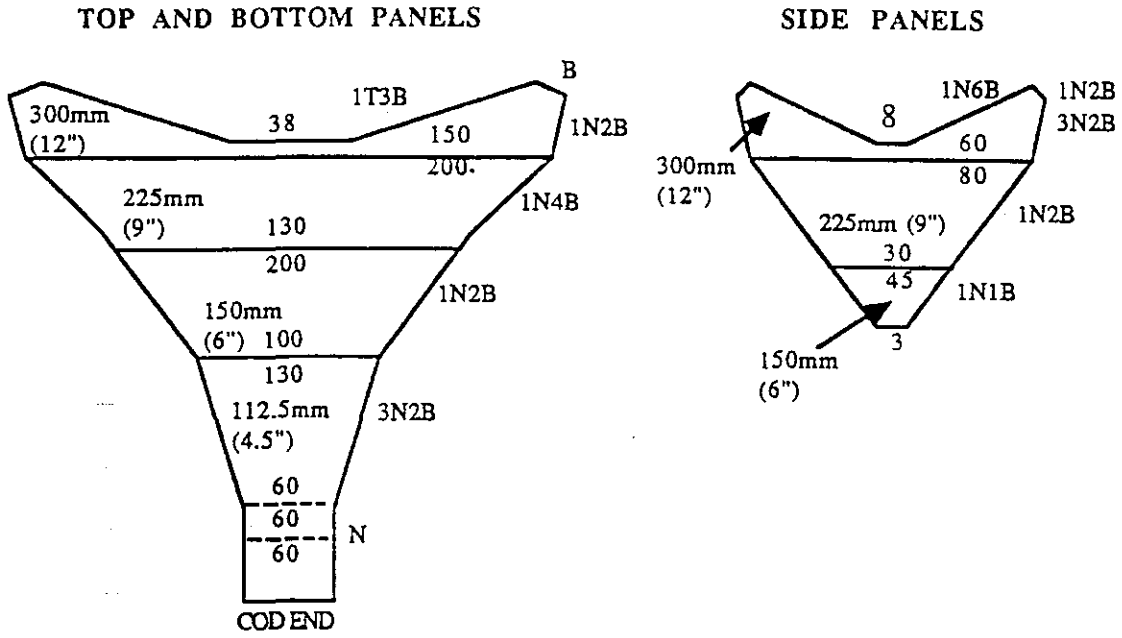

Figure 1.
Net plan for the Julie Anne trawl.

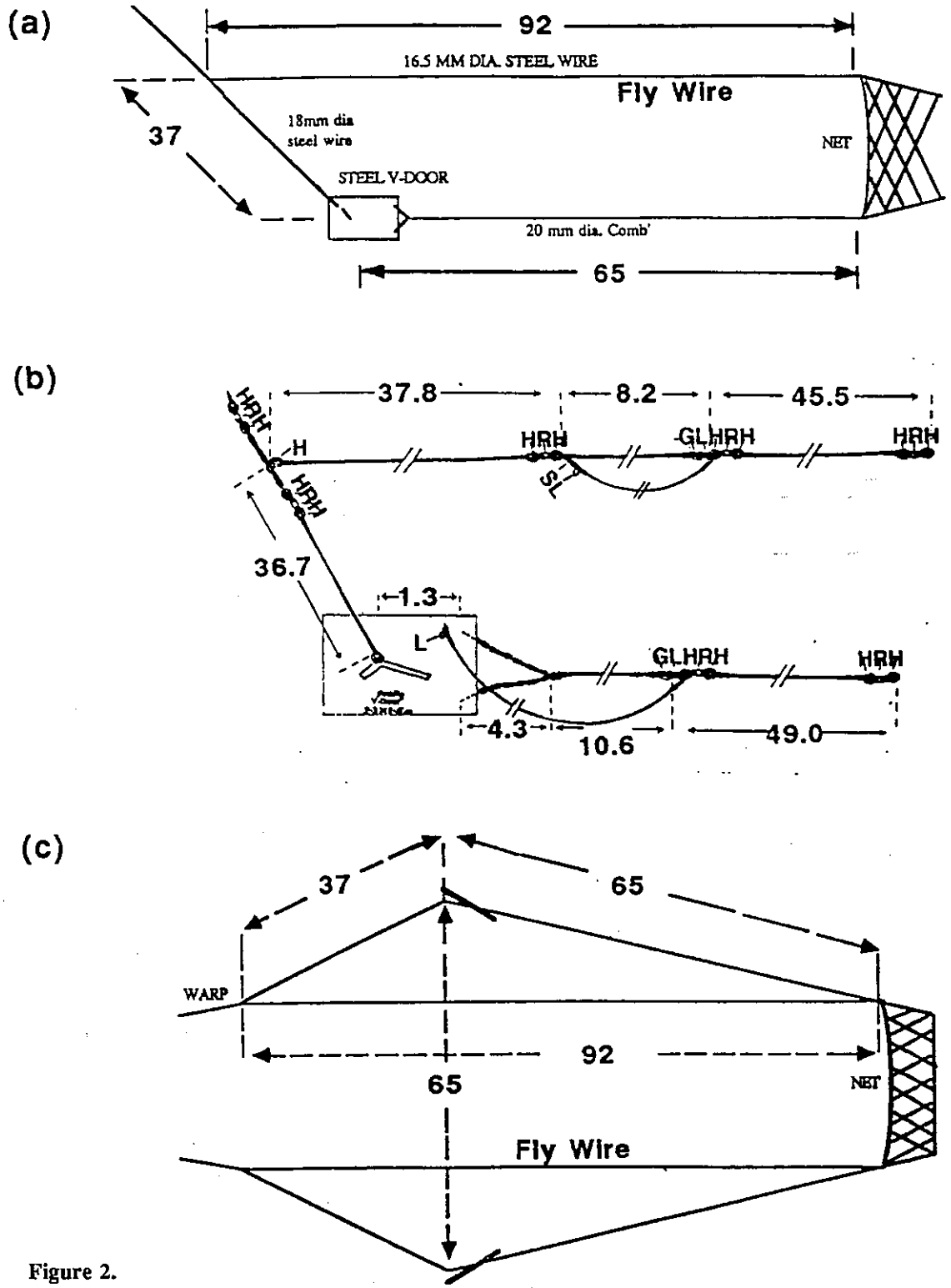

Figure 2.
Towing configuration for the Julie Anne trawl viewed from the side (a), from the side in detail (b) and from above (c). Hammer locks (H), roller bearing swivels (R), G-links (G), Recess links (L) and sister clips (S) are indicated. All lengths are in metres.

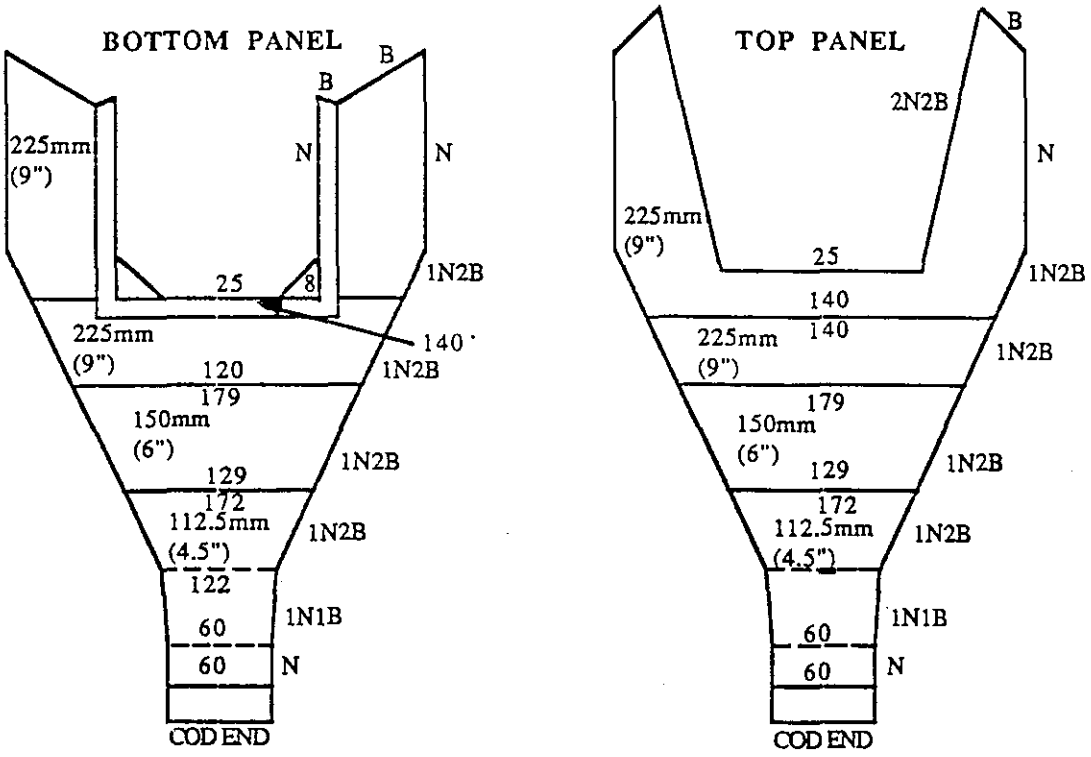

Figure 3.
Net plan for the Paulegro trawl.

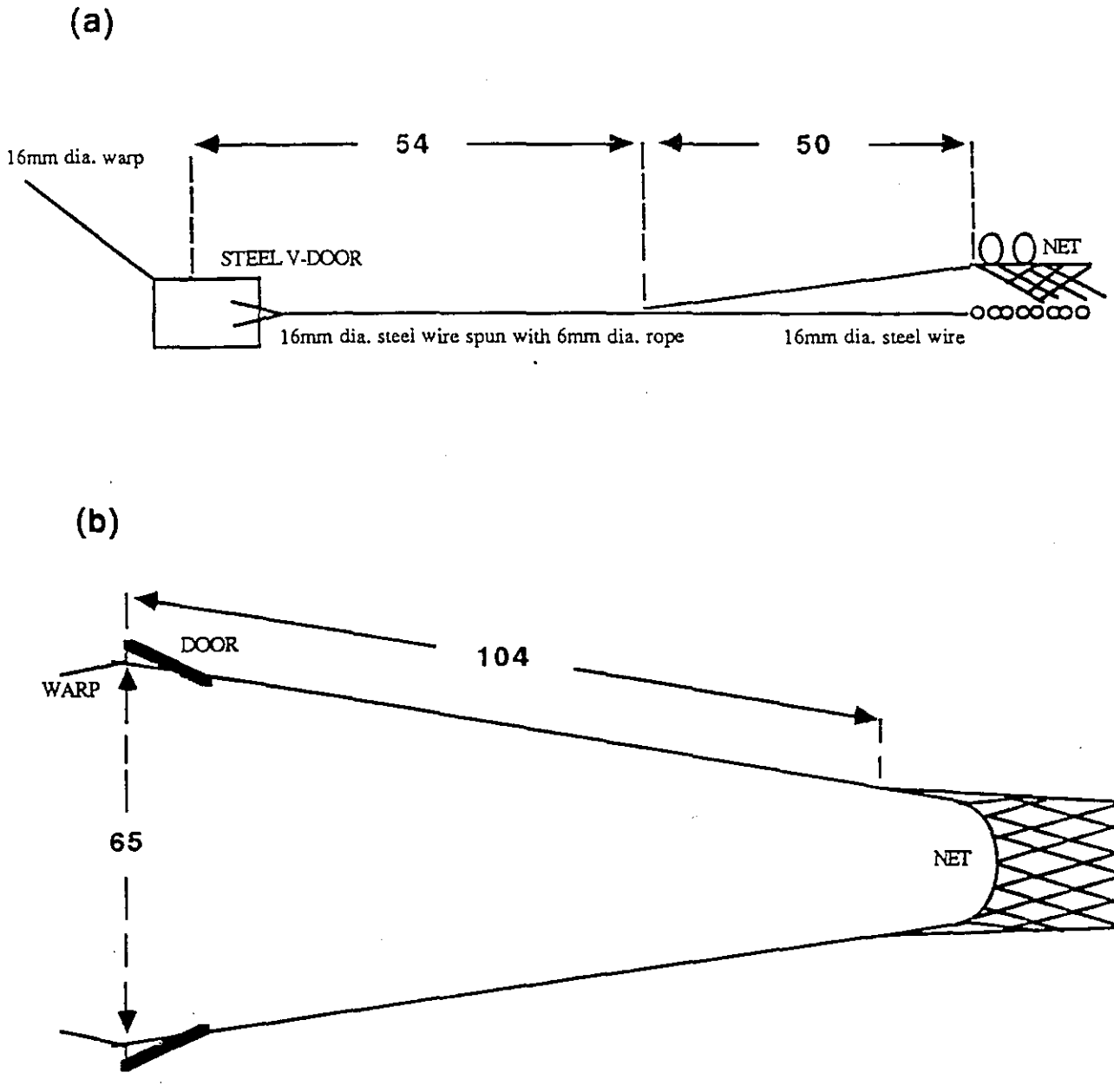

Figure 4.
Towing configuration for the Paulegro trawl viewed from the side (a), and from above (b). All lengths are in metres.

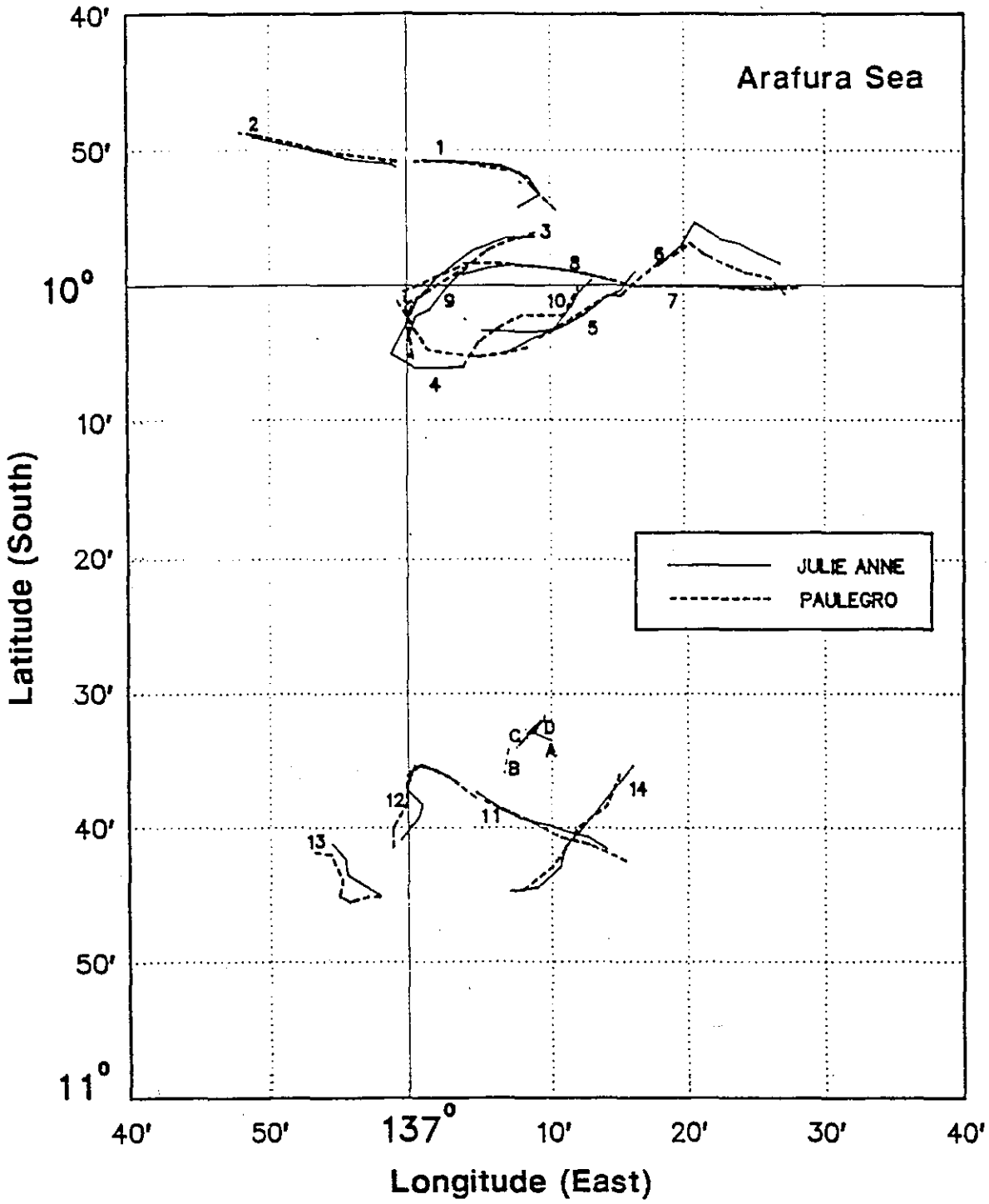

Figure 5.
Trawl ground with the locations of the 14 pairs of trawls (1-14) and the 4 target trawls (A-D).

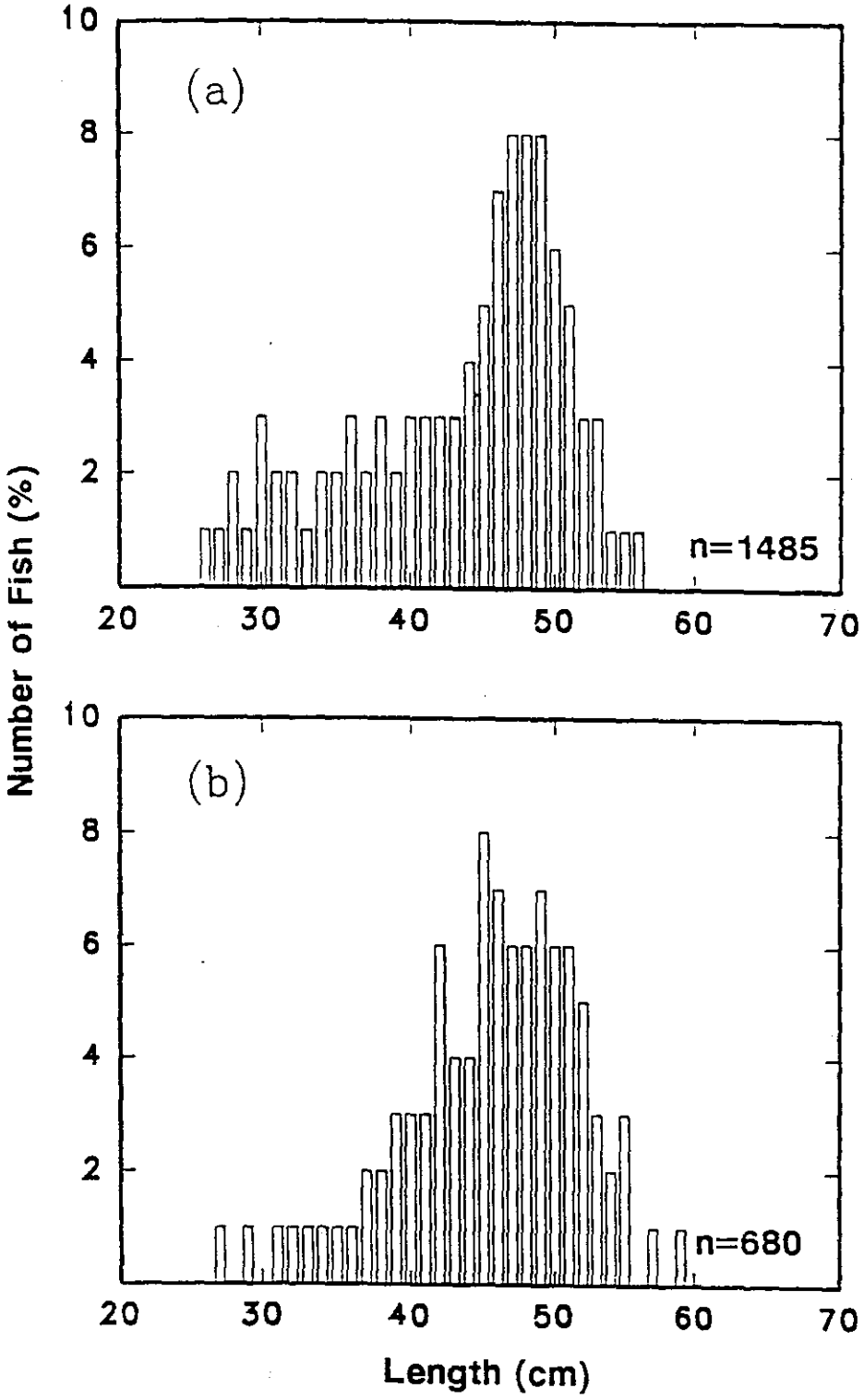

Figure 6.
Length-frequency distributions for scarlet snapper (*Lutjanus malabaricus*) observed in the Julie Anne trawl series (a), and the Paulegro trawl series (b). Lengths were measured to the caudal fork.

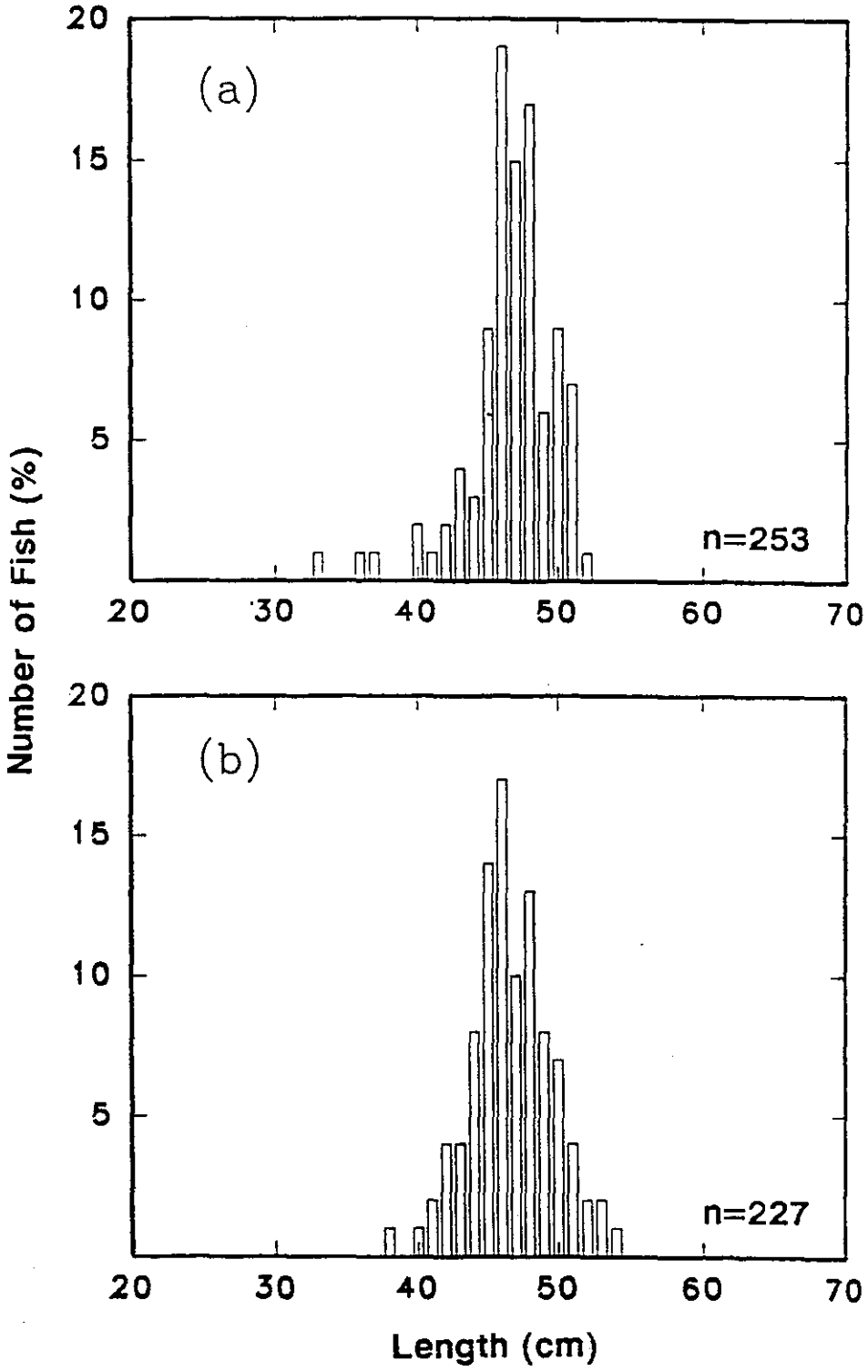

Figure 7.
Length-frequency distributions for red snapper (*Lutjanus erythropterus*) observed in the Julie Anne trawl series (a), and the Paulegro trawl series (b). Lengths were measured to the caudal fork.

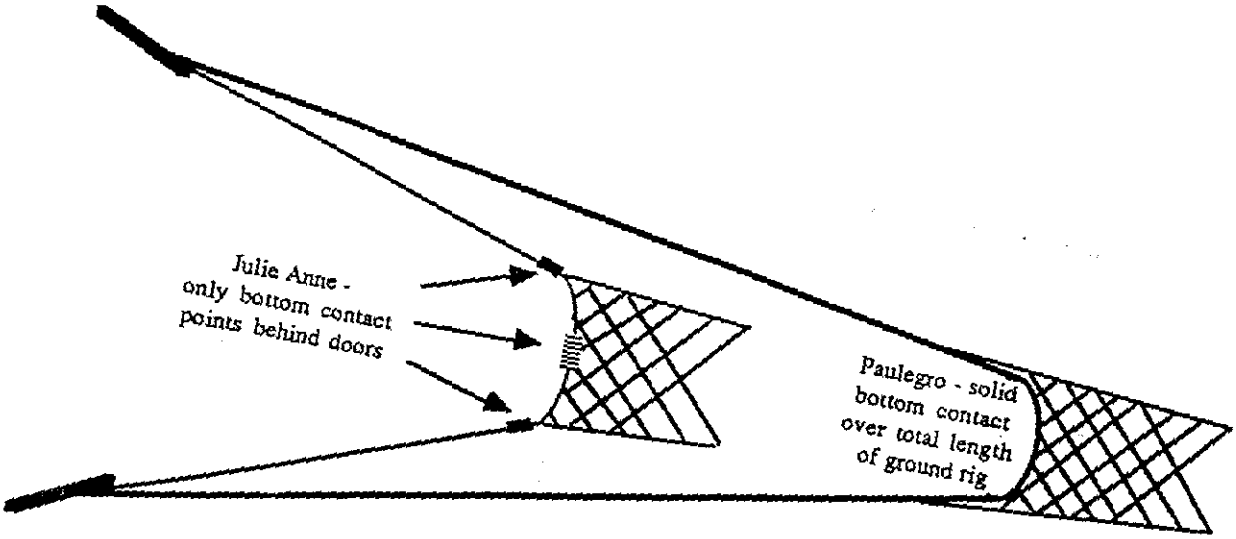

Figure 8.
Differences in bottom contact between the Julie Anne and Paulegro trawls.

PLATE CAPTIONS

Plate 1.
Construction of the Julie Anne trawl in Darwin.

Plate 2.
Testing the 1:10 scale model from the FRV "John Lake".

Plate 3.
Hauling the Julie Anne trawl onboard the FV "Clipper Bird".

Plate 4.
Underwater videocamera and frame.

Plate 5.
Typical catch from the Julie Anne trawl.

Plate 6.
Typical catch from the Paulegro trawl.

Plate 7.
Individual *Lutjanus malabaricus* from the Julie Anne (EF net) and Paulegro trawls.

Plate 8.
Fillets of *Lutjanus malabaricus* from the Julie Anne (EF net) and Paulegro trawls.